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Editors: Lijie Tan, Alan D. L. Sihoe, Lunxu Liu, Diego Gonzalez-Rivas

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Uniportal Video-Assisted Thoracic Surgery

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Foreword

Uniportal VATS is one of the innovative procedures that have revolutionized the field of minimally invasive thoracic surgery in the past 10 years. In spite of the lack of definitive and much awaited evidence of its role in the thoracic surgical armamentarium compared to traditional three port VATS or open surgery, surgeons are increasingly attracted to this approach and the trend is not subsiding. From the maintenance of bodily psycho-somatic integrity (ie, *Chi*) to the prompt return to the daily activities in the pain-free scenario provided by one small incision, uniportal VATS is being taught and learnt with an unprecedented rapidity given its undoubted safety and feasibility. Indeed, the concept of single port VATS was initially generated bearing in mind the supreme patient interest by fast-tracking him or her through the hospitalization. In fact, the most recent evolution of the uniportal VATS technique implies performing diagnostic or therapeutic procedures in a non-intubated or even awake patient. This book on Uniportal VATS -edited by Drs, Tan, Sihoe and Liu - comes at the right time to carve in stone the theoretical principles, the technical tips and the current indications of uniportal VATS. The number of experts involved is per se a demonstration of the worldwide interest that this technique has evoked to the point that, today, there is not one routine thoracic surgical procedure which has not been described by uniportal VATS surgeons. The current thoracic surgical armamentarium cannot ignore the role that uniportal VATS is progressively gaining and books like this one – along with the scientifically rigorous outcome analysis soon to be published – will contribute to the transfer of the single port philosophy to the generations to come.

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Preface

"Those who say it cannot be done should not interrupt those who are already doing it."
(Famous proverb often attributed to George Bernard Shaw)

In Thoracic Surgery, futile interruptions are common. Those who insist on using two chest drains after a lung resection have failed to interrupt those who have only been using one – or even none – for many years. Those advocating lymph node sampling only for lung cancer have failed to interrupt those who have demonstrated the safety and advantages of systematic nodal dissection. More recently, those who assert the supremacy of lobectomy for lung cancer have failed to interrupt those showing emerging evidence for the efficacy of sublobar resection in selected patients.

Perhaps the greatest futile interruption in our specialty has been the attempt to quash the usurping of the once-mighty open thoracotomy by the brash upstart Video-Assisted Thoracic Surgery (VATS). For many surgeons who have made their careers on the use of the thoracotomy, the VATS revolution that erupted in the last decade of the 20th Century was a nasty shock. The minimally invasive approach overturned many deeply-held paradigms about how thoracic surgery should be performed. Unsurprisingly, there was a maelstrom of fierce criticism thrown at VATS by many conservative voices. It took many years of dedicated and innovative clinical research to generate the data proving the value of VATS. Nowadays, conventional multi-port VATS has become a major element in our specialty, and is even recognized as the *preferred* surgical approach for a great variety of thoracic disease – including early stage lung cancer.

Today, a new battle has now arrived as conservative forces seek to 'interrupt' the latest change to the status quo: Uniportal VATS.

If the change from the hefty physical injury of thoracotomy to the reduced trauma of VATS is good, then it seems logical that a further minimization of surgical access using a Uniportal approach should be even better. This novel evolution of the VATS technique using only a single port has become the most talked-about subject in Thoracic Surgery today. Over the last decade or so, it has rapidly developed from a niche approach for minor procedures, to a sound alternative approach for major lung cancer resections, to even complex operations such as sleeve resections.

However, following tradition, the upstart is not universally welcome by followers of the old master. Not only has Uniportal VATS been viewed with scepticism by proponents of open thoracotomy, but it has also been questioned by some practitioners of multi-port VATS. It is perhaps ironic that those performing conventional VATS today are voicing the same doubts against Uniportal VATS that they themselves previously faced from disciples of open thoracotomy. Whatever the motivation behind their voices of caution, the upshot is that such voices force Uniportal surgeons to provide objective, sound clinical data to dispel the doubts over the approach – and this is fair to both patients and the specialty. To overcome the attempted interruption, advocates of Uniportal VATS will need to undergo the same trials as the pioneers of conventional multi-port VATS two decades ago: demonstrating the safety, feasibility, efficacy, and advantages of their single port method through the accumulation of hard clinical data.

This book does not contain that definitive data that will establish the role of Uniportal VATS in Thoracic Surgery. This approach is simply far too new. There is not enough data yet – at the time of this writing – to say that Uniportal VATS "*should* be performed".

Instead, this book is an emphatic statement that Uniportal VATS "*<u>can</u>* be performed" – and that it can be performed safely!

In the pages of this book, the world's leading experts in the Uniportal VATS approach share their wealth of experience. Its contents range from philosophical considerations on the development and theoretical advantages of using a single port, to highly practical instructions on how to perform the technique. The use of Uniportal VATS from minor procedures, to essential lung cancer surgery, to difficult operations and beyond are covered. Moreover, it assembles a montage of experience with this technique from all corners of the globe – demonstrating that the Uniportal approach is not a flash-in-the-pan phenomenon only possible in the hands of a few magically skilled surgeons, but a teachable and reproducible method that can be mastered by thoracic surgeons around the world.

This book aims to provide readers with the basic knowledge and skills to start learning the Uniportal VATS approach. Reading and understanding the authors' experience should help readers to plan safe, systematic surgery for their patients. By collating the know-how of the current leading Uniportal experts in one volume, this book also serves to set a benchmark for what Uniportal VATS should be – a standard to which future practitioners should meet or surpass.

Finally, it is hoped that this book will entice more thoracic surgeons to learn and practice the Uniportal approach. When there are many already safely 'doing it', those who say 'it cannot be done' may finally have to quit interrupting!

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The evolution of minimally invasive thoracic surgery: implications for the practice of uniportal thoracoscopic surgery

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Abstract: The history of Minimally Invasive Surgery in the thorax is one of evolution, not revolution. The concept of video-assisted thoracic surgery (VATS) to greatly reduce the trauma of chest operations was born over two decades ago. Since then, it has undergone a series of step-wise modifications and improvement. The original practice of three access ports in a 'baseball diamond' pattern was modified to suit operational needs, and gradually developed into 'next generation' approaches, including Needlescopic and 2-port VATS. The logical, incremental progression has culminated in the Uniportal VATS approach which has stirred considerable interest within the field of Thoracic Surgery in recent years. This measured, evolutionary process has significant implications on how the surgeon should approach, master and realize the full potential of the Uniportal technique. This article gives a précis of the evolutionary history of minimally invasive thoracic surgery, and highlights the lessons it provides about its future.

Keywords: Single-port VATS; thoracoscopic surgery; video assisted thoracic surgery (VATS); Uniportal VATS

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Evolution, not revolution

Without doubt, the single greatest advance in Thoracic Surgery of this generation has been the advent of video assisted thoracic surgery (VATS) (1,2). Over the past 20 years since its birth, VATS has been demonstrated to significantly reduce pain, hasten recovery, minimize complications, and improve post-operative quality of life for patients requiring Thoracic Surgery when compared to open thoracotomy (3,4). VATS is now so well established around the world that it is no longer correct to describe it as an 'emerging' or 'new' approach. It is in fact now the 'conventional' approach for almost every common thoracic operation in a number of centers around the world.

Since the birth of VATS, however, the pace of progress appears to have slowed (4). Although much fine work has produced incremental improvement in surgery in the chest, the search for the 'next big breakthrough' of the scale of VATS has been in vain for many years. It was wondered whether minimally invasive thoracic surgery had reached a zenith beyond which no further great advance was possible.

The recent emergence of Uniportal VATS has now promised a breath of fresh air to purge the stagnation (5,6). The change from conventional multi-port VATS to the use of just a single port seems like such a radical step that many have viewed it as perhaps the single greatest leap forward in minimally invasive thoracic surgery since the birth of VATS itself. Indeed, many have described it as 'revolutionary'.

The truth is, though, that this description is wrong. Far from being a sudden revolution, Uniportal VATS is actually simply the next step in the evolution of minimally invasive thoracic surgery itself. When viewed in the context of the history of VATS over the last two decades, Uniportal VATS is technically still just another step forwards—though a very exciting step forwards at that.

The use of the word 'evolution' has become very much clichéd in the medical literature in recent years. However, the distinction between revolution and evolution is far more than an issue of pedantic semantics. The fact that this is a process of evolution has very important implications for the practice of Uniportal VATS. This article aims to summarize the evolutionary history of minimally invasive thoracic surgery culminating in Uniportal VATS, and to demonstrate how the lessons from that evolution should guide surgeons learning this technique.

A brief history of minimally invasive thoracic surgery

To operate in the human thorax, a surgeon must place three things into it: a right hand; a left hand; and a pair of eyes to look inside (4). To place these in between the tight intercostal spaces, one must forcibly retract the ribs for up to several hours for a major operation. This causes significant trauma, pain and potential peri-operative morbidity. VATS actually does not deviate from the principle of placing these same three things into the chest. However, surgical instruments are used to replace the right and left hands, and a video-thoracoscope is used to replace direct vision through the wound. All of this is done using three small ports without rib-spreading. VATS therefore allows the same complex operations to be performed, but the avoidance of forcible rib-spreading means that surgical trauma is greatly reduced (1,2). In this way, VATS achieves the good post-operative outcomes so well documented in the literature (1-3).

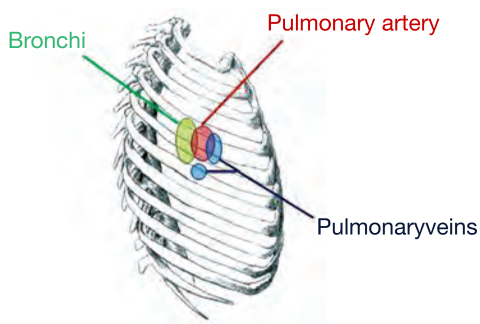

Figure 1 Schematic of the right thorax, showing approximate relative locations of the main hilar structures.

Early 3-port VATS

When VATS was first described some 20 years ago, the approach typically used three small ports without rib-spreading (1,2). For a VATS lobectomy, this typically meant two 10 mm ports plus one 3-6 cm 'utility' port for delivery of the resected lobe of lung. The strategy for ports placement was described in the early literature as the 'baseball diamond' (*Figures 1,2*). The surgeon typically stands at the 'home base' like a baseball batter looking out towards the pitcher and the baseball field—and therefore the camera port representing the surgeon's eyes are placed at the 'home base' position of the diamond. The target lesion being faced by the surgeon is at 'second base' opposite the surgeon. The other two ports are placed at the 'first base' and 'third base' positions to allow the right and left hand instruments to be placed and triangulated forwards towards the target at 'second base'. Using this strategy, the camera port was typically in about the 7^{th} or 8^{th} intercostal space in the mid-axillary line, and the posterior port just anterior the tip of the scapula. The utility port was

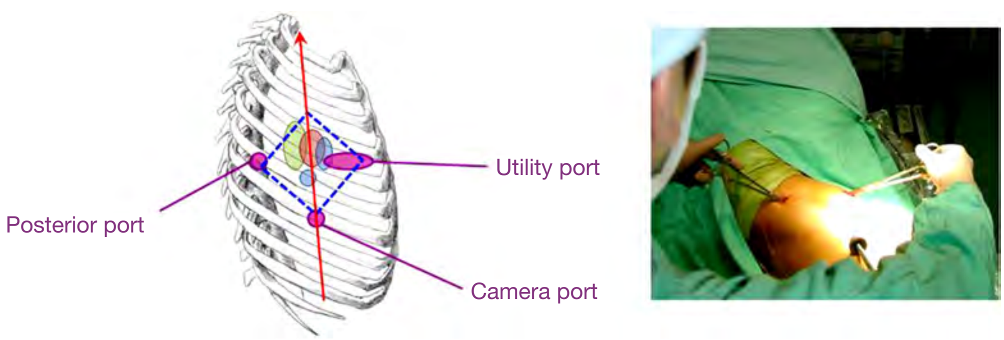

Figure 2 The 'classic' 3-port VATS lobectomy. In a right-side operation, the 'baseball diamond' (dotted blue line) has a 10 cmm camera port at 'home base', a 3-5 cm utility port at 'first base', and a 10 mm posterior port at 'third base'. The axis of the operation (red arrow) is a straight line from 'home base' through the 'second base'—and in this classic early VATS approach the axis is essentially in a hip-to-head direction along the patient's body's longitudinal axis. VATS, video-assisted thoracic surgery.

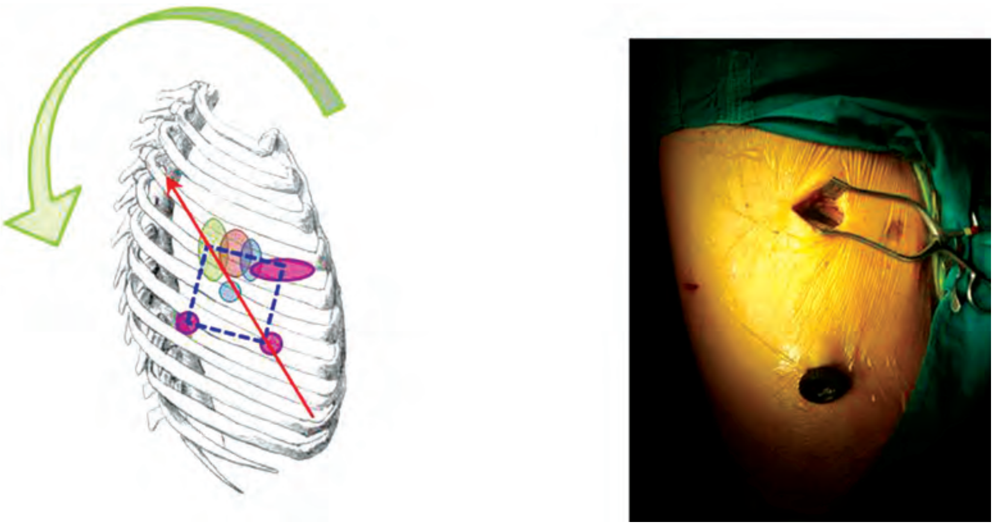

Figure 3 The 'modified' 3-port VATS lobectomy. The 'baseball diamond' (dotted blue line) and axis of the operation (red arrow) have essentially been rotated in a posterior direction—and the axis direction is now umbilicus-to-shoulder, better reflecting the fact that in reality the surgeon stands anterior to the patient (rather than sits on the patient's hip!). VATS, video-assisted thoracic surgery.

usually placed in the anterior axillary line to take advantage of the naturally wider intercostal space towards the front of the chest to facilitate specimen retrieval. The utility port was typically sited in the 4^{th} intercostal space for an upper lobectomy or 5^{th} intercostal space for a lower lobectomy, and was at the 'first base' for right-side operations and at 'third base' for left side operations.

This strategy of port placement allowed the 'axis' of the operation—a straight line from the 'home base' through the 'second base'—to follow the natural longitudinal axis of the patient from feet towards the head. The right and left hands ('first and third bases') straddled this axis on both sides and reduced fencing between instruments and camera.

The above reflects the early approach of conventional VATS in Hong Kong, and there are of course many variations described (4).

Modified 3-port VATS

The problem with the conventional 3-port VATS approach as described above was that the port placement did not reflect the reality of how surgeons and assistants stood around the operating table. No surgeon can really stand at the patient's feet (or hip) where the 'home base' is. In reality, to facilitate principal instrumentation via the utility port, many surgeons would stand anterior to the lateral-lying patient. The actual axis of the operation is actually not from the hip to the head of the patient, but from the umbilicus towards the back of the shoulder (i.e., from an anterior-to-posterior as well as inferior-to-superior direction). Adhering to the port placement in the classic 'baseball diamond' strategy above would therefore mean the posterior port would be too far 'superior' along the axis and the surgeon would have to reach uncomfortably far to effect instrumentation there. In addition, if the camera-holding assistant stands on the opposite side of the operating table from the surgeon (as per classic open surgery), the assistant's visual axis would be completely different to the surgeon's—running from the patient's sacrum towards the chin. This is one of the key reasons for 'mirror imaging' and fencing between camera and the surgeon's instruments commonly noted in the early experience with VATS.

To remedy this, the 3-port VATS port placement strategy was modified slightly (*Figure 3*). The camera port was brought more anterior to the anterior axillary line. The posterior port was lowered from anterior to the scapula tip to a lower intercostal level. The utility port position is unchanged. The end result of this modification was a posterior rotation of the 'baseball diamond' (4). Although the diamond shape was preserved, the axis now reflected the umbilicus-towards-shoulder direction and was more comfortable for the surgeon. The camera-holding assistant now stands on the same side of the operating table as the surgeon and slightly behind. The assistant thus shares the same axis as the surgeon, improving surgeon-assistant co-ordination. The lower posterior port also means that for upper lobectomies, a stapling device placed via that port approaches hilar vessels from a slightly posterior-to-anterior direction and can more easily negotiate around those vessels without the anvil being impeded by other structures behind.

For the author, this has become the standard port placement strategy for 'conventional' 3-port VATS lobectomy in Hong Kong. Again, it is acknowledged that myriad detail differences in technique exist in different centers around the world, but the basic principles remain.

However, although conventional multi-port VATS greatly reduces morbidity, it does not completely eliminate it. Studies have shown that even with conventional VATS, up to 32% of patients still have some residual discomfort for up to years after surgery (7). We have also found that 53% of patients still feel chest wall paresthesia distinct from nociceptive wound pain at 19 months after VATS (8). Even though such complaints cannot detract from the need to perform curative surgery for lung cancer, there is clearly room for improvement to improve the lot for our patients.

Robot-assisted thoracic surgery

One of the developments causing the most excitement soon after the turn of the Century was the introduction of robotic surgical systems to Thoracic Surgery. Initially, the robot was used to help perform simple mediastinal operations, but today some are routinely using it even for lung cancer resections (9,10). Nonetheless, the overall narrative of the robot story in the last 10 years has been one of relatively slow and limited acceptance globally.

There are a number of reasons for the missed opportunity for the robot system to become established in Thoracic Surgery. The upfront costs of purchasing the system and—more importantly—the costs of the surgical consumables remains daunting, often prohibitively so in the many countries. The cost in terms of prolonged preparation times for each operation taking up valuable operating theatre time is another important cost issue. The robotic system's promises of 3D vision, greater intra-thoracic dexterity and steadier instrumentation have also not fully compensated for the loss of tactile feedback so crucial to the thoracic surgeon (11). In terms of wounds, the robot required the same number and sizes of wounds as conventional 3-port VATS, and indeed sometimes required an extra fourth one.

There is no doubt that robotic system has a niche role for delicate mediastinal surgery, but for most Thoracic Surgeons its place in mainstream practice remains limited. Instead, trends over the last several years have showed clearly that the evolution of minimally invasive thoracic surgery has taken a different direction: towards an upgrading of fine surgical technique over the influx of expensive technology.

Needlescopic VATS

Needlescopic VATS is the use of very fine thoracoscopes (2-3 mm diameter) and instruments (3-5 mm diameter) to replace the 10mm versions used in conventional VATS equipment (12). Needlescopic VATS was first used for sympathectomy surgery to treat palmar hyperhidrosis and sympathectomy disorders (13). The small wounds ensured not only reduced pain, but excellent cosmesis with the incisions becoming virtually completely invisible within a few weeks after surgery. From this, we have further extended its use to treating pneumothorax with considerable success (14).

The next step was of course to apply the Needlescopic VATS approach to lung cancer surgery (4). Using the same ports positions as the modified 3-port strategy above, the posterior port is reduced from 10 to 3 mm, although the utility port has to remain at 3-5 cm purely for the purposes of extracting the resected lobe of lung (*Figure 4*). The camera port is made by using a No. 11 scalpel blade to stab and create a 3 mm skin puncture. A 3 mm trocar is pushed through and the 3 mm 30° video-thoracoscope placed through that. Alternatively, a tract is created into the pleural space by pushing a small mosquito forceps through the skin stab incision, and a 5 mm 30° video-thoracoscope is placed directly through this tract without a trocoar. The lens tip can be wiped within the chest using a pledget held on a Roberts forceps, lightly soaked with anti-fogging solution and inserted via the chest tube thoracostomy wound. The reduction in ports sizes may not sound like much, but in reality the difference is noticeable. Given the narrowness of the human intercostal space, a conventional 10 mm thoracoscope, for example, can lever against and cause blunt trauma to the intercostal bundles during manipulations to look up and down during the operation. By using a much finer thoracoscope and instruments, this torquing at the wound is intuitively reduced. Cosmesis is of course much better. At the same time, because three ports are still being used, the conduct of the operation is essentially the same as with conventional VATS—making it much easier for the experienced VATS surgeon to master. Complete lymph node dissection is also eminently feasible.

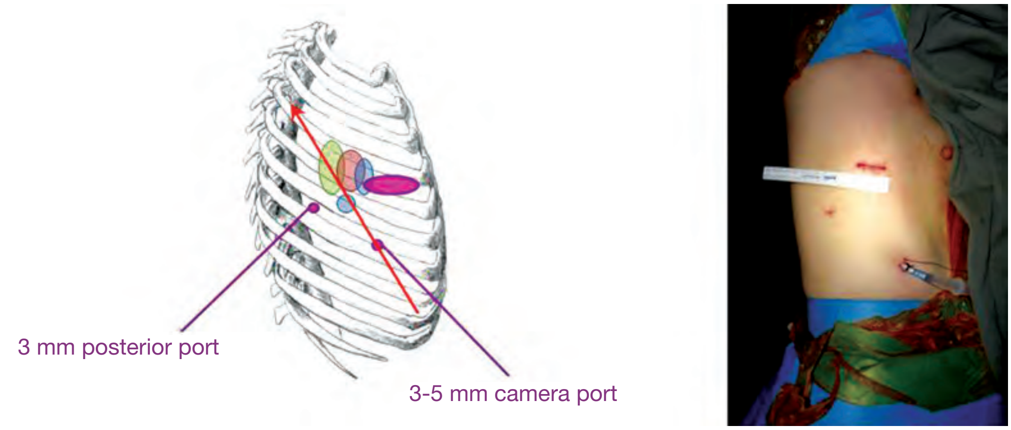

Figure 4 The Needlescopic VATS lobectomy. The ports positions (purple) and axis of the operation (red arrow) are the same as for the 'modified' 3-port VATS approach. However, the posterior and camera ports have been reduced in size to 3 mm in diameter only. VATS, video-assisted thoracic surgery.

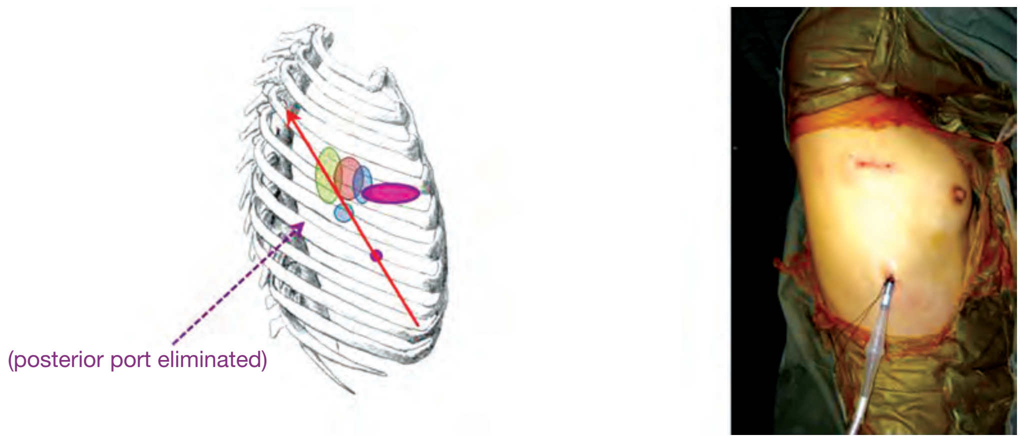

Figure 5 The 2-port VATS lobectomy. The utility and camera ports are identical to the Needlescopic approach, but the posterior port has been eliminated. VATS, video-assisted thoracic surgery.

The author routinely uses a 3 mm (or sometimes a 5 mm) 30° video-thoracoscope. A commonly voiced concern about the use of such fine thoracosocopes is regarding the brightness and resolution of the video image produced. Thankfully, modern high-definition surgical video cameras have such good light sensitivity and superb resolution that this is in practice never a noticeable problem.

2-port VATS

After gaining experience with a 3-port Needlescopic VATS approach, it was soon realized that the posterior 3 mm port was not always essential. The added retraction using a 3 mm instrument through that port did not contribute greatly, and in fact it was possible to deliver such surgical retraction and manipulation using another instrument via the utility port. The natural progression was therefore to omit that posterior port altogether—resulting in a 2-port VATS technique (*Figure 5*). This delivers all the advantages of Needlescopic VATS, but with one fewer port. If the patient's lung has no air leak at the end of a lobectomy operation, sometimes a chest tube as small as 16F can be placed via the camera port, further reducing post-operative discomfort and enhancing the cosmetic appeal. The downside is that using only one utility port for all the instrumentation during 2-port VATS requires considerably more VATS experience on the part of the surgeon. Having said that, this approach is now rapidly gaining in popularity, and many large centers in mainland China are already using this technique routinely.

At the University of Hong Kong, the author has

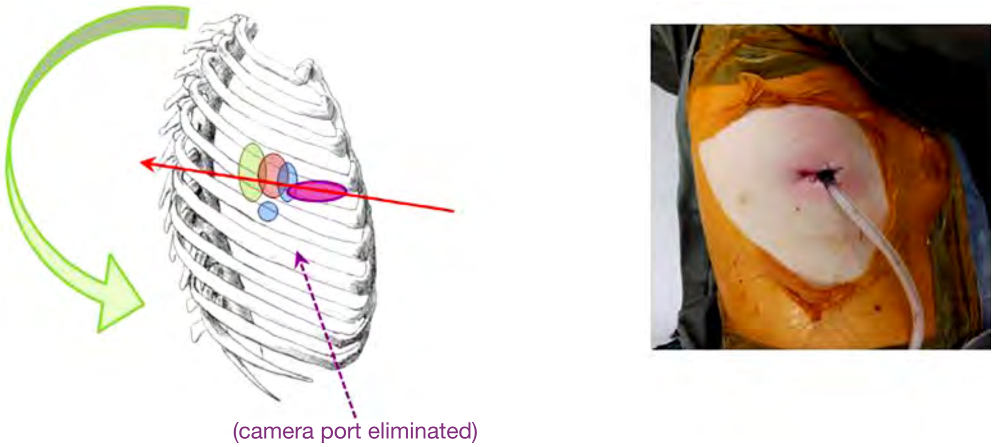

Figure 6 The Uniportal VATS lobectomy. Compared to the 2-port approach, the camera port has been eliminated. The Uniport is in the 5th intercostal space and is largely unchanged from the utility port of all previous iterations of VATS lobectomies. VATS, video-assisted thoracic surgery.

switched completely from using conventional 3-port VATS for routine lung cancer surgery to using these 'Next Generation' approaches of Needlescopic and 2-port VATS. The median length of stay after lobectomy is now 3 days. Although in Asia there is less pressure for early discharge home after surgery, unlike in many Western countries, this outcome serves as a useful indicator of the excellent recovery experienced by patients using these 'Next Generation' techniques.

Compared to robot assisted surgery, these newer VATS evolutions require no expensive equipment (most hospitals already have needlescopic instruments), take no longer than conventional VATS, and can be quickly learned by experienced VATS surgeons by further honing their skills.

Uniportal VATS

From the above progression from conventional VATS to Needlescopic VATS to 2-port VATS, it was merely logical to try to simply forego the separate camera port altogether and have the video-thoracoscope placed through the utility port as well (5). The concept of Uniportal VATS was actually first pioneered by Dr Gaetano Rocco for simpler intra-thoracic procedures over a decade ago (15,16). However, as with so many innovative ideas in surgery, the gestation period of Uniportal VATS prior to global acceptance has been a long one. It was eventually developed in more recent years to allow major lung resections by Dr. Diego Gonzalez-Rivas of A Coruna, Spain (5,6). His extensive experience now includes a few hundred lobectomies, and has extended to complex procedures such as sleeve lobectomies and pulmonary artery reconstructions.

The author typically uses a single 3-5 cm incision in the anterior axillary line for Uniportal VATS major lung resections, essentially in the same place as with Needlescopic and 2-port VATS (*Figure 6*). The only minor difference in port strategy is that the 5th intercostal space is preferred for both upper and lower lobectomies. A 5 mm diameter 30° video-thoracoscope is placed alongside the instruments used by the surgeon's right and left hands. This 'shared port' technique makes for a very 'cosy' operating environment, and requires a degree of skill not only from the surgeon but from the assistant.

Another significant challenge for the conventional VATS surgeon converting to the Uniportal approach is the further rotation of the whole axis of the operation towards a posterior direction. With Needlescopic and 2-port VATS, the visual axis is the same as with the modified 3-port VATS approach, and hence very easy to get used to. But with the Uniportal approach, the axis is changed from an umbilicus-to-shoulder direction to a nipple-to-scapula tip direction. Furthermore, instead of the 'looking across a baseball field' horizontal perspective offered by multi-port, Needlescopic and 2-port VATS, the perspective in Uniportal VATS is more vertical and more like looking down a tunnel. Consequently, the surgeon and the assistant must to some

Table 1 Outcomes for the author's first 15 consecutive patients receiving Uniportal VATS lobectomy

Characteristic/Outcome	First 5 patients	Next 10 patients	P value
Mean pre-op predicted FEV1 (%)	110.0±11.0	88.0±11.0	<0.01
Upper lobectomy	1.0 (20%)	8.0 (80%)	0.03
Mean operation time (min)	161.0±32.0	204.0±62.0	0.10
Mean blood loss (mL)	101.0±122.0	161.0±152.0	0.43
Mean tumor diameter (mm)	16.0 (range, 9-35)	25.0 (range, 13-40)	0.15
Mean NO. of lymph node stations dissected	4.4±1.8	5.4±1.0	0.30
Mean chest drain duration (days)	2.4±0.5	2.4±0.9	0.89
Mean length of stay (days)	3.4±0.5	3.7±1.3	0.45
Post-op minor complications	1.0 (20%)	2.0 (20%)	1.00

extent re-learn the hand-eye co-ordination.

Nevertheless, potential benefits for patients are promised by Uniportal VATS. In the author's experience, the safety profile has been excellent and the conversion rate has been less than 5%. Patients have had a median length of stay post-operatively of 3 days. Critics are not incorrectly in pointing out that there has so far been no evidence to unequivocally prove the superiority of Uniportal VATS over other forms of minimally invasive Thoracic Surgery. However, there has been enough clinical data to show that the approach can be performed with equal levels of safety and oncological adequacy as conventional VATS. It is therefore not unreasonable to further develop and accumulate experience with it in the hope that patients may ultimately benefit.

Lessons from history

What is clear from the above history is that Uniportal VATS is a product of a gradual evolution of minimally invasive thoracic surgery: from classical 3-port VATS, through Needlescopic and 2-port VATS, to eventually Uniportal VATS. The evolution has primarily involved a gradual rotation of the axis of the operation as well as a step-wise reduction in the size and number of the incisions.

This evolution has taught the author a number of very important lessons that should be shared with any surgeon approaching the Uniportal VATS approach. These lessons can be summarized thusly:

(I) Single-port instrumentation;
(II) Coping without the posterior port;
(III) Axis and perspective;
(IV) Troubleshooting;
(V) Peri-operative care;
(VI) Dealing with the rookie.

Single-port instrumentation

To the beginner starting to learn Uniportal VATS, it may feel very uncomfortable having to place the instruments from both right and left hands through the same port, and furthermore having to share that port with a video-thoracoscope. One would think that this is a technique that required considerable time to master. However, in reality, the author's learning curve was surprisingly short. *Table 1* summarizes only the very first 15 consecutive lobectomies performed by the author using the Uniportal VATS approach. Although the operations in the latter 10 patients were technically more challenging than in the first 5 patients (poorer lung function, more upper lobectomies), results in terms of operation times, blood loss and post-operative recovery were no worse. In all of these outcome measures, the results achieved even with these first 15 operations were already equivalent to those being obtained with conventional VATS. The key to obtaining good results so quickly was not in the personal skill of the author, but in the fact that Uniportal VATS was indeed simply a natural evolution of minimally invasive thoracic surgery.

As the author progressed from conventional and Needlescopic 3-port VATS to 2-port VATS, the lesson learned was that all instrumentation could be accomplished readily via a single utility port. Maintaining the camera in the classic lower position of conventional and Needlescopic 3-port VATS made it easy for the assistant to provide a familiar, orthodox view of the operative field while the surgeon experimented with placing right and left hand instruments via the utility port only during 2-port VATS. During this time, a greater appreciation of using curved or right-angled instruments (such as long curved ring forceps, or simply Roberts and Rumel forceps) to facilitate dissection through a shared port is quickly gained. Because the utility port is in the same place as with conventional and Needlescopic 3-port VATS, most of the very same instruments could also be used—including standard Metzenbaum scissors, Debakey forceps, hand-control diathermy devices with long-tip extensions, and so on. This proved invaluable by allowing a familiar set of instruments to be maintained without the surgeon having to learn to use new ones alongside learning a new technique.

Once one has mastered using right and left hand instruments via the same shared utility port, proceeding to a Uniportal VATS approach merely becomes the transferral of the video-thoracoscope to the same port. By breaking down VATS into the manual and visual elements, and then learning the manual element before the visual element, it was quite easy for the author to acquire proficiency of Uniportal VATS. As the video-thoracoscope is brought up to the utility port, the same right and left hand instrumentation is preserved as before with 2-port VATS, and that allows the surgeon the comfort of a familiar manual element whilst only having to focus on learning the visual element.

This author highly recommends that learning Uniportal VATS should take this step-wise approach. For the surgeon familiar only with open surgery, it is advised that experience first be acquired with 3-port VATS. After mastering that, it is advised that some time is spent with 2-port VATS. Only when that has been accomplished should the surgeon proceed to Uniportal VATS. It is understandable that the number of operations performed using 3-ports and then 2-ports before going on to Uniportal VATS will vary greatly from surgeon-to-surgeon depending on prior experience with conventional VATS and other factors. The author appreciates that there are a number of surgeons who have successfully gone from performing open surgery straight to Uniportal VATS. Nonetheless, in general, the technical challenges posed by Uniportal VATS should never be underestimated, and the safety of the patient must come first. A step-wise approach to acquiring the manual and visual skills is intuitively more cautious and theoretically safer. It should never be considered (at present anyway) that Needlescopic, 2-port or even 3-port VATS is 'inferior' to Uniportal VATS. Evidence for that does not currently exist. Hence, the surgeon should rest assured that when providing these other forms of VATS he/she is giving the patient virtually equally good care–even as he/she is learning to eventually perform Uniportal VATS. Furthermore and by the same logic, Needlescopic and 2-port VATS need not be merely considered 'stepping stones' along the path to Uniportal VATS, but as the destination in their own right. If a surgeon feels that Uniportal VATS is not the right approach for him/her for any reason, there is nothing wrong with sticking to Needlescopic and 2-port VATS.

Another point to make about the evolution of sharing a port is the fact that using familiar instruments and techniques is important. When changing from 3-ports to 2-ports, the instruments via the utility port can stay the same as with 3-ports. When changing from 2-ports to Uniportal and only the video-thoracoscope position is changed, again the instruments used in 2-ports VATS can be kept unchanged. The implication of this is that it is not necessary to purchase any expensive new instruments to 'allow' one to start performing Uniportal VATS. Instead, it is better to approach the new technique using familiar instruments. Not only will this make it easier to learn, but it will allow the surgeon to gradually understand exactly where the old instruments may or may not be deficient when performing Uniportal VATS. There are many so-called 'dedicated for Uniportal' instruments available, some of which are very good but many of which are quite expensive. It is advised that the surgeon should gain some experience with the technique and understand the specific areas where an expensive new instrument may help before splurging on a new purchase.

Coping without the posterior port

When transitioning from a conventional 3-port VATS approach to a Needlescopic and then a 2-port approach, it becomes evident what the posterior port is used for. Primarily, it is a port for retraction. A grasping instrument (such as a Rampley forceps) is used to distract the lung allowing instrument(s) from the anterior utility port to approach the targets for dissection. The second most common use is for introduction of the staple-resection device (or 'stapler' for short). As mentioned above in relation to the modified 3-port VATS approach, introduction of the stapler from a posterior-to-anterior and inferior-to-superior direction has advantages, particularly in avoiding impingement of the anvil against other hilar structures as the stapler is passed around vessels. A third (less common) use is placement of the video-thoracoscope to look behind or above the lung hilum during certain points

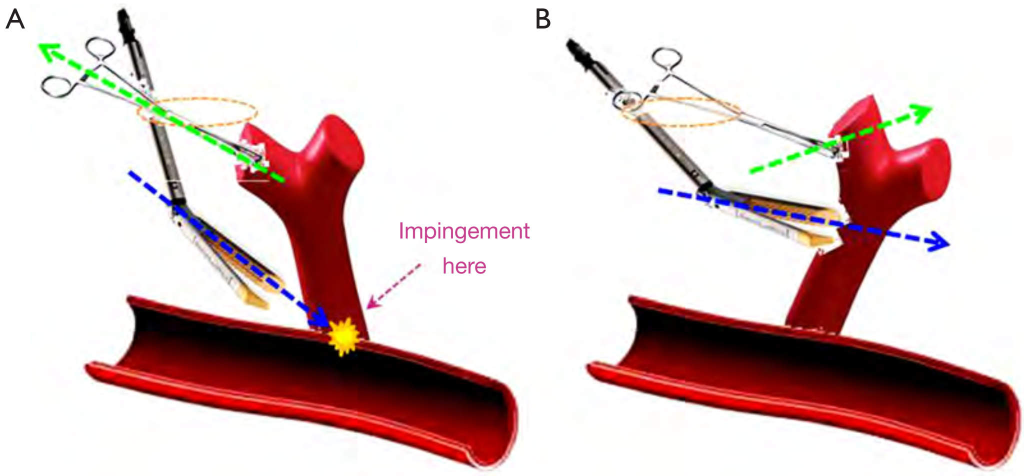

Figure 7 Example of manoeuvring the lung to enable the correct angulation for stapling. (A) If the lung is simply retracted upwards (green arrow) or towards the Uniport (yellow ring), the stapler is inserted downwards near-vertically (blue arrow) and even with reticulation of the stapler head the stapler tip will impinge against the mediastinal or hilar structures, impeding passage of the stapler around the vessel branch; (B) if the lung is instead distracted away (green arrow) from the Uniport (yellow ring), the target vessel branch is better displayed, allowing the reticulated stapler to approach perpendicularly at a 'flatter' angle (blue arrow) and avoid impingement against any structures on the far side.

of the dissection. Therefore, when progressing to 2-port and Uniportal VATS, the surgeon must compensate for the loss of these three uses of the posterior port.

Distracting the lung from the area of dissection can be accomplished to some degree by greater use of rotation of the operating table. Approaching the anterior hilum can be facilitated by tilting the table posteriorly, and approaching the upper mediastinum by tilting it 'head up', for example. More importantly, experience with 2-port VATS shows that effective retraction can be easily provided using curved lung clamps—such as curved ring forceps or Harken clamps. These are usually completely sufficient, and there is no need for more fanciful endoscopic rectractors. However, the surgeon may find that an ability to hold more than one retractor with the fingers of the non-dominant hand while performing intricate dissection with the dominant hand is an invaluable skill. This is because with a 2-port or Uniportal VATS technique, there is little or no room for an extra assistant to reach in and help with retraction.

The loss of the posterior port for introduction of the stapler is compensated for by better understanding of how to manoeuvre the lung (*Figure* 7). Simple 'pulling up' retraction of the lung can result in the wrong angle of approach for the stapler, with medial or posterior structures impeding the passage of the anvil. For example, this is often the problem when beginners find it difficult to pass the stapler around a superior pulmonary vein during Uniportal VATS. Because the port is sited immediately over the vein, passing a stapler straight into the wound means that the near-vertical direction causes the anvil to be blocked against the hilum posteriorly. Instead, the retraction should aim to lift the lung in such a way as to allow the stapler to approach a vessel in a perpendicular direction. Using the above example, retracting the lung in a cephalad and slightly anterior direction allows the stapler placed via the uniport to approach the superior vein in a more horizontal direction without hitting the hilar structures behind the vein. It goes without saying that a reticulating stapler is a must to facilitate stapling during Uniportal VATS. The use of curved tip reloads also greatly helps to negotiate vessels in the absence of the posterior port for staler introduction. It should also be noted that the use of the 5th intercostal space for upper lobectomies is also because it allows a more horizontal angle for the stapler to approach the superior pulmonary vein.

The lack of the posterior port to allow the video-thoracoscope to look 'behind' or 'above' the hilum is actually not the problem it first appears to be during Uniportal VATS. The simple reason is that the scope is now placed via the utility port anyway, which is already at a higher level than the posterior port. Using a 30° video-thoracoscope via the Uniport already gives at least as good a view over the hilum as would have been obtained via the old posterior port.

Axis and perspective

The evolution of the VATS approaches has highlighted the concepts of the operative axis and of the visual perspective during surgery. The axis is that imaginary straight line from the surgeon (or camera port) through the point of dissection to the video monitor. Using the 'baseball diamond' imagery, this is the line from the 'home base' to the 'second base' and beyond. If the ports at 'first and third bases' are on a line perpendicular to this axis, then the left and right hand instruments will triangulate towards 'second base' and fencing between instruments with each other and with the camera is theoretically reduced. Also, the closer line between the surgeon and the monitor is to the line between the 'home base' camera port and the monitor ('second base'), less discrepancy there is between the visual axis and the actual operative axis—and consequently the easier the hand-eye co-ordination will be.

Understanding the role of this axis explains why the modification of the classic 3-port VATS ports placement was necessary, and why it is relatively easy transitioning from 3-port VATS to Needlescopic VATS. When changing to a 2-port VATS approach, the axis is maintained as for Needlescopic VATS, but essentially the dissection is now done exclusively from 'first base'. When changing to Uniportal VATS, the axis is rotated posteriorly as already described earlier. A grasp of this evolution of the axis direction-coupled with knowledge of the hilar anatomy-helps in understanding how to visualize the surgery during Uniportal VATS and to negotiate the dissection.

The concept of perspective is different from that of the axis (*Figure 8*). With 3-port, Needlescopic and 2-port VATS, the surgeon's perspective of the operative field is exactly that of the 'baseball diamond'. Namely, the surgeon's view is that of a batter standing at 'home base' and looking out across a flat horizontal baseball field towards 'second base' with 'first and third base' on the same horizontal plane to the right and left respectively. Because this same perspective of looking out across a field is the same between these approaches, it is relatively easy to switch between these approaches. It also makes sense that the 'first and third base' ports are 'above' the level of the camera port. With Uniportal VATS, the camera looks down the same wound as the instruments, and the perspective is instantly changed (17). This calls for a bit of adaptation of the usual hand-eye co-ordination to get used to. It also means that the surgeon looks into the wound from the perspective of a standing human looking down into a mine-shaft instead of across a horizontal field. In this position of a human looking downwards, the eyes are actually 'above' the right and left hands. Therefore in the uniport (assuming the surgeon stands anterior to the patient), if the camera is placed at the lower or more anterior part of the wound and the right and left hand instruments enter the wound 'above' the camera at the more posterior part of the wound, it becomes disorientating for the surgeon. Instead, to maintain the normal perspective of a human looking down a mine-shaft, the camera should be kept at the posterior end of the wound and the right and left hand instruments should enter anterior ('below') to the camera or 'eyes'. Obviously, this rule may sometimes be overruled for certain situations, but keeping to it makes Uniportal VATS less disorientating for most of the time.

Troubleshooting

The realization that Uniportal VATS is part of the evolution of minimally invasive thoracic surgery means that whenever difficulties are encountered, the same solutions that are used in other forms of VATS can also be applied just as effectively (1,2). Some examples include:

- ❖ Bleeding: mild bleeding can be effectively controlled with topical hemostats and compression. More severe bleeding can be amenable to endoscopic suturing. It is again emphasized that experience with 3-port and 2-port VATS may be invaluable in providing proficiency with endoscopic suturing and hemostatic techniques prior to embarking on Uniportal VATS;
- ❖ Fused interlobar fissure: the 'fissure-less' (or 'fissure last') approach to a lobectomy is now commonly used in conventional VATS (18), and remains perfectly applicable for dealing with fused fissures during Uniportal VATS;
- ❖ Air leaks detected on-table: as with conventional VATS, major air leaks can be repaired by endoscopic suturing. Minor air leaks are effectively treated with the application of topical sealants. In the author's experience, aerosolized fibrin sealant sprayed onto areas of small air leaks can reduce both chest drain durations and lengths of stay after VATS lung surgery. The cost of the sealant is usually more than offset by the reduced costs in post-operative hospital stay. If in doubt, the degree of air leak can be assessed by connecting a portable digital chest drain system whilst the patient is still on-table, and the digital reading

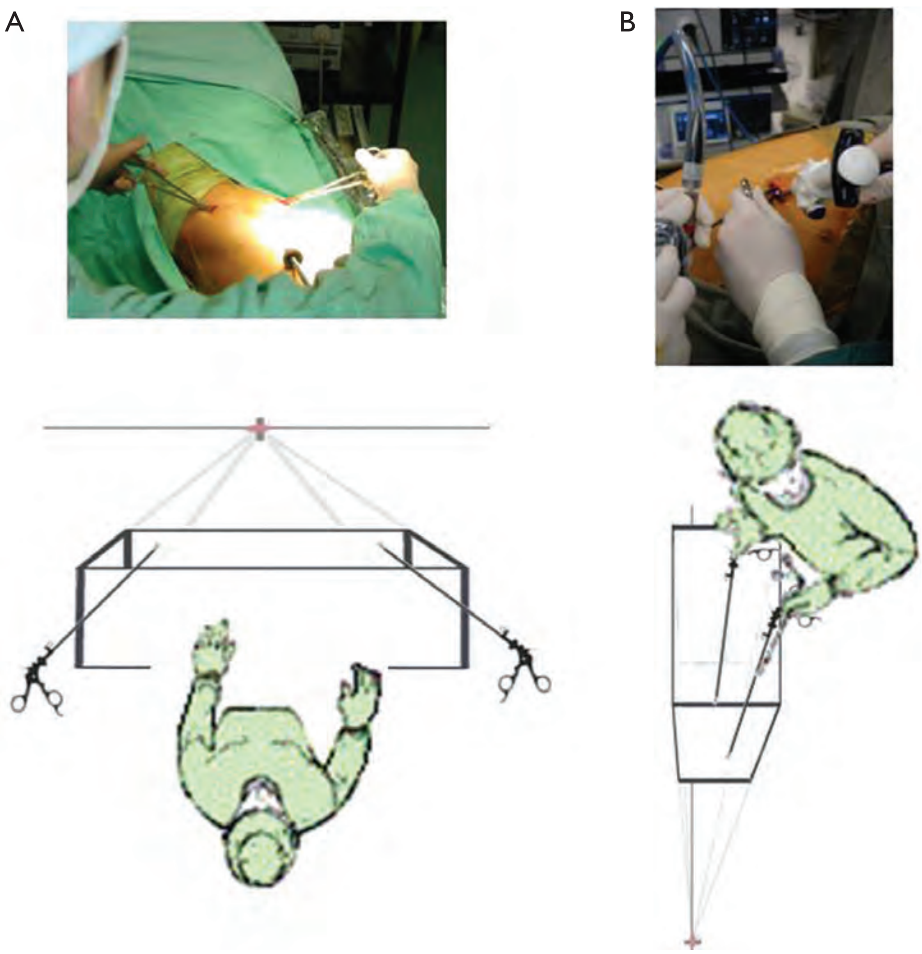

Figure 8 The issue of perspective. (A) With classic 3-port VATS, the surgeon looks out onto a flat, horizontal baseball field. With the surgeon at 'home base', the right and left hand instruments at 'first and third bases' are in front of the surgeon and farther along that flat field. This translates into a camera port positioned 'lower' (closer to the surgeon) than the right and left ports; (B) with Uniportal VATS, the view is more like looking downwards into a mine shaft. As the surgeon looks into the mine shaft, the eyes are naturally at a higher level than the right and left hands. This translates into the camera placed in the Uniport 'higher' (father from the surgeon) than the right and left hand instruments. For a surgeon standing anterior to the patient, this means the camera is placed towards the posterior end of the wound. VATS, video-assisted thoracic surgery.

of how much air flow is coming out can help guide whether further on-table intervention is required. It is the author's preference to always deal aggressively with air leaks, because a prolonged air leak can negate the advantages of any form of VATS in reducing patient lengths of stay and allowing faster recovery;

- Large tumors: it is frustrating for the surgeon to complete a major resection and then find that the resected specimen is too large to deliver via the patient's intercostal space. Converting to a thoracotomy or use of forcible rib-spreading would negate the advantages of any form of VATS in reducing pain. In such situations, the author uses a technique of controlled cutting of a rib anteriorly to allow the intercostal space to be widened with minimal force (19). This technique was developed for multi-port VATS, but has proved useful in 2-port and Uniportal VATS.

Peri-operative care

One of the more important lessons learned during the evolution of VATS was that how the patient is managed outside the operating room is just as important as how well he/she is managed inside it. In the early days of VATS, patients receiving a VATS procedure were nursed and rehabilitated exactly the same as a patient who received the same procedure via an open thoracotomy. The result was that such patients recovered or were mobilized so slowly that they did not enjoy the full potential benefits of having received Minimally Invasive Surgery.

With all VATS patients in the author's institute today, a bespoke Clinical Pathway is used to guide their peri-operative care from all clinical disciplines (4). The Pathway (equivalents are also referred to as 'fast track' or 'expedited recovery' in other centers) covers every aspect of nursing, physiotherapy, mobilization schedules, peri-operative investigations, pain management, chest drain management, nutrition, communication with the family, and so on. Goals for each day are set and monitored. Using this Pathway has already reaped significant benefits in terms of: pre- and post-operation lengths of stay; morbidity; readmission rates; and so on. Consistent, objective care is also ensured for all patients regardless of which member of the surgical team sees each patient. The Pathway has been updated to complement the increasing use of Needlescopic and 2-port VATS in recent years, and further updating is planned to take advantage of Uniportal VATS. Any center planning to introduce 'next generation' VATS approaches is urged to first plan a Clinical Pathway, lest the advantages of good operating become squandered.

Another area where peri-operative care is augmented to complement VATS is the infusion of cost-effective new technology. A prime example is the use of the aforementioned portable digital chest drainage system (20). This system is a small, portable box connected to a patient's chest tube that has an internal suction mechanism delivering any level of negative pressure set by the clinician. The negative pressure level is regulated very precisely, avoiding variations that may prolong post-operative air leaks. The mechanism is also completely internal (it runs on internal rechargeable batteries like a mobile phone) and does not require connection to any outside contraption such as wall suction. The advantage is that even with negative pressure applied, the patient is not tied down and can freely mobilize even on the day of surgery. this complements VATS—and especially our 'Next Generation' and Uniportal VATS—perfectly, allowing the faster physical recovery expected of such techniques. The 'digital' part of the system refers to an in-built digital air flow monitor that accurately displays in real-time the flow of air coming out of the chest tube from the patient's thorax, providing an objective quantification of any air leak after surgery. This avoids the inherent uncertainty in identifying air leaks using a water seal system, which can lead to hesitancy in chest drain removal or air leak interventions, and hence in turn to prolonged lengths of stay. We have previously reported significantly reduced chest drain durations and lengths of stay for our patients using the new digital chest drain systems (20). When developing a Uniportal or 'next generation' VATS program, it is therefore advised that one should look out for peri-operative technology that can complement the operation and help it fulfill its potential for patients.

Dealing with the rookie

One lesson from natural history is that evolution does not occur at the same pace for everyone. Even within a surgical team, different individuals may have evolved to different degrees. In the author's unit, the surgeon may have acquired advanced VATS skills in the step-wise fashion as described above, but the assistants are often very inexperienced—often barely out of internship. The frustration is that regardless of how good a surgeon's manual dexterity is, if the assistant is unable to deliver a decent view with the video-thoracoscope then visual element of the surgery will impede the performance of the operation. The rookie assistant therefore becomes the rate-limiting step. The evolution of VATS has taught us three simple lessons on how to help the rookie deliver a better performance.

First, the rookie assistant may need to undergo the same step-wise progression through the various incarnations of VATS. The classical 3-port VATS uses a fixed camera port with a trocar and is perhaps the easiest for the beginner camera-assistant to cope with. The fixed port reduces camera wandering and the trocar protects the lens from becoming easily smeared when introducing the video-thoracoscope into the chest. On the other end of the spectrum, Uniportal VATS is the greatest challenge for the camera-assistant. The video-thoracoscope is not held in a snug port but is actually free to wander around the entire 3-5 cm length, and the lack of a trocar means the lens can be easily smeared. This is made even worse by the fact that the wound is only a short distance from the point of dissection with performing Uniportal VATS (as opposed to the camera coming in from a distance via a low camera port with other types of VATS). With inexperienced camera-assistants, therefore, it may always be a good idea to start with 3-port or 2-port VATS before moving on to a Uniportal operation. It does not matter how experienced the surgeon is: if the camera-assistant cannot cope with handling a Uniportal VATS procedure, then for the sake of patient safety, it is best to fall back to 3-port or 2-port VATS without hesitation. The rookie can then be trained up from there.

Second, a system of effective verbal instructions must be developed. The surgeon's hands during Uniportal VATS are often 'busier' than with 3-port or 2-port VATS, because retraction is so much more critical to exposure of the site of interest or dissection. As said before, each hand may hold more than one retractor in order to adequately expose the site. The surgeon therefore cannot reach out to physically correct a badly positioned video-thoracoscope. Verbal instructions to the rookie are all-important. For example, even seemingly simple commands as 'higher/lower' must be clarified before starting: does this mean to look up/down or to go more cephalad/caudal? More importantly when using a 30° video-thoracoscope, the inexperienced camera-assistant needs to be told how to use the angled view. The author uses the clock face to tell the assistant how to do this when using a conventional video-thoracoscope setup with both a video-camera and a separate light cable attached. A '12 o'clock' view means to hold the light cable at the top side of the video-thoracoscope, so that the 30° is from the top looking downwards. A '3 o'clock view' means to hold the light cable at the right side of the video-thoracoscope, so that the 30° is from the right looking leftwards.

Third, the lesson about perspective above is employed: the inexperienced camera-assistant is given a simple instruction to keep the video-thoracoscope lightly pressed at the posterior end of the Uniport throughout the procedure. This allows a steadier view as the scope rests against the posterior edge of the wound, whilst maintaining the 'eyes-above-hands, looking down into a mine-shaft' perspective. A simple instruction like this is much easier for the rookie to follow than more complex ones.

What evolution means for VATS

The fact that the development of minimally invasive thoracic surgery is an evolutionary process has implications for those looking to learn and practice Uniportal VATS as discussed above. To summarize, the take home message for surgeons is threefold:

(I) Uniportal VATS is not an 'all-or-nothing' proposition. There are many steps between open thoracotomy and Uniportal VATS. These are not only steps along the path of training, but legitimate alternative approaches in their own right;

(II) For the surgeon with experience in conventional VATS, there is no need to be intimidated. Because Uniportal VATS is 'just' another step in the evolutionary process, the same basic principles and techniques of conventional VATS are all applicable–including instruments, methods for trouble-shooting, and so on. This reassurance of familiarity should help guide the learning of the Uniportal approach;

(III) The surgeon is not the only one evolving. As with the evolution of any species, a change in one individual can perpetuate if it can be shared with the population. In VATS, a skilled surgeon alone cannot sustain a new approach or technique. It is necessary to train the assistant, involve the multi-disciplinary team in a Clinical Pathway, and introduce appropriate complementary technology, and so on.

Looking ahead, the evolution of VATS holds another message for the future–and that is that evolution never stops. It is an ongoing process. That means that even Uniportal VATS is not the end of the road, and future advances great or small are inevitable. This in turn means that each new surgical technique must not only be mastered, but very well studied and analyzed for its strengths and weaknesses. Just as the analysis of classical 3-port VATS, Needlescopic VATS and 2-port VATS over the years have provided vital lessons about how to perform Uniportal VATS today, a close study of the practice of Uniportal VATS may provide invaluable experience to help nurture future generations of minimally invasive thoracic surgery.

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The uni-portal video-assisted thoracic surgery: achievements and potentials

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Abstract: Described for the first time in 2004 for performing minor lung resection, during the following ten years a growing scientific evidence supported the spread and evolution of the uni-portal video-assisted thoracic surgery (VATS). This novel approach, performed using a single thoracic incision, requires a change of perspective in relation to traditional VATS, offering on the other hand a great versatility for numerous surgical procedures. The present work reviews the literature inherent to the uni-portal VATS with the aim of highlighting the principles of this technique, the fields of application, the obtained results and the future perspectives.

Keywords: Minimally invasive; video-assisted thoracic surgery (VATS); uni-portal VATS; lung resection

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Introduction

During the last fifteen years, we have seen a substantial change of course in the scenario of thoracic surgery. The minimally invasive video-assisted surgical approach has spread in a gradually wider and more rapid way, being nowadays the treatment of choice for many thoracic disease traditionally managed by open surgery.

This is the result caused by a growing scientific evidence demonstrating the effectiveness of the video-assisted thoracic surgery (VATS) at various levels: reduction of tissue damage, postoperative pain and immunological impact, lower postoperative complications rate, shortening of length of stay, more rapid postoperative recovery of physical, emotional and social role, cost containment.

In this context, the uni-portal VATS plays a prominent role, representing the VATS with the least possible trauma for thoracic operations.

It has been performed a literature search using the following MeSH terms: "lung resection" AND "uni-portal VATS" AND "single port VATS"). The obtained papers were examined by both authors, which selected those to retrieve considering the titles (first exclusion process) and then the abstracts of the remaining studies (second exclusion process). Review papers were also searched for cross-references (*Figure 1*). We decided of considering exclusively those papers in English language and the search was carried out in March 2014.

Brief technique description

In 2004 Rocco *et al.* described for the first time a novel technique to perform pulmonary wedge resections through a single thoracic incision, with the assistance of a 5 millimeter thoracoscope (1). The theoretical and practical aspects of the so-called uni-portal VATS were more widely explained in two other papers published in 2005 (2,3) by the same group of authors.

The uni-portal approach for the treatment of thoracic diseases implies a substantial mindset change in comparison to the three-portal VATS, with consequent technical implications.

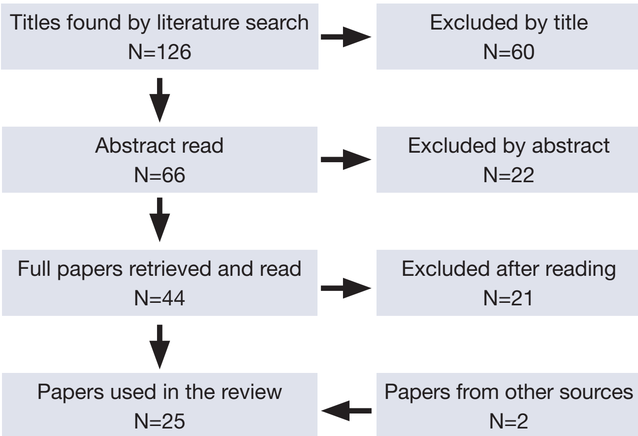

Figure 1 Literature search method.

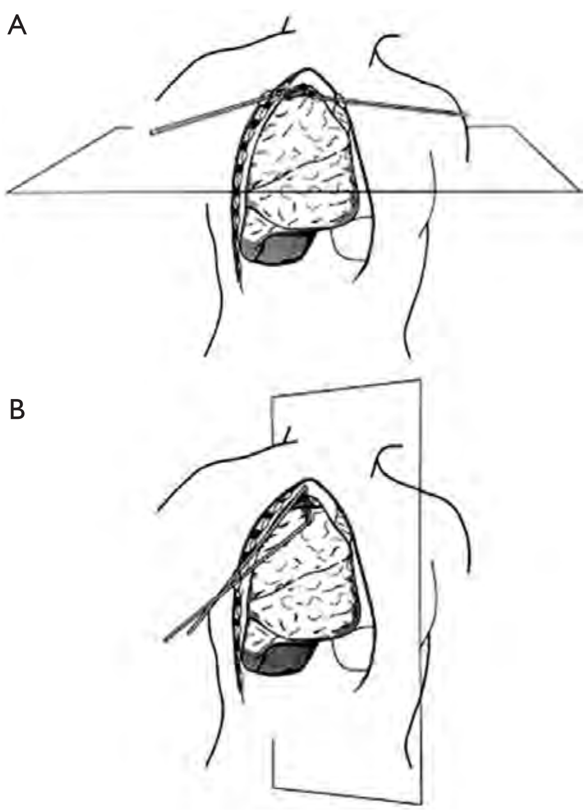

Figure 2 (A) Different approach to the target lesion in three-portal uni-portal (B) VATS. VATS, video-assisted thoracic surgery.

The single incision of the chest has a variable extent between 1 and 2.5 centimeters in relation to the different indications for the operation and eventually to the extent of resection. In any case the operative instruments as well as the videocamera lies in the same hole of the intercostal space, representing the fulcrum where they mutually move in. This fulcrum and the target lesion settle a unique plane, within which the surgical instrument and the thoracoscope operate. Changing the fulcrum point (varying the intercostal space, or the location in the same intercostal space) dependently to the target, it is possible to create infinite planes, able to reach virtually all the positions and lesions inside the chest cavity (1-4). As a result, this approach offers a considerable freedom of movement in spite of only one access point, that is further increased by the use of reticulating instruments and videocamera with 30 degrees vision. *Figure 2* shows the different working planes and the strategy to reach the target lesion for the uni-portal and traditional three-portal VATS.

The geometrical and optical benefits of the uni-portal VATS have been recently described by Bertolaccini *et al.* (5). In 2013 they published a paper that describes the advantage of the uni-portal approach, offering a projective plane with a cranio-caudal perspective that maintain the depth of intraoperative visualization and a more intuitive instrumentation movement.

Literature revision

The first paper published by Rocco *et al.* about the use uni-portal VATS in 2004, described the feasibility of wedge pulmonary resection (1). The authors reported fifteen cases performed by a single port approach without complication intra- or postoperatively, and without any conversion to three-port VATS or thoracotomy.

Since then the indications of this technique have increased considerably.

In 2007 Rocco described the use of this technique for the sympathectomy in the treatment of hyperhidrosis (6). Chen *et al.* published in 2009 the results of a comparison between 20 patients submitted to video-assisted thoracoscopic sympathectomy by a single port and 25 treated by a bi-portal approach (7). For both groups the treatment was effective (hands warm and dry for all patients), without any conversion to a more invasive procedure for the uni-portal patients. Moreover the authors found a reduction of the operative time (uni-portal 39.5 min *vs.* bi-portal 49.7, P=0.02) and inpatient pain scores (uni-portal 0.8 *vs.* bi-portal 1.6, P=0.02) in favor of the uni-portal approach, with comparable results in terms of mean hospital stay, compensatory sweating, and patient satisfaction.

The uni-portal VATS was then used for performing wedge lung biopsy in order to obtain specific diagnosis in patients affected by interstitial lung disease, as reported by Rocco *et al.* in 2005 (3). They were able to perform a median of two lung biopsies for each of the 20 patient treated, obtaining a diagnosis that altered the therapeutic management in 14 of them.

In 2005 and 2008 two different papers assessed the advantages of the uni-portal VATS for the treatment of primary spontaneous pneumothorax in comparison to the traditional three-portal approach (8,9). Jutley *et al.* compared 16 pneumothorax patients submitted to surgery using the uni-portal approach to 19 patients treated by the three-portal VATS. They found similar drainage time, length of stay and recurrence rate but a lower post-operative pain and paraesthesia incidence in favor to the uni-portal group. In 2008 Salati *et al.* reported the clinical and economic results of the use of uni-portal VATS versus the traditional three-portal approach for the treatment of primary spontaneous pneumothorax (uni-portal group: 28 patients *vs.* three-portal group: 23 patients). All the patients were submitted to bullectomy and pleural abrasion. The uni-portal group experienced a faster hospital stay (3.8 *vs.* 4.9 days, P=0.03) and a lower incidence of paraesthesia (35% *vs.* 94%, P<0.0001). Moreover the authors found an overall cost reduction for the uni-portal technique (1,407 Euros *vs.* 1,793 Euros, P=0.03).

In 2006 Rocco *et al.* reported the feasibility of pericardial window using an uni-portal approach (10). They described the technique to perform this procedure in four patients with malignant pericardial effusion, underlining the possibility of performing concomitant procedures (as mediastinal nodes biopsies) and the minimization of the patient discomfort.

In a paper of 2006 the uni-portal VATS was presented as a valuable technique supplementary to the conventional approach (mediastinoscopy, anterior mediastinotomy, three-port VATS) for the mediastinal nodes diagnosis (11). The authors described 13 patients operated by a single video-assisted access: the diagnosis was obtained in all cases (primary malignant nodal disease—5, secondary malignant nodal disease—6, granulomatous systemic disease—2), with a median postoperative hospital stay of 1 day.

The versatility of the uni-portal VATS technique made possible its use for the treatment of a patient affected by penetrating chest trauma (shotgun) (12). The authors reported the possibility of performing the procedure through the same incision of the chest tube inserted to evacuate the hemothorax. They were able to explore the entire thoracic cavity and remove the bullet situated in the costophrenic recess.

The last frontiers of implementation of the uni-portal VATS have made possible its use in the treatment of patients in an ambulatory setting without general anesthesia and in the execution of major anatomic pulmonary resections.

In 2010 and 2011 Rocco *et al.* described two different cases of pulmonary wedge resection performed through a video-assisted single access (13,14). Both patients received a mild sedation and an epidural anesthesia, moreover an intra-bronchial ballon catheter, bronchoscopically positioned, excluded from ventilation the lobe containing the target lesion. The authors performed the pulmonary resection using multiple endo staplers firings (resection of pulmonary nodule—first case and bullectomy for pneumothorax—second case), and they were able to discharge the patients the day after the surgical procedure. In 2014 Galvez *et al.* (15) confirmed the feasibility of the procedure, performing a metastasectomy of the left upper lobe without the necessity of endoscopic procedure for lobar collapse. It should be underline that the surgical incision was 5 cm long in this case.

In 2011 Gonzalez *et al.* reported a case of left lower lobectomy performed by a video-assisted single-port incision (16). This novel technique adopted several methodological aspects clearly stated by the uni-portal VATS and modulated them to perform anatomic major lung resection. The single access is 4 cm long and allows inserting all the operative instruments as well as the videocamera (usually 10-mm thoracoscope, 30-degrees), that is placed at the tail of the incision. The methodology and the operative steps of this novel technique were extensively described in a paper published in 2012, with specific annotation for each type of lobar resection (17). In the same year, Gonzalez-Rivas *et al.* published their initial experience of 23 patients treated by the uni-portal VATS lobectomy (18), showing a success rate of 87% with no mortality and a postoperative length of stay of about 3 days. Parallel with the refinement of the technique and the evolution of the operative armamentarium, the uni-portal VATS for major lung resection was applied for performing progressively more challenging operation, as anatomic segmentectomy (19), pneumonectomy (20), sleeve lobectomy (21) and pulmonary artery reconstruction (22).

Conclusions

From the first report published 10 years ago, the uni-portal VATS has greatly expanded its scope. The progressive refinement of the technique associated with a broader range of surgical instruments made possible the treatment of the vast majority of the pathologic intra-thoracic conditions (23), including the major anatomic pulmonary resections for primary lung malignancy (24).

Neverthless, due to its relatively recent description and implementation, this minimally invasive approach has the potential and the urgency to expand the scientific evidence about its benefits as well as to explore new areas of use.

In this sense, some papers have already demonstrated the advantage of the uni-portal VATS in comparison to the traditional multi-portal techniques. The reduction in postoperative pain and neurologic complaints was showed by more than one study which verified the uni-portal VATS outcomes in patients treated for primary spontaneous pneumothorax (4,8). Moreover it has been documented a faster postoperative hospital stay and recovery of daily life activities as well as a clear cost reduction in the same group of patients (4). At the same time, there is lack of large comparative or randomized studies aimed at verifying a reasonable positive effect of this minimally invasive approach on the above-mentioned outcomes and on the immunologic status of the patients, particularly in those submitted to major lung resection for neoplasm.

Finally, reflecting a constant evolution of the uni-portal VATS, this approach was also adopted to identify and resect peripheral lung nodules with the help of an articulating endoscopic ultrasound (25). This opens another scenario where the uni-portal VATS could play a prominent role, contributing at the identification and diagnosis of lung or mediastinal lesion not reached until now.

At the same time, it is desirable the growth of solid scientific evidence to confirm the advantages of this technique over the traditional approaches.

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Evolving from conventional video-assisted thoracoscopic lobectomy to uniportal: the story behind the evolution

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Diego Gonzalez-Rivas personal experience: how the idea of uniportal VATS lobectomy was born

"Humans are allergic to change. They love to say, we've always done it this way. I try to fight that. That's why I have a clock on my wall that runs counter-clockwise."

—Grace Hopper

When I started my training in thoracic surgery in 1999, I realized that the post-operative period for patients were very painful and hard because the incision we used to operate was very large, about 15 cm with rib spreading. So very often I thought of ways on how to improve this post operational period of our sick patients. In short, what could we do to reduce this pain and facilitate a better quality of life?

"There is always a way to do it better, so find it."

—Thomas Edison

So I started to study the origins of thoracoscopic surgery and this approach started to fascinate me. In the year 1910, Jacobaeus, described the first thoracoscopy to release adherences in patients suffering from tuberculosis. Before him, Kelling had done this in 1901 in dogs but not in humans. He did not publish this though and therefore Jacobaeus is claimed to be the first surgeon to use thoracoscopy in 1910. For many years this procedure was relegated to diagnostics and therapeutic procedures up till 1992 when Giancarlo Roviaro decides to do the first lung resection to surgically treat lung cancer through small incisions, looking at a screen and no rib spreading. He went from an aggressive open surgery to a minimally invasive surgery by using only three small incisions enabling the patient to a better postoperative recovery. This revolutionized the world of thoracic surgery. He was criticized for many years by the more traditional surgeons who considered themselves more prestigious than him by claiming that this procedure was not a total oncological procedure.

Time proved him right. Giancarlo Roviaro believed in his idea that the post-operative period of his patients could be improved by doing surgery with small incisions. His experience doing surgery through small incisions showed him this was not only possible but that his patients had much less pain and faster recovery after surgery.

The medical community did not see it this way and many years had to go by before he was recognized for his work. This is the story of medicine and in general of mankind.

I decided I had to learn this technique so I searched which hospital in the world had the most video surgery experience. So, in 2007 I went to Los Angeles in the United States and learned the surgical technique through 3-4 incisions with one of the most expert surgeons of the world (Dr. Robert Mckenna) and I put to it practice at my hospital. When we gathered enough experience I decided I had to improve my technique further, so I went back again to New York. By chance, I met a person there who changed my way of thinking. I had gone to New York to improve my three incisions technique and this person told me they were doing two incisions at Duke University Medical Center in North Carolina. This thought really confused me as I couldn't understand how surgery could be done through

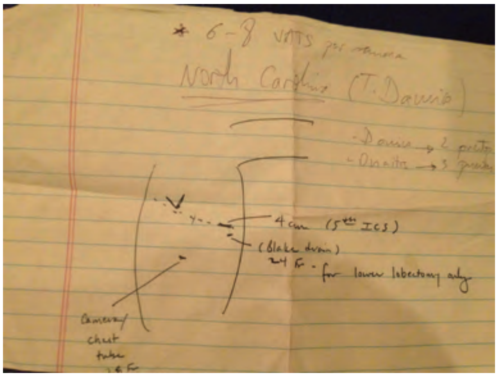

Figure 1 Drawing showing the double port technique from Duke medical center, US.

two incisions only. In my head I had the concept that three incisions were necessary: utility incision for instrumentation, inferior port for the camera and posterior incision for holding the lung. I wasn't able to think differently so I asked this person to draw it on a piece of paper (*Figure 1*).

After I returned to Spain this piece of paper kept me thinking and rethinking about how this could be done. I couldn't understand it. I decided then to go to Duke. I contacted the chief surgeon at Duke and he answered that he didn't accept people whom he did not know so you can imagine my disappointment. I couldn't accept a "no" for an answer so I persisted. I had to meet him. I decided to go to a congress that he would attend so I could meet him in person. I attended the annual meeting of the American Thoracic Society to meet Dr. Damico, and after an unforgettable conversation I asked him about the possibility to visit his institution and then I was accepted. Thanks to persistence Dr. D'Amico and I are very good friends and we organize courses together. Thanks to the persistence of an idea. If I wouldn't have believed in this I would've never met him and I wouldn't be where I am nowadays.

So it is important to never stop thinking and to never let your ideas go if you believe they are important.

However, thinking differently has produced a lot of troubles to those who came up with new ideas or innovations. A clear example of this was Galileo—Galileo during his time dared to say that the world was round and as a consequence was sentenced to be arrested for a long time at home. In order escape from this punishment he had to reject his idea and say all was a lie.

Another example of innovation and ideas, this time in relation to medicine, was Semmelweis. This person discovered asepsis. He tried to convince his colleagues that if people washed their hands their patients would have less post-operative infections. He was expelled from the international scientific community and finally died from an infection (after cutting himself during an autopsy).

Obviously, people who think differently, who are visionaries are the ones who change the world. The founder of Apple, Steve Jobs was a visionary and he became a genius. He pronounced these words:

"Here's to the crazy ones, the misfits, the rebels, the troublemakers, the round pegs in the square holes the ones who see things differently—they're not fond of rules. You can quote them, disagree with them, glorify or vilify them, but the only thing you can't do is ignore them because they change things, they push the human race forward, and while some may see them as the crazy ones, we see genius, because the ones who are crazy enough to think that they can change the world, are the ones who do".

But think differently especially in the medical world can be very risky because we are affecting the most valuable asset human beings have, health. I knew though, that I had to think differently because I was a restless person and I liked to innovate.

During the double port technique I was working most of the time with the camera located through the utility incision because I realized that I had a better direct view. So I thought: for lower lobes, all instruments and staplers are inserted through the utility incision but the view came from another perspective, not anatomic. Why not have the same view as we have during an open thoracotomy approach? Thus, in June 2010 after thinking a lot I decided to do the first lobe resection through one single port. I placed all instrumentation and the camera through the same utility incision. I realized during the surgery that I felt comfortable, with a better view and was able to finish it completely very fast. The evolution of the patient was excellent, discharged on the second postoperative day with no pain. This motivated me to continue further with this approach. When I first published it in an international journal the conclusion I drew was that this surgery was only meant for tumors in the lower lobes. For the upper lobes I thought we needed new technology to access them due to angulation a physical problem. Nothing further from reality. In time, with the evolution I realized that if we thought differently and we exposed the lung in a different way, no new technology was needed. Thus, all surgery could be done, and so we did. We published all our cases and results in the most important journals and textbook of thoracic surgery. Thanks to team work, we could teach our technique to our colleagues and residents who were starting.

In 2012, in an international congress, an Italian surgeon

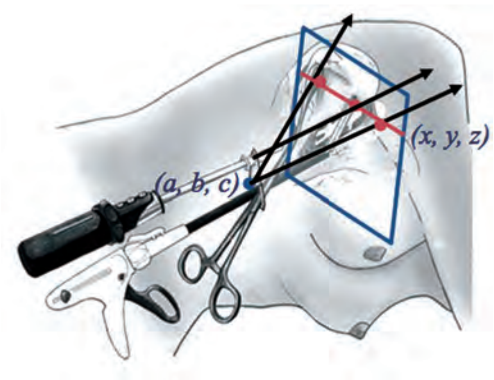

Figure 2 Geometric concept of uniportal VATS. VATS, video-assisted thoracoscopic surgery.

called Luca Bertolaccini with a background in physics and fascinated by our technique made a physical and mathematical demonstration with equations of why our uniportal technique (through one incision) was better than other techniques which were being used by some of the best surgeons in the world. The advantage of using the camera in coordination with the instruments is that the vision is directed to the target tissue, bringing the instruments to address the target lesion from a straight perspective, thus we can obtain similar angle of view as for open surgery (*Figure 2*). Conventional three port triangulation makes a forward motion of video-assisted thoracic surgery (VATS) camera to the vanishing point. This triangulation creates a new optical plane with genesis of dihedral or torsional angle that is not favorable with standard two-dimension monitors. Instruments inserted parallel to the videothoracoscope also mimic inside the chest maneuvers performed during open surgery. This mathematic explanation made me understand many things, such as why I felt so comfortable that first time, why were we able to teach the technique and reproduce it successfully in other parts of the world.

We were invited to many different countries to give conferences: China, Taiwan, Korea, Rusia, Israel, Indonesia, Brazil, Chile, Colombia, Turkey, United States, France, Italy, Germany. What first started as a curiosity, a special ability of one surgeon—I heard this thousands of times—in time it became a reproducible technique which all members of my department performed. This created even more interest. The uniportal technique was adopted in other parts of the world and we received even more demand. It's not because the technique was interesting for being a unique thing, but it's being applied all over the world and its expansion continues.

During all this time we've had many obstacles. It hasn't been a walk through the park. Because when you're doing a new technique, you need to design many new things in your head. You need to learn how to expose the lung properly, you need to search for strategies, how to teach these and not only that—the obstacles posed by people, surgeons of prestige who see themselves threatened by this novel technique because they are unable to learn it. Then critics and envies happen opposition takes place.

Because every innovation comes with restriction. Therefore, these obstacles made us grow and all critics from other colleagues we heard predicting the future such as: you're not going to reach anywhere; this technique doesn't have any future ended in nothing.

Life is full of erroneous predictions—In 1913 the president of the Michigan bank advised Henry Ford's lawyer not to invest in Ford Motor Company arguing that the horse was here to stay and the automobile was just a fad. Luckily this person didn't listen to the advice. He invested and became a multimillionaire.

We've always followed the philosophy of never be intimidated by the obstacles and be always open to progress. Because we never know what the future will bring. The next generation will be with the robotic technology, single port devices, wireless cameras. We are sure of this because the future will be the minimum invasiveness. This is why we believed in our idea. Who knows if in the future we will have devices of robotic surgery at home? What we can't do is close ourselves to evolution and make predictions on things that won't work.

I've learned that in life if you walk alone, you will get there faster but if you walk in company you will get further. And without the support of the people who love you and a good team, we would've never been able to reach where we are now. Who would've told us that from a small corner of Spain, with the several colleagues against our innovation, after a lot of work, dedication and confidence we would do something that was going to bring revolution to surgery in the world.

This is why the key is to think differently, measure risks, be innovative, believe in an idea, fight for it and overcome obstacles, because "*Impossible is nothing*".

"Intelligence is the ability to adapt to change."

—Stephen Hawking

Figure 3 Video-Conference during international symposium on uniportal VATS held in Coruña (7). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/317

Coruña University and Minimally Invasive Thoracic Surgery Unit (UCTMI) experience: a coordinated teamwork

We started to perform VATS lobectomies in our department in 2007 after learning the technique at Cedars Sinai, LA (1). After performing over 80 lobectomies with three ports, we eliminated the posterior incision, and subsequently performed most lobectomies through only two ports according to the technique described by D'Amico (2). But the final step of the surgical evolution in our unit, to minimize chest wall trauma, was the uniportal approach for major lung resections.

We developed the technique to perform major pulmonary resections by uniportal approach in June 2010 (3) thanks to the previous experience in double-port VATS for lobectomy and single-port technique for minor procedures (wedge resections, pneumothorax, etc). Initially only lower lobes cases were selected.

This evolution in the approach from three ports to single port technique required a new learning curve: different lung exposure and learning how to coordinate the instruments and the camera with no interference during surgery. As with all new surgical procedures, there was a certain learning curve component but not comparable to the one experienced when starting a VATS program (4).

For double port VATS lower lobectomies all the instrumentation and stapler insertion are performed through the utility incision. Therefore we decided to insert the optic through the utility incision working in coordination with instruments to perform a single incision lobectomy. The first case we performed was accomplished in 90 minutes and the patient was discharged on the second postoperative day with no complications (3). When several lower lobes cases were performed with good results, the upper lobes were attempted (5). With gained experience the more complex resections were accomplished (6) (*Figure 3*).

Results (4 years' experience)

- June 2010-April 2014: 362 uniportal lobectomies (>900 total uniportal VATS);
- 2.4% conversion rate;
- Most frequent resection: RUL;
- Mean surgical time: 150.62 [40-310] min;
- Mean number of lymph nodes: 14.8 [5-38];
- Mean nodal stations: 4.7 [3-8];
- Median chest tube: 2 days;
- Median hospital stay: 3 days;
- Complications: 69 patients.

Tips and tricks: the uniportal approach can be adopted following two different ways

(I) Learning from conventional VATS to uniportal (our evolution)
- Remove the posterior port;
- Adopt the double port technique;
- For lower lobectomies place the camera at the posterior part of utility incision;
- Use bimanual instrumentation with curved instruments;
- For upper lobectomies place the camera through utility incision and use inferior port only for stapler insertion or for instrumentation;
- Use the inferior port only to expose the lung (camera, staplers and instrumentation through the incision);
- Remove the inferior port;
- Use vascular clips when no angle for staplers;
- Always insert the staplers with angulation for vascular division;
- Start with lower lobectomies (female and thin patients preferably).

(II) Learning from open approach to uniportal (uniportal mimics the open maneuvers)
- Adopt the Anterior small thoracotomy approach (10-12 cm incision);

- Add the thoracoscope to thoracotomy (use monitor view and open direct view during surgery);
- Remove rib spreader (same incision). Move instruments and camera along the 10 cm incision;
- Reduce progressively the size of incision after gained experience.

Future

The future of the thoracic surgery is to reduce the surgical and anesthetic trauma. We truly believe on the use of the single port technique for major pulmonary resections because we understand that the future goes in that direction, i.e., robotics and single-port. We expect further development of new technologies like sealing devices for all vessels and fissure, robotic arms that open inside the thorax and wireless cameras, which will probably allow the uniportal approach to become the standard surgical procedure for major pulmonary resections in most thoracic departments. The combination of nonintubated or awake thoracoscopic surgery and single-port VATS technique is promising because it represents the least invasive procedure for pulmonary resections (8). Thanks to avoidance of intubation, mechanical ventilation and muscle relaxants the anesthetic side effects are minimal allowing to most of the patients to be included in a fast protocol avoiding the stay in an intensive care unit.

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Geometrical characteristics of uniportal VATS

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Abstract: In terms of accuracy and efficacy Uniportal Video-Assisted Thoracic Surgery (VATS) resections are comparable to standard VATS. In standard three-ports VATS, the geometric configuration of a parallelogram generates interference with the optical source, creating a plane with a torsion angle not favorable on the flat two-dimensional vision of currently available monitors. The potential advantages of single-port VATS approach include not only the one intercostal space incision (reduction of postoperative pain) but also a translational approach of VATS instruments along a sagittal plane. Accordingly, the Uniportal approach enables VATS instruments to draw two parallel lines on the plane, bringing them to approach the target lesion from a caudo-cranial perspective thus achieving a projective plane. As a consequence, taking advantage of the unique spatial features specific to uniportal VATS, the surgeon is enabled to bring the operative fulcrum inside the chest to address the target lesion in a fashion similar to open surgery.

Keywords: Single access thoracoscopy; three access thoracoscopy; minimally invasive thoracic surgery; geometry

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Introduction

The surgical technique and current indications of Uniportal Video-Assisted Thoracic Surgery (VATS) have already been described in detail (1,2). Nevertheless, thoracic surgeons do not completely understand the potential use of Uniportal VATS because they do not completely understand the advantages of the geometrical uniportal approach.

Notes of geometry

The geometric construction of VATS is almost similar to the real word since there is a profound interplay between the natural world and the laws (3) of thought. The most fundamental and firmly accepted parts of our general scientific knowledge of the world involve mathematical models. Geometry is the field of mathematics whose main source of intuition is human visual perception. Vision is one of our most important senses giving contact with the world outside of us. In other words, visual perception is the construction, inspired by images recorded by early vision, of hypotheses which produce visual images that match physical reality in accordance with our previously acquired experience of the same reality.

According to Herodotus, geometry developed first in Egypt: "*They say that king Sesostri (2000 B.C.) distributed the land among all of the Egyptians, each one having an equal lot in a square shape, and from these subdivisions obtained tribute, having imposed an annual payment. If the river bore away a part, the owner announced the loss, and officials were sent to observe the extent to which the plot had been diminished for the purpose of adjusting the tribute payment. It is my feeling that this indicates the invention of geometry here, prior to its passing to Greece*".

Since the primary school, we are familiar with Euclidean geometry and with its well description of our world. Euclid of Alexandria was the most prominent mathematician of antiquity best known for his treatise on mathematics "The Elements", a compilation of knowledge that became the core of mathematical teaching for 2000 years. In "The Elements" the building blocks of geometry are described,

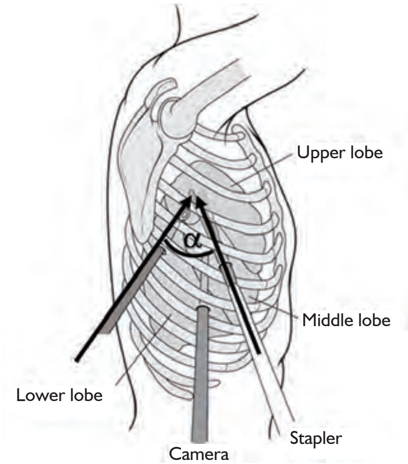

Figure 1 In the three-port access VATS the geometric configuration of lozenge interferes with optical source creating a new optical plane with the genesis of torsion angle (α) that is not favorable with standard two-dimensional monitors.

such as points (figures without size, a location in space), lines (a set of infinitely many points, with one dimension and no thickness that goes on forever in both directions), planes (with a length, a width and without thickness, that extends infinitely in two-dimensions), and rays (a part of a line that starts at a point that extends infinitely in one direction). Also, five postulates are described in "The Elements". The fifth postulate, so-called *parallel*, states that one and only one line can be drawn through a point parallel to a given line. It was not until the 19th century that this postulate was dropped and non-Euclidean geometries were studied. In Euclidean geometry, the sides of objects have lengths, intersecting lines determine angles between them, and two lines are said to be parallel if they lie in the same plane and never meet (1).

Geometry of three port access thoracoscopy

When we consider the imaging during a VATS operation, it becomes clear that Euclidean geometry is insufficient: lengths and angles are no longer preserved, and parallel lines may intersect. Lobacevskian geometry discards Euclid's 5th postulate replacing it with the following one: given a line and a point not on in, there are infinitely lines going through the given point that is parallel to the given line.

Therefore, the classic three-port approach, in which the lozenge geometric configuration allows maximal convergence of operative instruments from each side of target lesion, produces an interference with the optical source. In coordinate geometry, a lozenge is similar to an ordinary parallelogram with the addition that its position on the coordinate plane is known (*Figure 1*).

Geometry of single access thoracoscopy

Projective geometry well reflects the imaging process of VATS, because it allows a much larger class of transformations than just translations and rotations, a class which includes perspective projections. We must start from Euclidean geometry to understand the reason why knowledge of projective geometry is required to appreciate the optical advantages of Uniportal VATS. Two lines (two-dimensional geometry) almost always meet in a point. A common linguistic artifact for getting around this is to say that parallel lines meet "*at infinity*" enhancing the Euclidean plane by the addition of these points at infinity where parallel lines meet, and resolving the difficulty with infinity by calling them "ideal" points. By adding these points at infinity, the familiar Euclidean space is transformed into a new type of geometric object, the *projective space*. The projective space is an extension of Euclidean space in which two lines always meet in a point, at infinity. It turns out that the point at infinity in the two-dimensional projective space form a line, usually called the line at infinity. In the three-dimension vision they form the plane at infinity. In the real world, there are no points at infinity, namely the line at infinity in the flat image and the plane at infinity in the world (4). For this reason, although we usually work with projective spaces, we are aware that the line and plane at infinity are in some way special. Generally, we try to have it both ways by treating all points in projective space as equals when it suits us, and singling out the line at infinity in space or the plane at infinity in the image when that becomes necessary. The Uniportal approach requires the translation of the thoracoscope instruments 90° along a sagittal plane, thus bringing the operative instruments to address the target lesion from a vertical, caudo-cranial perspective. To avoid mutual interference, the use of reticulating instruments is of paramount importance for their ability to rotate the stem and the jaws independently on different planes and with multiple angles. The shift from three-dimensional world to a two-dimensional image is a projection process in which we lose one dimension. The usual way of modeling this process is by central projection in which a ray from a point in space is drawn from a three-dimensional

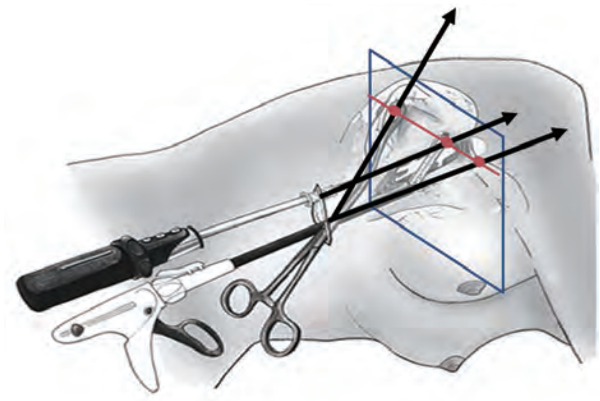

Figure 2 The Uniportal VATS approach is along a sagittal plane that reaches the target lesion from caudo-cranial perspective in a projective plane preserving the depth of intraoperative visualization *(Image courtesy of Dr. Diego Gonzalez Rivas)*.

world point through a fixed point in space, the so-called "centre of projection". This ray will intersect a specific plane in space chosen as the image plane. The intersection of the ray with the image plane represents the image of the point. If the three-dimensional structure lies on a plane then there is no drop in dimension. For the purposes of image projection, it is possible to consider all points along such a ray as being equal. We can go one step further, and think of the ray through the projection centre as representing the image point. Thus, the set of all image points is the same as the set of rays through the camera centre. Thus two images taken from the same point in space are projectively equivalent (5).

Therefore, Uniportal VATS technique is based on a completely different geometric concept compared with conventional three-port VATS (6). In fact, the approach to the target lesion in the lung is substantially similar to the approach that the surgeon would use in open surgery (2). Because the visualization of the target lesion occurs along the same axis, the target lesion in the lung would be elevated with forceps perpendicularly from the parenchymal profile and resected by applying a stapler (or a curved clamp and overseen) at the base of this newly created, cone-shaped parenchymal area (1). The instruments inserted parallel to videothoracoscope mimic inside the chest the maneuvers performed during open surgery (6). In the Uniportal VATS approach, the target lesion is located in a projective plane with homogeneous coordinates and represents the point at infinity (*Figure 2*). The epipolar geometric explanation of the advantages of Uniportal VATS is that, in the projective plane, the sagittal approach to target lesion preserves the depth of intraoperative visualization provided by the currently available two-dimensional video monitors (6).

Conclusions

Standard three-port VATS has a geometric configuration of lozenge that interfere with optical source with a creation of a new optical plane for the genesis of a dihedral or torsion angle not favorable with monitors. On the contrary, the Uniportal VATS approach the lesion along a sagittal plane; the target lesion is reached forma a caudo-cranial perspectives that realize a projective plane that preserve the depth of intraoperative visualization. In Uniportal VATS instruments are parallel lines drawn on the plane that enables surgeon to bring operative fulcrum inside the chest.

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General Consideration

Uniportal video-assisted thoracoscopic lymph node dissection

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Abstract: Lymphadenectomy is an important part of lung cancer surgery. At the moment, video-assisted thoracoscopic (VATS) is the most common approach to remove these tumors, when it is technically possible. With our current experience in VATS in major resections we have obtained a radical videothoracoscopic mediastinal lymphadenectomy, and single-port provides us with the best anatomic instrumentation and a direct view.

Keywords: Video-assisted thoracoscopic (VATS); lymphadenectomy; lung cancer; uniportal

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Introduction

Lymphadenectomy is important to identify the N, because it has a direct relationship to the prognosis after a lung tumor resection. For this reason, during the surgery, we have to be very careful with the N2 stations.

We have to distinguish between: (I) lymph node biopsy; obtaining a fragment (II) sampling: to obtain a node from each station and (III) the standard mediastinal dissection: which is to remove all the lymph nodes from at least three mediastinal stations from the affected side.

One of the principal concerns that appeared with video-assisted thoracic surgery (VATS) lobectomy was whether we could perform the same lymphadenectomy with VATS as we could perform with thoracotomy.

At present, with our current experience using VATS in many groups, we have achieved the same lymphadenectomy results with VATS as was previously obtained by a thoracotomy with even better results.

Thereby D'amico TA supports the view that videothoracoscopic mediastinal lymphadenectomy is just as feasable as conventional surgery, with similar results (1).

Watanabe A *et al*. analyzed a group of patients with lung tumor diagnosis and clinical N0, but with pathological N2 following lung resection by VATS or thoracotomy: they did not find any differences between groups in: (I) number of nodes, (II) number of nodal metastasis and (III) the 3- and 5-year recurrence-free survival. The authors concluded that it is unnecessary to convert the VATS approach to thoracotomy to do a radical mediastinal lymphadenectomy (2).

Wang W *et al.* compare the differences between VATS group and thoracotomy group in VATS lymphadenectomy results for 5,620 patients. They perform a systematic lymph node dissection with a greater number of nodes in VATS group, in addition to the known advantages of the VATS approach (3).

Figure 1 Paratracheal lymph node dissection (5). Available online: http://www.asvide.com/articles/336

Figure 2 Energy device for paratracheal lymph node dissection (6). Available online: http://www.asvide.com/articles/337

Operative techniques

We analyzed our experience in VATS for major resections for over a 3-year period [2007-2010] involving 200 cases, and we compared the differences between the three periods of time. We started performing VATS lobectomies with three ports (99 cases in the first year) and after that with only two ports or even the first single port lobectomy in the third year (4).

We observed improvements with the experience; we reduced the conversion rate, the mean surgical time, the number of lymph nodes as well as the explored nodal stations.

We must bear in mind the importance of the surgical material, which helps us to improve the lymphadenectomy. Especially with regards to:

(I) 10 mm thoracoscope (HD 30 degree);
(II) High definition monitor screen;
(III) Long, short and double-jointed curved ring forceps;
(IV) Long and double-jointed Metzenbaum scissors;
(V) Curved suction;
(VI) Long and double jointed thoracoscopic dissector;
(VII) Endopath 5 mm endoscopic peanut (×2);
(VIII) Energy devices;
(IX) Sponge stick.

Curved ring forceps are very useful to dissect and to pull the lymph nodes. We use the curved suction and sponge stick to dissect and to expose the structures. The Harmonic scalpel makes the haemostasis easier. To sum up, we give more than one use to the different instruments.

Instrumentation in VATS lymphadenectomy is vital because the surgeon works in a reduced space: in single port the camera goes into the posterior part of the incision. We obtain a direct view which makes the instrumentation easier since the view of the camera and the surgeon moving are in parallel.

The technical aspects in mediastinal spaces are:

(I) Right paratraqueal space: we remove all the mediastinal nodes and fat between trachea and cava vein (*Figure 1*). Usually it is not necessary to open the mediastinal pleura, we dissect going under the azygos vein, the result is a tunnel view (*Figure 2*). A long endothoracoscopic peanut is very useful to separate the join between azygos and cava vein. The use of energy devices facilitate the dissection and reduce the rate of postoperative bleeding.
(II) Subcarinal space: the most difficult lymphadenectomy is left subcarinal lymphadenectomy, because it is the deepest area. You have to retract the aorta on the left side and the oesophagus on both sides. That is possible with a sponge stick or another instrument like curved suction. With single port VATS you can even see the main contralateral bronchus, and the contralateral lower vein (*Figure 3*).
(III) Aortopulmonary window space: For this procedure lymph nodes should be removed from the aorta and the pulmonary artery and usually it is necessary to retract the phrenic nerve to better expose the prevascular area (*Figure 4*). Sometimes even with single port you can perform a left paratraqueal lymphadenectomy under the aortic arch (*Figure 5*).

The key for a correct lymphadenectomy in single-port VATS is good exposition and bimanual instrumentation. Moving the surgical table allows for better results thus improving the lung exposition; moving the table anteriorly

Figure 3 Left subcarinal lymph node dissection (7).
Available online: http://www.asvide.com/articles/338

Figure 4 Aortopulmonary window lymph node dissection (awake patient) (8).
Available online: http://www.asvide.com/articles/339

Figure 5 Left paratracheal lymph node dissection (9).
Available online: http://www.asvide.com/articles/340

exposes the subcarinal space and the anti-trendelenburg position which exposes the paratraqueal area.

Comments

We currently perform a complete and radical lymph node dissection by VATS. In our experience the lymphadenectomy achieved by uniportal VATS can be even better than open approach thanks to the high definition. As more cases are treated with the single-port approach, the number of lymph nodes removed increases—thus reflecting improvement in the surgical technique. In our uniportal series, the mean number of lymph nodes resected is greater than the mean number we reported by two or three port VATS (14.5±7 *vs.* 11.9±6.7) (10).

If we divide the period into two years, we observe more lymph node dissection performed during the second period: 12.2±4.7 *vs.*16±8 (P=0.055).

Conclusions

(I) Lymphadenectomy is an important part of the lung cancer surgery.
(II) To perform a standard lymphadenectomy by single port approach is possible and represents the best view if we compare with three and two ports.
(III) We can use conventional material, but it is easier with double-jointed and long instruments.
(IV) Do not forget the importance of the learning curve.

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Management of complications by uniportal video-assisted thoracoscopic surgery

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Abstract: Since the video-assisted thoracoscopic surgery (VATS) anatomic lobectomy for lung cancer was described two decades ago, many units have successfully adopted this technique. VATS lobectomy is a safe and effective approach for the treatment not only of early stage lung cancer but also for more advanced disease. It represents a technical challenge. As the surgeon's experience grows, more complex or advanced cases are approached using the VATS approach. However, as VATS lobectomy has been applied to more advanced cases, the rate of conversion to open thoracotomy has increased, particularly early in the surgeon's learning curve, mostly due to the occurrence of complications. The best strategy for facing complications of VATS lobectomy is to prevent them from happening. Avoiding complications is subject to an appropriate preoperative workup and patient selection. Planning for a VATS resection as safely as possible involves the consideration of the patient's characteristics and the anticipated technical aspects of the case. Awareness of the possibility of intraoperative complications of VATS lobectomy is mandatory to avoid them, and the development of management strategies is necessary to limit morbidity if they occur.

Keywords: Complications; uniportal; video-assisted thoracic surgery (VATS); bleeding; lobectomy

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Introduction

The video-assisted thoracoscopic surgery (VATS) lobectomy is a safe and effective approach for the treatment, not only of early stage lung cancer but also for more advanced disease.

It represents a technical challenge, perhaps due to perceived technical challenges when compared to the more conventional open approach and because of the intraoperative complications, particularly early in the surgeon's learning curve.

The best strategy for facing the complications of VATS lobectomy is to prevent them from happening. Avoiding complications is subject to an appropriate preoperative workup and patient selection (1).

Planning for a VATS resection to be as safely as possible involves the consideration of the patient's characteristics, the radiographic appearance of the area of the lung to be removed and the anticipated technical aspects of the case (1).

Our objective is to describe how to solve intraoperative complications and avoiding catastrophic complications. Catastrophic complication is defined as an event that results in an additional unplanned major surgical procedure other than the intended lobectomy (2).

Operative technique

There are different causes of complications that could lead us to convert to open thoracotomy. Generally, we can classify the reasons for conversion into four categories:

- ❖ Technical problems;
- ❖ Bleeding;
- ❖ Airway injury;
- ❖ Oncological reasons.

Technical problems

These are some of the technical problems that can lead us to have intraoperative complications.

A fused or complex fissure or true pleural symphysis present a technical challenge to VATS lobectomy. The key to an adequate detachment is to find the correct plane in the pleural cavity and to create a space; then we can perform the adhesiolysis using a combination of sharp and blunt dissection (1). With the uniportal approach we have the advantage in visualizing, with high resolution for details, the apex and the base of the hemithorax (*Figures 1,2*).

Complex artery/vein or bronchus dissection or a difficult anatomy can also lead to abandonment of the VATS approach, although with improving surgeon experience and comfort with VATS lobectomy, these cases can be accomplished. The presence of calcified hilar and/or periarterial lymph nodes can likewise complicate vascular dissection. Regarding complex hilar structures dissection, the key is to find the adventicial plane (*Figure 3*). In the video, we see an artery fused to the vein and to the lymph node. Note the utility of the bimanual instrumentation and how we can perform the dissection with simple instruments (curved ring forceps, long scissors, suction and a conventional dissector).

A previous ipsilateral surgery is also no longer a contraindication as Redo-VATS surgery had been reported.

Another reasons for conversion could be emphysematous lung or the absence of lung collapse, due to the small space available to perform the surgery. The difficulty for digital palpation or identification of the target lesion (mostly, small nodules) is another cause of conversion.

The uses of high doses of prior chemo-radiotherapy have previously been considered a relative contraindication, but VATS lobectomy can be performed safely and effectively for these patients (1).

Finally, chest involvement requires thoracotomy for resection, but VATS can be used to perform the lobectomy and allow placement of the better incision to the chest wall removal.

Bleeding

Without doubt the most dangerous intraoperative complication is major bleeding. The uniportal VATS approach usually offers excellent visibility of the operative field, thus intrathoracic hemorrhage is rare.

If bleeding occurs, a sponge stick should be available to apply pressure immediately to control the hemorrhage; it is always important to remain calm and not to panic. With the bleeding temporarily controlled, a decision must be made promptly as to whether thoracotomy is needed (3) or if it can be solved through the VATS approach. This will depend mostly on the surgeon's experience.

Focusing on the artery bleeding, care must be taken during the vascular dissection as well as to the lung traction, especially if an advanced case is performed. Dissection of the vessels can be difficult due to a wide variety of causes and bleeding can be high even by thoracotomy depending on the complexity of the procedure. For example, during the approach of the artery from the hilum, a bleeding can occur (*Figures 4,5*). In this case, we did not know exactly where it was coming from. So, the first step in order to achieve any bleeding control was made: compression with a sponge stick and consideration of the appropriate strategy. Then, the anterior arterial trunk was divided and the anterior portion of the minor fissure completed; these steps allowed us to reduce tractions and improve the vascular control. Then the posterior ascending arterial branch to the right upper lobe could be identified and also another arterial branch (which probably was the one that caused the bleeding). At last, the bleeding was controlled with a proximal vascular clip.

Regarding the correct planning of the VATS lobectomy, consideration of the patient's characteristics is very important. Furthermore, certain vascular anomalies resulting in conversion are often visible on preoperative enhanced CT. Care must be taken to avoid injuring unexpected small branches (*Figure 6*). In this case a left upper lobectomy was performed. After the bronchus transection, a bleeding was caused. Again, the first step must be to remain calm and think of a new strategy. "Are we able to control the bleeding?" "Is the bleeding very important?" Once these questions were answered, we placed a vascular clip using bimanual instrumentation and the complication was solved through VATS.

Nevertheless, the use of several developments to avoid the bleeding problems or even to the vascular division can also be the cause of bleeding. For example, an unexpected displaced clip can cause a bleeding (*Figure 7*). Looking at the top left corner we can identify the source of the bleeding: an accidental displacement of the proximal vascular clip during the lung retraction. We proceed to stem the bleeding with compression. Then, the change of the lung exposure allowed us to identify the source of the bleeding and finally reclipping the artery.

Another key point to take into consideration occurs

Figure 1 Adhesiolysis (3).
Available online: http://www.asvide.com/articles/341

Figure 2 Adhesiolysis (4).
Available online: http://www.asvide.com/articles/342

Figure 3 Complex hilar structures dissection (5).
Available online: http://www.asvide.com/articles/343

Figure 4 Arterial branch bleeding (7).
Available online: http://www.asvide.com/articles/344

Figure 5 Arterial branch bleeding (8).
Available online: http://www.asvide.com/articles/345

Figure 6 Unexpected bleeding (9).
Available online: http://www.asvide.com/articles/346

during the lymphadenectomy, due to the major vascular structures nearby. As in this situation, while the right paratracheal lymphadenectomy was being performed (*Figure 8*), the azygos vein was injured in its proximal aspect without us noticing. The bleeding was controlled with a vascular clamp and by stapling the azygos vein.

With advanced skill and experience in VATS surgery, in the event of minor to moderate bleeding, conversion can

Figure 7 Bleeding after unexpected displaced clip (10).
Available online: http://www.asvide.com/articles/347

Figure 8 Azygos vein bleeding (11).
Available online: http://www.asvide.com/articles/348

Figure 9 Bleeding control with suture (12).
Available online: http://www.asvide.com/articles/349

often be avoided. For example, during the performance of an upper lobectomy, one of the branches can be injured (*Figure 9*). After compression, the mediastinal trunk was dissected and controlled, so the tear was sutured.

Figure 10 Left upper lobectomy. Bleeding control (13).
Available online: http://www.asvide.com/articles/350

Figure 11 Airway injury (14).
Available online: http://www.asvide.com/articles/351

Finally, the last example of bleeding control: a left upper lobectomy performed on a patient who had received prior induction chemotherapy. During the arterial dissection, a branch was damaged. Then we dissected one of the branches of the vein in order to get obtain a good angle to control the mediastinal trunk of the artery. Once the mediastinal trunk was controlled, the arterial branch was clipped in the proximal and distal aspect (*Figure 10*).

Airway injury

Although this is not the most common cause of conversion, it has to be taken into consideration. The failure of the stapler or a major air leak after performing a lobectomy on a patient with severe emphysema or a complex/fused fissure, can lead to conversion in order to repair the air leak.

Another cause would be the bronchus or trachea injury by the endotracheal tube. As in the video (*Figure 11*), after a uniportal VATS left lower lobectomy, small bubbles were identified deep down in the subcarinal space during the dissection of the subcarinal station. Also, mediastinal emphysema and air leak from the aortopulmonary window were noticed. There was no air leak from the bronchus stump, nor at the anesthetic monitor, so the patient was extubated. When the patient was at the ICU, a CT scan was performed due to subcutaneous emphysema, where a right tracheal wall disruption caused by the double lumen tube was observed. Suturing the wall of the trachea through a right thoracotomy repaired the problem.

Comments

During VATS lobectomy the most important aspect is to prevent complications. Avoidance is enhanced by a solid knowledge of the anatomic relationships, careful dissection, awareness of the potential complications and the judicious conversion to thoracotomy when appropriate (2). If a complication occurs, we have to consider the management strategy. It is essential to have a good preoperative workup, the bimanual instrumentation and a good exposure of the lung or the target area. Ultimately, the decision for conversion is left to each surgeon's skills and patience. The surgeon has to feel comfortable with the approach, whatever it is. Finally the most important consideration above all is never panic and always keep calm.

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General Consideration

VATS biopsy for undetermined interstitial lung disease under non-general anesthesia: comparison between uniportal approach under intercostal block *vs*. three-ports in epidural anesthesia

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Objective: Video-assisted thoracoscopic (VATS) biopsy is the gold standard to achieve diagnosis in undetermined interstitial lung disease (ILD). VATS lung biopsy can be performed under thoracic epidural anesthesia (TEA), or more recently under simple intercostal block. Comparative merits of the two procedures were analyzed.

Methods: From January 2002 onwards, a total of 40 consecutive patients with undetermined ILD underwent VATS biopsy under non-general anesthesia. In the first 20 patients, the procedures were performed under TEA and in the last 20 with intercostal block through a unique access. Intraoperative and postoperative variables were retrospectively matched.

Results: Two patients, one from each group, required shift to general anesthesia. There was no 30-day postoperative mortality and two cases of major morbidity, one for each group. Global operative time was shorter for operations performed under intercostal block (P=0.041). End-operation parameters significantly diverged between groups with better values in intercostal block group: one-second forced expiratory flow (P=0.026), forced vital capacity (P=0.017), oxygenation (P=0.038), $PaCO_2$ (P=0.041) and central venous pressure (P=0.045). Intraoperative pain coverage was similar. Significant differences with better values in intercostal block group were also experienced in 24-hour postoperative quality of recovery-40 questionnaire (P=0.038), hospital stay (P=0.033) and economic expenses (P=0.038). Histology was concordant with radiologic diagnosis in 82.5% (33/40) of patients. Therapy was adjusted or modified in 21 patients (52.5%).

Conclusions: Uniportal VATS biopsies under intercostal block can provide better intraoperative and postoperative outcomes compared to TEA. They allow the indications for VATS biopsy in patients with undetermined ILD to be extended.

Keywords: Interstitial lung disease (ILD); lung biopsy; video-assisted thoracic surgery (VATS)

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Introduction

Despite the advent of high-resolution computed tomography (HRCT) or fine needle biopsy surgical lung biopsy is still considered the gold standard to achieve a definitive diagnosis in undetermined interstitial lung disease (ILD) in order to establish a correct therapy and to predict a reliable prognosis (1-3). These procedures have successfully been accomplished via video-assisted thoracic surgery (VATS) with a lower morbidity, less pain and a shorter hospital stay (4-7) in comparison with traditional open accesses. However, one of the major risks during surgical biopsy is still represented by the general anesthesia under one-lung ventilation, which may precipitate altered respiratory function, pulmonary hypertension and infections (8,9). Current guidelines by the American Thoracic Society/European Respiratory Society (10,11) recommend surgical biopsy only for those ILD

Table 1 Demographic variables and histologic findings of the study population

	TEA (n=20)	IB (n=20)	P value
Age [years]	61 [48-70]	61 [48-70]	0.911
Oxygen support (n, pts)	6 (30%)	7 (35%)	0.122
Oral steroids dependant (n, pts)	16 (80%)	15 (75%)	0.234
Azathioprine user (n, pts)	4 (20%)	3 (15%)	0.327
Body mass index [kg/m^2]	22 [18-25]	22 [18-25]	1
6-minute walking test [%, pred]	62 [54-69]	60 [53-71]	0.312
Forced expiratory volume one-second [%, pred]	65 [56-72]	61 [50-69]	0.653
Forced vital capacity [%, pred]	66 [54-76]	64 [56-75]	0.327
Diffusion lung carbon-monoxide [%, pred]	50 [41-59]	51 [42-62]	0.211
PaO_2 [mmHg]	82 [78-95]	84 [76-92]	0.645
$PaCO_2$ [mmHg]	43 [38-55]	42 [39-54]	0.783
American Society of Anesthesiology score [1-4]	2 [1-3]	2 [1-3]	1
Histology			
Idiopathic interstitial pneumonia			
Idiopathic pulmonary fibrosis	8 (40%)	9 (45%)	0.749
Nonspecific interstitial pneumonia	2 (10%)	1 (5%)	0.548
Cryptogenic organizing pneumonia	2 (10%)	2 (10%)	1
Acute interstitial pneumonia	1 (5%)	1 (5%)	1
Respiratory bronchiolitis-associated ILD	1 (5%)	–	0.311
Desquamative interstitial pneumonia	–	1 (5%)	0.311
ILD, not specified	2 (10%)	3 (15%)	0.633
Other diffuse diseases			
Granulomatous disease	1 (5%)	–	0.311
Hypersensitivity pneumonitis	–	1 (5%)	0.311
Other	2 (10%)	2 (10%)	1
Inadequate biopsy	1 (5%)	–	0.311

TEA, thoracic epidural anesthesia; IB, intercostal block. Data are expressed as median (interquartile range).

patients who are at acceptable risk to tolerate the procedure and this has severely limited the use of this precious diagnostic device.

To avoid potential complications we initially introduced awake VATS biopsy under thoracic epidural anesthesia (TEA), but more recently we established a new procedure through a unique access under a simple intercostal block in non-general anesthesia (12). Hereby we analyzed comparative merits of this procedure in comparison to VATS biopsy under TEA.

Methods

This investigation is a branch of the mainstay program started in 2001, previously referred to as "awake thoracic surgery" and now more widely defined as "thoracic surgery under monitored anesthesia care" (13).

Patients

From January 2002 onwards a total of 40 consecutive patients with an undetermined ILD underwent VATS biopsy under non-general anesthesia. In the first 20 patients the VATS biopsy was performed under TEA and in the last 20 with intercostal block through a unique access. Demographics variables and histologic findings are summarized in *Table 1*. Patients were selected according to clinical and radiologic findings by a multidisciplinary panel formed by one pulmonologist, one thoracic surgeon, one anesthesiologist experienced in non-intubated procedures and one radiologist dedicated to ILD. Patients routinely underwent HRCT (General Electric Medical Systems, Milwaukee, WI, USA) and evaluation included the pattern of parenchymal abnormality (i.e., consolidation, ground-glass opacity, reticular pattern), anatomic distribution and presence of associated pathologies (i.e., mediastinal lymphadenopathy).

Imaging of diffuse honeycombing pattern was considered by itself a criteria for excluding lung biopsy. Other exclusion criteria were age >75 years, end-stage disease with need of mechanical ventilation, BMI >22 and <30, diffusing lung capacity for carbon monoxide (DLCO) <30% predicted, basal room air PaO_2 <50 mmHg, $PaCO_2$ >50 mmHg, American Society of Anesthesiology score <3 and presence of immunodeficiency status or active cancer. We considered tenacious pleura-pulmonary adhesions or patient's anxiety common contraindication for a non-general anesthesia procedure.

All patients gave their written informed consent. Local institutional review board approval was obtained for study (ref #CT0013-7268). Respiratory assessments included timed spirometry and plethysmography with single-breath DLCO (V_{max} 22; Sensor Medics, Yorba Linda, CA, USA) and arterial blood gas analysis. Exercise tolerance was assessed with the standard 6-minute walk test. Quality of life was assessed with the St. George Respiratory Questionnaire (SGRQ) general score (best =0, worst =100) (14,15). In addition all patients underwent preoperative fiberoptic bronchoscopy with bronchoalveolar lavage and cardiac evaluation including color Doppler echocardiography for pulmonary artery pressure non-invasive estimation. Right heart catheterism was performed in selected cases only. Laboratory tests entailed complete blood cell count with differential leukocyte counts, renal and liver function tests, and urinalysis.

Technique

Lung areas suitable for biopsy were chosen after panel discussion. We preferentially chose the middle lobe and the lingula, which are the lung areas most suited to surgical biopsy. The other most targeted areas were the apical segment of the lower lobe or the ventral of the right upper lobe. All these regions easily provided a large quantity of tissue, with a relatively short and straight suture line. The ultimate decision of the area targeted for biopsy was taken intraoperatively according to the most diagnostic site and the most reachable area in a breathing lung. Generally, target areas appeared as cobblestone road with subpleural nodularity, covered by thick and greyish visceral pleura with evidence of neoangiogenesis. These visible findings were usually coupled by the palpatory sensation of an anelastic parenchyma with increased resistance.

A resection volume greater than 1 mL (1 cm^3) was usually considered satisfactory and we routinely collected two or more biopsies without creating supplementary incisions.

Patients were continuously monitored by electrocardiogram, pulse oxymeter, systemic and central venous blood pressure, body temperature, arterial blood gases, and end-tidal CO_2 by insertion of one detector into a nostril. Forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) were re-assessed immediately pre and postoperatively by a portable spirometer (V_{max} Encore 29, Sensor Medics, Yorba Linda, CA, USA).

Intraoperative monitoring included assessment of all these parameters at different standardized times: before incision, at pneumothorax induction, at chest closure and 1-hour postoperatively. Evaluation of acute pain was assessed using a visual analogue scale (VAS) (0= absent, to 10= most severe imaginable pain) (16). Procedures took place in a calm and cooperative setting with a low-volume classical or melodic music played in the background. During the procedure, a venturi mask was used to keep oxygen saturation greater than 90%. Hypercapnia was well tolerated and correction was performed only when PH decreased to less than 7.2.

A chest drain with an underwater seal or a simple endoscopic suction device system was always kept ready to rapidly contrast a discomfort secondary to iatrogenic pneumothorax. Mild sedation with midazolam or propofol was useful to control the discomfort induced by pneumothorax or panic attacks. Shift to general anesthesia was allowed only in the following conditions: irritation or intolerance of the patient before the accomplishment of the biopsy, elevated level of $PaCO_2$ (50 mmHg), operation technically difficult or hemorrhagic complications.

VATS biopsy under TEA

After insertion of venous and radial artery catheters, an epidural catheter was positioned at T4-T5 level through which a bolus of 5 mg ropivacaine plus 5 µg sufentanyl was injected. Continuous infusion of ropivacaine 2 mg/mL (5 mL/hour) was then started 20 minutes prior to operation with the patient lying on the side targeted for biopsy. After achievement of satisfactory anesthesia the patient was turned on the other side ready for the operation.

The procedure was classically carried out through three ports. Usually the camera port was placed in the eighth intercostal space along the midaxillary line, the operating ports were usually placed in the fifth intercostal space, anterior and posterior axillary lines. In the case of biopsies located in the posterior segments of the lower lobes, theoperative port was set more caudally than the camera port and the monitor was positioned at the bottom of the patient to avoid mirror image effect. The biopsy was preferentially performed along a straight line an endostapler endopath® 30 or 45 with staples of 4.5 mm suturing with as less number of bites as possible in order to decrease the risk of bleeding. Blood and air leakage from the resection line were carefully controlled both at the time of suture completion and at chest closure. A 28 CH chest tube was inserted through the lowest incision. At end-procedure, lung re-expansion was achieved under thoracoscopic vision by asking the patient to breathe deeply and cough repeatedly. The epidural catheter was usually removed on postoperative day one.

Uniport VATS biopsy under intercostal block

After insertion of venous and radial artery catheters, an aerosolized 5 mL solution of 2% lidocaine was administered for 5 minutes in order to avoid cough reflex. The intercostal block was accomplished by local injection of 20-30 mL solution of 2% lidocaine and 7.5% ropivacaine, for achieving a rapid onset with a long duration of the analgesic effect. Site of inoculation was done along the space selected for uniportal VATS and included subcutaneous layers, intercostal nerves and parietal pleura. The grade of local anesthesia was always adequate. In a few cases benzodiazepine (midazolam 0.03-0.1 mg/kg) or opioids (remifentanil 15 µg/kg/min) were intravenously supplemented during lung manipulation or stapling manoeuvres.

All VATS biopsies were carried out from a single small 30-40 mm uniport skin incision carried out along the space judged the most suitable to reach the foreseen area. In the case of lingula or middle lobe biopsy incision was usually performed along the fourth intercostal space medially from the anterior axillary line, whereas posterior segments were biopsied through an eighth intercostal space posterior incisions. Rib spreading by retractor was always avoided. Through the incision we introduced the operative thoracoscope, the articulated stapler and incidentally a gauze pad mounted on a ring-forceps in order to contrast lung movements during breathing or coughing. In many instances we were able to exteriorize the most distal target area and accomplish the resection outside from the chest. At the end of the procedure one 28 CH chest tube was collocated through the posterior end of the incision. No trans-intercostal suture was necessary. Muscle sutures were tightened after asking the patient to breathe deeply or cough to achieve maximal lung re-expansion.

Postoperative care

Postoperative care was similar after both procedures. After a short stage in the weaning areas the patient was directly sent to the ward. Liquids infusion was stopped immediately and drinking, meal intake and ambulation were started on the same day of surgery. Chest X-ray was routinely performed at 24 hours from the procedure to confirm adequate lung expansion.

State of consciousness and postoperative recovery was evaluated by the quality of recovery (QoR-40), which is a 40-item self-administered questionnaire (17). Each item is linked to a 5-point Likert scale [1-5] with a minimum cumulative score of 5 (maximal impairment) and maximum of 200 (no impairment). Time of discharge was determined by chest tube removal, which generally took place in the absence of air leak and with a daily fluid leakage less than 150 mL.

The biopsy samples were sent fresh and reviewed by the institutional pathologist with a hub on ILD. A fragment was also sent for microorganism cultures.

Statistics

All data was statistically analyzed using the SPSS (SPSS® 9.05 for Windows, SPSS Inc., Chicago, 1998). Interdependence among factors and group comparisons were prudentially assessed by non-parametric tests. Data were expressed with median and interquartile range deviation. P values <0.05 were regarded as statistically significant in two tailed tests.

Results

Two patients, one from each group, required the shift to general anesthesia with intubation and single lung ventilation. No patient needed conversion to open thoracotomy.

A total of 95 biopsies were performed: 48 (2.4 per patient) in TEA group and 47 (2.35 per patient) in intercostal block

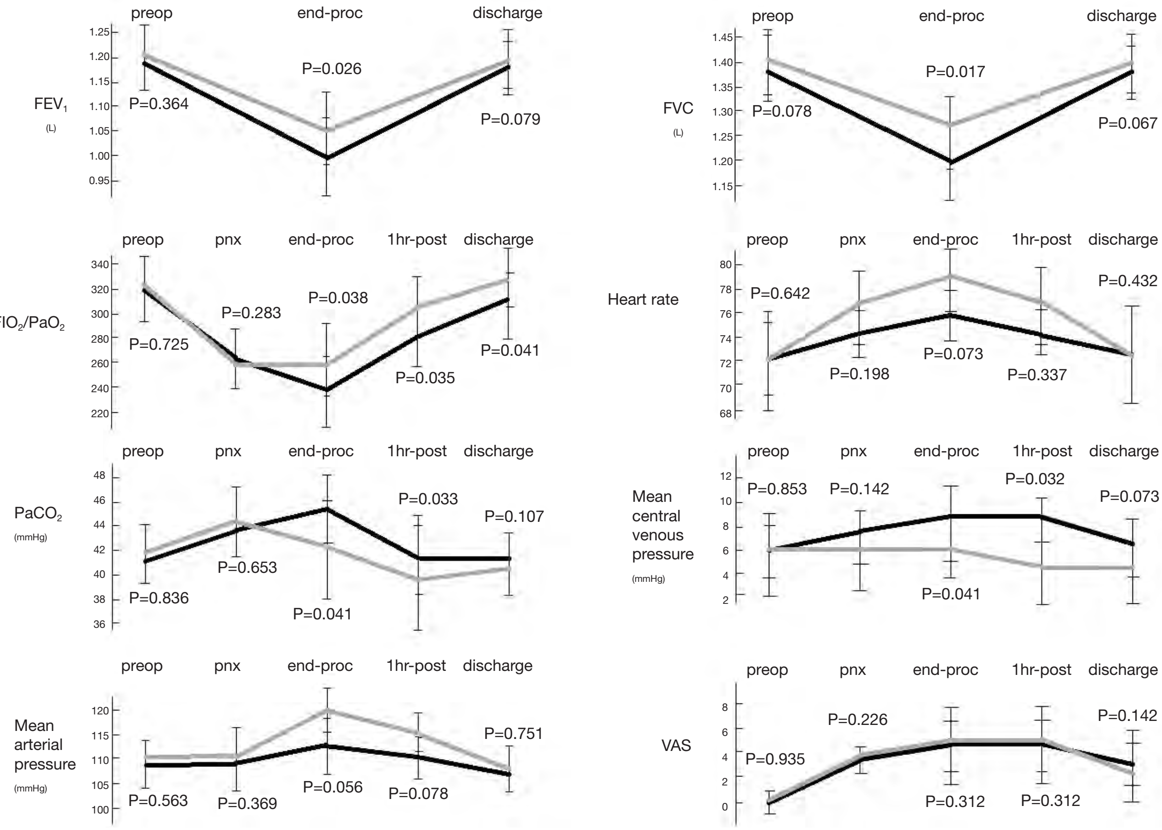

Figure 1 Intraoperative measurements of patients undergoing intercostal block (gray line) and thoracic epidural anesthesia (black line).

group, respectively. No 30-day postoperative mortality was experienced. We reported one case of acute respiratory insufficiency resolved by non-invasive ventilation in the TEA group and one acute pneumonia in the intercostal block group. We also recorded minor complications related to TEA: hypotension antagonized by noradrenalin infusion (n=2) and urinary block (n=3) requiring catheterization.

Global operative time was significantly shorter for operations performed under intercostal block {61 [53-68] *vs*. 70 [62-78]; P=0.041} and this was mainly due to the lack of epidural catheter introduction and time for the onset of anesthesia.

Intraoperative findings of main physiologic parameters are shown in *Figure 1*. FEV1 and FVC presented a significant decrement in both groups at end-operation, but the fall was lesser in the intercostal one, with a significant difference at intergroup analysis (FEV1, P=0.026 and FVC, P=0.017). As a result, oxygenation (FiO_2/PaO_2) and $PaCO_2$ were significantly different between groups at end-operation (P=0.038 and P=0.041, respectively) and at 1 hour postoperatively (P=0.035 and P=0.033, respectively). Interestingly, the values of central venous pressure were significantly less elevated during intercostal block at the end of the procedure (P=0.041) and after 1 hour from the procedure (P=0.032). Pain coverage was satisfactory throughout the procedure and without significant differences in both groups (*Figure 1*). Similarly, there was no difference in basal and under cough VAS at 24 and 48 hours, respectively. Postoperative QoR was significantly better in intercostal group after 24 (P=0.038) hours from the operation, whereas quality of life at 7 and 30 days was similar between groups. Hospital stay was significantly shorter in patients undergoing intercostal block (P=0.033) and this also impacted the economic expenses (P=0.038) (*Table 2*).

A reliable pathologic specimen was obtained by surgical biopsy 97.5% (39/40) of the patients, and in 94.7% (90/95) of biopsies. The biopsy specimens were concordant in 82.5% (33/40) of patients and in 68.4% (65/95) of the biopsies. No differences were found between groups (*Table 2*). On the basis of histopathology findings, therapy was adjusted or modified in 21 patients (52.5%).

Table 2 Comparison of outcomes between groups

Patients	TEA (n=20)	IB (n=20)	P value
Global in-operating room [min]	70 [62-78]	61 [53-68]	0.041
Operative time [min]	38 [32-48]	40 [31-49]	0.082
Biopsy number (n, pts)	2.3 (1.6-2.8)	2.1 (1.5-2.6)	0.623
Biopsy cumulative volume (cm^3)	6.4 (5.3-6.9)	6.1 (5.6-7.3)	0.831
HRCT/histology concordance per patient [%]	17/20 [85]	16/20 [80]	0.677
HRCT/histology concordance per lesion [%]	32/48 [67]	33/47 [70]	0.710
24-hour postop QoR40 [5-200]	114 [96-138]	126 [89-157]	0.038
24-hour postop basal VAS	4.4 [2-6]	4.3 [2-6]	0.621
24-hour postop cough VAS	5.9 [3-7]	5.2 [3-7]	0.041
48-hour postop QoR40 [5-200]	156 [122-194]	164 [131-183]	0.054
48-hour postop basal VAS	2.1 [1-4]	2.0 [1-3]	0.765
48-hour postop cough VAS	4.4 [2-6]	4.3 [2-6]	0.212
Hospital stay [day]	3.7 [1-6]	3.0 [2-4]	0.033
Major morbidity n [%]	1 [5]	1 [5]	1
7-day quality of life (SGRQ) [%]	38 [29-48]	35 [28-49]	0.342
30-day mortality rate [%]	0	0	1
30-day quality of life (SGRQ) [%]	21 [12-40]	23 [19-41]	0.547
Estimated costs [euro]	3,124 [2,334-4,190]	2,632 [2,088-3,253]	0.038

TEA, thoracic epidural anesthesia; IB, intercostal block. Data are expressed as median (interquartile range). HRCT, high resolution computed tomography; VAS, visual analogue scale; QoR, quality of recovery questionnaire; SGRQ, St.George respiratory questionnaire.

Discussion

The use of intercostal block associated with intravenous sedation during thoracoscopy for diagnostic and therapeutic purposes has already been described in different thoracic pathologies with satisfactory results (18-21). In this personal series we presented the additional advantages of intercostal block compared to TEA during VATS lung biopsy in patients with ILD undetermined lesions.

In our study we experienced that intercostal block may significantly attenuate intraoperative lung-volumes fall as well as hypoxia (FiO_2/PaO_2) and hypercapnia respect to same procedures under TEA.

It has been reported that TEA causes a significant decrement of inspiratory capacity (22) as a probable blockade of efferent or afferent pathways of the intercostal nerve roots resulting in a decreased contribution of the rib cage to tidal breathing (23). TEA may also produce a wide adrenergic tone fall with prevalence of bronchus-constriction as evidenced by FEV1 decrement (24). The documented increment of the central venous pressure in TEA could be a consequence of lung flow reduction as well as of the impairment of ventricle sympathetic outflow due to the adrenergic block (25-27).

These effects are absent or minimal under intercostal block, which leaves normal adrenergic tone without interfering on skeletal, bronchus and cardiac muscle motility (12) also avoiding the intrinsic risks and unpleasant side-effects related to TEA.

The risk of coughing is high when stapling the lung under intercostal block but it can be minimized by the use of aerosolized 2% lidocaine with transitory side effects. As far as the expected lesser duration of pain coverage is concerned, we found it more useful to have pain control with intravenous drugs rather than the prolonged and fastidious disturbances following TEA. Furthermore, the QoR-40 questionnaire clearly documented a significant greater and faster postoperative recovery after the intercostal block.

This study is retrospective and non-randomized and the results need to be interpreted as such. Another potential limitation is represented by the reliability of respiratory functional tests performed during a surgical operation, which can be altered by patient fatigue, lack of cooperation and iatrogenic pneumothorax. However these potential artifacts were homogeneous between groups and do not appear to interfere with the global trend of the measurements.

Conclusions

We would suggest that uniportal VATS biopsies under intercostal block can provide better intraoperative and postoperative outcomes compared to TEA, thus increasing the safety as well as enlarging the indication of VATS biopsy in presently not-eligible patients. These results stimulate our interest in thoracic surgery under monitored anesthesia care (12), which permits a quicker postoperative recovery as well as lower morbidity, hospital stay and economical costs with satisfaction of patients, surgeons, pneumologists and administrators.

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Both authors made substantial contributions to conception, design, acquisition or analysis and interpretation of data; Vincenzo Ambrogi has drafted the submitted article; Tommaso Claudio Mineo has provided final approval of the version to be published; each author has agreed for all aspects of the work in ensuring that any part of the work is appropriately investigated and resolved.

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Worldwide Experience

Uniportal VATS in Asia

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Abstract: The history of uniportal Video-assisted thoracic surgery (VATS) stretches back almost a decade with the treatment of simple thoracic conditions. As the technique matures with increasing ability to tackle the full spectrum of thoracic surgical diseases, most notably major lung resections for lung tumours, the spread of uniportal VATS across the globe has been phenomenal. VATS centres in Asia are now performing uniportal VATS, and developing their individual styles and techniques with great successes. The enthusiasm from surgeons, demand from patients, as well as the dynamism and diversity of uniportal VATS in the region have helped fuel this excitement and change. The 1st Asian Single Port VATS Symposium in 2013 heralded the beginning of academic exchange between uniportal VATS centres in Asia and experts from around the world. Wetlabs in the region will provide further training for thoracic surgeons interested in super-specializing in uniportal VATS. The future of this approach will hinge on good regional collaboration, research and training.

Keywords: Asia; lung resection; single port; training; uniportal; Video-assisted thoracic surgery (VATS)

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Introduction

"The future belongs to those who believe in the beauty of their dreams."

Eleanor Roosevelt, U.S. First Lady 1933-45

Video-assisted thoracic surgery (VATS) has evolved rapidly in the last two decades. Uniportal VATS has become an increasingly popular approach to manage thoracic surgical diseases, because of the reduced access trauma and better cosmesis. These advantages together with patient demand have seen uniportal VATS spreading across the globe. Furthermore, improvements in camera systems, instrumentation, and stapler technology have all facilitated this change.

Uniportal VATS started from humble beginnings, with an initial report of uniportal VATS thoracic sympathectomy in 2002 (1). Nevertheless, this paved the way for the development of more complex uniportal procedures for an ever increasing range of thoracic condition. In the following decade, uniportal VATS was performed for pleural and mediastinal biopsies, deloculation of pleural effusion, pleurodesis and lung wedge resection (2-4). Most of the progress in these areas has been pioneered by Gaetano Rocco's group from National Cancer Institute, Italy. A major milestone for this approach came in June 2010 in the form of the world's first uniportal VATS lobectomy, which was subsequently reported in 2011 by Gonzalez Rivas's group in Coruna, Spain (5). Since then, complex uniportal VATS lung resection involving pneumonectomy, segmentectomy, bronchoplastic procedures and chest wall resection have been successfully accomplished. The initial clinical outcomes and short term results are encouraging, and more long term data is eagerly awaited (6).

More recently, uniportal VATS development has grown in popularity in Asia, with several centres in Hong Kong, Taiwan, Mainland China and Korea beginning to perform uniportal VATS major lung resections. The demand for increasingly more minimally invasive surgical approaches is perhaps even more important within the Asian culture. Interestingly, different uniportal approaches and techniques are emerging from different VATS centres across the Asian continent, making the future of uniportal VATS in this region even more exciting. This concise review is composed from literature search of all articles from Medline with keywords uniportal and single port VATS, as well as from discussions based on personal experience and those from acquaintances, with a strong focus on the Asia region.

Crouching Tiger Hidden Dragon

The history of uniportal VATS in Asia is considered by many to be relatively short and limited. However, a literature search shows that quite possibly the first reported uniportal VATS procedure was by Asians. A group from Israel in fact performed uniportal videothoracoscopic sympathectomy for palmar hyperhidrosis back in the 1990s (1). Subsequently, groups in China and Turkey were able to perform and report their experience of uniportal VATS sympathectomy in 2009 and 2012 respectively (7,8). The most popular approach was a single 15 mm incision near the axilla using thoracoscope and endoscopic instruments to complete the sympathectomy. More innovative techniques for sympathectomy have also been attempted, including Vasoview sympathectomy which utilizes a 12 mm diameter integrated device encompassing both a thoracoscope, and a working channel for diathermy scissors or other energy source for the sympathectomy (9).

Uniportal VATS for the management of pleural pathologies including pneumothorax, pleural effusion and empyema have also been successfully performed by several groups in Asia.

Although numerous centres around Asia have performed uniportal VATS for the treatment of primary spontaneous pneumothorax in sporadic and selected cases, it was not until 2011 that a group in Taiwan (10) published their experience of a small series of 10 patients who received this procedure. By utilizing a single 2.5 cm incision, specialized 5 mm roticulating endoscopic instruments and a 10 mm thoracoscope, blebs and bullae were resected using endostaplers followed by mechanical abrasive pleurodesis. When compared with patients who had standard 3-port VATS pleurodesis in their centre, those who underwent uniportal procedure had less pain and higher patient satisfaction on postoperative day 1 and 2. However, no long term outcomes, such as recurrences, were investigated. Interestingly, the management of empyema by uniportal VATS within Asia was reported much earlier in 2007. Tander *et al.* reported their technique of balloon-assisted uniportal thoracoscopic debridement in children with late-stage parapneumonic empyema thoracic (11). Like in many parts of the world, it was the simpler thoracic procedures such as, sympathectomy, treatment of pneumothorax and empyema which formed the basis from which uniportal VATS took off in the Asia region.

It was initially interesting and surprising to find that amongst publications from Asia, a group in Beijing, China had already published in an article in 2010, their early experience of performing 21 "single port" VATS lobectomies (12). However, upon closer inspection of the article, the lobectomies were in fact performed with a "single utility port" in the anterior aspect of the upper chest with an additional smaller inferior port for the thoracoscope thus making it a two port VATS technique. Two years later, Chen's group in Taiwan reported their initial experience of 3 cases of uniportal VATS lobectomies for tumour within left lower lobes and a right middle lobe (13). The approach was through a small 3.5 cm incision at the 5th intercostal space near the anterior axillary line, and utilized a mix of VATS and endoscopic instruments. Report such as this not only heralded the beginning of uniportal VATS major lung resection in Asia, but also perhaps provided the impetus to overcome psychological barrier that is often associated with introducing a new technique to a region. With increasing familiarity with the uniportal approach in Asia, more innovative techniques such as incorporating hook-wire guidance into uniportal VATS lung resection has emerged, further increasing the effectiveness of uniportal VATS (14).

As confidence grew, other centres in Taiwan as well as numerous countries around Asia, for example Korea and Hong Kong, began performing uniportal VATS major lung resections (15). It is interesting to note that rather than developing the technique together or adopting a particular uniportal approach within the region, each VATS centre has invented their own signature uniportal VATS approach based on their 3 port VATS experience. Some centres would utilize the 30 degree 5 mm thoracoscope while others prefer a more versatile 120 degree larger thoracoscope for vision (16). For tissue dissection, different surgeons would incorporate the use of either or a mixture of, conventional instruments, standard VATS instruments, specially designed uniportal VATS instruments (curved) or 5 mm endoscopic instruments (straight or angulated) (13,16,17). Furthermore, heterogeneity in the approaches is perhaps most evident in the positioning of the single incision and operating surgeon. For example, many Korean surgeons prefer to stand at the posterior side of the patient and operate through a lateral port incision, while surgeons trained in Taiwan or Hong Kong usually perform uniportal VATS positioned in front of

Figure 1 An anteriorly positioned uniport incision for lobectomy. A 120 degree thoracoscope, flexible endostapler and sponge forceps are placed through the port.

Figure 2 Uniportal VATS wound following lobectomy for early stage lung cancer.

the patient through a port incision placed at a more anterior aspect of the chest to take advantage of wider intercostal spaces (18) (*Figure 1*). Like with 3 port VATS, there is never going to be "a best approach" for uniportal VATS for whole of Asia, but it is this diversity that will make the evolution of uniportal VATS major lung resection in the region of utmost interest.

Asian perspective

As uniportal VATS begin to spread across Asia, questions are being asked as to whether the Eastern culture, people and above all the Asian spectrum of diseases are suited for uniportal VATS. In the same way, when 3-port VATS was developing in Asia in the 1990s, many questioned whether the results, techniques and approach from the West are applicable to the Asian region (19). The high prevalence of pulmonary tuberculosis in Asia was an initial concern when 3-port VATS was introduced. Extensive pleural adhesions, difficult to dissect calcified lymph nodes that may be associated with history of tuberculosis did not stop the development of 3-port VATS in Asia (20). In fact, the earlier teaching that severe pleural adhesions is a contraindication to VATS may even have been dispelled at least in part by the experience of VATS from Asia. The uniportal VATS experience so far from personal view as well as from uniportal authorities in Europe and US, suggest that pleural adhesions and indeed history of pulmonary tuberculosis are not contraindications to this new technique. The use of specially designed long instruments and energy sources including, ultrasonic Harmonic® and pressure energy Ligasure™ devices, as well as curved dissecting instruments have made difficulties associated with VATS pleural adhesiolysis a thing of the past.

Cost is always a concern for this region. Often, the success and failure of a new technique or approach in Asia is dictated by the cost of the change which correlates reciprocally with its adoptability. To fully explore the potential of uniportal VATS in major lung resection and allow minimization of the uniport incision, the availability of flexible endostaplers is important to allow the best angles for staple-resection of major pulmonary vessels and bronchus. In order to save costs, some Asian centres are using suturing techniques to tackle these structures while performing 3-port VATS, however, it may not be possible for uniportal VATS. In general, we have always advocated the use of conventional instruments to perform VATS because it is less costly and are much more familiar to the surgeon (18). Certainly, the use of conventional instruments for retraction and dissection during uniportal VATS major lung resection is possible but far from ideal. Specifically designed uniportal VATS instruments are available with slight curvature and narrower shaft to allow for a smaller incision and reduce instrument fencing (16,17). The smaller body habitus of the Asian population in general should also be taken into account when purchasing equipment for uniportal VATS. Whatever changes are needed to pursue uniportal VATS are probably far smaller than adopting other new forms of technology such as robotic thoracic surgery, which has very high cost, development and training burden.

Finally, there is "That Asian Thing". Patients in Asia demand all things minimally invasive, and smaller or less wounds are very attractive features of uniportal VATS (*Figure 2*). Even before robust or long term data are available for important endpoints such as survival and recurrence, often patients will still ask for the "latest", "most minimally invasive" or "least traumatic" approach to treat their diseases. This is perhaps best illustrated in the over liberal use of percutaneous interventions for treatment of coronary artery diseases compared with coronary artery bypass grafting surgery in Asia. The fear of postoperative pain and disturbance of inflammatory and immune function, also known as "flow of life energy" or "Chi" in Asian culture, by surgical access trauma are probably the main reasons behind this thinking (21,22). Over the last 2 years, the rapid adoption of uniportal VATS major lung resection in countries like Hong Kong, Korea, Taiwan and China may be in part a reflection of these patient demands and beliefs.

Training and the future

Training and education is an integral part of introducing a new technique to a region, and for uniportal VATS, this is no different. The 1st Asian Single Port VATS symposium and Live Surgery meeting (www.surgery.cuhk.edu.hk/vats2013) held earlier this year in Hong Kong, not only heralded the formal recognition of the uniportal VATS technique in Asia, but at the same time allowed the gathering of like minded uniportal surgeons and interested parties to exchange ideas. The successful Live Surgery demonstrations of uniportal lobectomies by world leaders for the audience also dispelled any myths surrounding the validity and limitations of this approach.

Following the symposium, several well established VATS centres in China and Taiwan began to experiment with and started performing uniportal VATS lobectomies, confirming that there is indeed great enthusiasm in Asia for this technique. In addition, it is a testament to the ease of learning uniportal VATS. Interestingly, one of the centres that has embraced uniportal VATS lobectomy have only performed open lung resection surgery in the past, hence making a "direct leap" from open to uniportal VATS. In fact, some surgeons have found uniportal VATS easier to learn than 3-port VATS lobectomy probably because the surgeon is working with their eyes and hands in the same plain, much like open surgery, which in contrast to 3-port VATS require operating through a diamond-like configuration (2). Therefore, this also begs the question whether it is necessary to be trained in 3-port VATS before a surgeon is allowed to progress to uniportal VATS. Certainly, from our centre's experience and that of Dr Gonzalez Rivas's department in Coruna Hospital, uniportal VATS lobectomy can be taught to residents in training, even if they have little or no experience of 3-port VATS. Although the learning curve may be steeper for those already familiar with 3-port VATS, we believe it is certainly not a prerequisite for learning the uniportal technique. However, in my experience, mastering the 3-port VATS technique can be an effective bail out approach when difficulty is encountered during uniportal VATS surgery, without the need to convert to a full thoracotomy.

Apart from symposiums and meetings, animal wetlabs will likely form an integral part of uniportal VATS training. Currently, centres in Asia capable of providing such facilities are few and far between, located in the larger cities of Hong Kong, Shanghai and Singapore. Wetlabs for "standard" VATS have been carried out to full capacity at these institutes for a number of years with great successes, however we are yet to see the inaugural uniportal VATS wetlab in Asia. Uniportal VATS wetlabs in Europe are fully booked for the next two years, and based on this enthusiasm it appears that a uniportal VATS wetlab in Asia is long overdue.

Besides training, the future of uniportal VATS in Asia will also depend on other key issues. Immediate and long term outcomes are important considerations for any surgical procedure, especially one that deals with oncological diseases. In the past, numerous studies, many of them conducted on Asian population have investigated the postoperative effects of 3-port VATS major lung resection on the physiology (inflammatory and cytokine responses, immune dysfunction, and angiogenic responses) (23-26) and functionality (shoulder function, quality of life) of the patient (27,28). These have shown that standard 3-port VATS had equivalent or superior results when compared with open procedure. Perhaps more importantly, studies investigating the 3-port VATS and open approaches have found comparable, if not better, quality of mediastinal lymph node sampling, as well as mid and long term recurrence and survival rates in the minimally invasive group (29-31). As a Chinese Philosopher, Confucius (551-479 BC) once said, "Study the past if you would define the future". The uniportal VATS approach will likely require a re-run of these studies to provide robust data for dispelling doubts from sceptics of this novel technique. The future of uniportal VATS in Asia will depend on regional collaborations, and high quality research and training.

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Single-port video-assisted thoracoscopic surgery for lung cancer

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Abstract: In 2004, novel results using pulmonary wedge resection executed through single-port video-assisted thoracoscopic surgery (VATS) was first described. Since that time, single-port VATS has been advocated for the treatment of a spectrum of thoracic diseases, especially lung cancer. Lung cancer remains one of the top three cancer-related deaths in Taiwan, and surgical resection remains the "gold standard" for early-stage lung cancer. Anatomical resections (including pneumonectomy, lobectomy, and segmentectomy) remain the primary types of lung cancer surgery, regardless of whether conventional open thoracotomy, or 4/3/2-ports VATS are used. In the past three years, several pioneers have reported their early experiences with single-port VATS lobectomy, segmentectomy, and pneumonectomy for lung cancer. Our goal was to appraise their findings and review the role of single-port VATS in the treatment of lung cancer. In addition, the current concept of mini-invasive surgery involves not only smaller resections (requiring only a few incisions), but also sub-lobar resection as segmentectomy. Therefore, our review will also address these issues.

Keywords: Lobectomy; lung cancer; segmentectomy; single-port; video-assisted thoracoscopic surgery (VATS)

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A new trend: video-assisted thoracoscopic surgery (VATS) for lung cancer

On October 19, 2013, four live demonstrations of successful single-port VATS lobectomies were performed at Shanghai Pulmonary Hospital. More than 200 chest surgeons witnessed this demonstration and shared their thoughts. Based on this response, it is clear that lung cancer, and, in particular, single-port VATS lobectomy for lung cancer, are popular topics among Asian thoracic surgeons (1,2).

Both the general public and the government are aware of the high incidence, morbidity, and mortality rates (as well as the high medical costs) associated with advanced-stage lung cancer. Several screening tools, including chest radiography and low dose computed tomography (CT) (3,4), have been advocated in high risk patients. As a result, more patients are presenting with early-stage lung cancer. If they can be adequately treated, they usually harbor a better prognostic outcome. These patients are also, potentially, the best candidates for minimally invasive surgery which can reduce their recovery time and suffering after surgery. Thus, we will focus on the role of single-port VATS for lung cancer lobectomy.

Current VATS practice in Taiwan

Before 2000, conventional posterolateral open thoracotomy remained the "gold standard" for the treatment of patients with lung cancer. However, VATS has replaced open thoracotomy and has become the current mainstay of lung cancer surgery (5). Actually, the penetration rate of VATS in Taiwan is extremely high. As surgical creativity

Table 1 Comparisons among RATS, non-intubated VATS, and single-port VATS

	Special equipment	Cost	Experienced anesthesiologist	Operator skill demands	Experienced cameraman	Experienced assistant	Surgeon's satisfaction	Patient's satisfaction
RATS	Robotic system	+++	–	+	–	For stapling	++	?
Non-intubated VATS	–	–	+++	+	+	–	?	+
Single-port VATS	Double joint instruments	–	–	+++	+++	–	?	++

–, not required; +, low level of requirement; ++, medium level of requirement; +++, high level of requirement; ?, uncertain; RATS, robotic-assisted thoracoscopic surgery; VATS, video-assisted thoracoscopic surgery.

and innovation have progressed, three variants of VATS have been developed in our society, the robotic-assisted thoracoscopic surgery (RATS), non-intubated VATS, and single-port VATS (6,7). Differences regarding cost, instrument settings, special anesthesia demands, surgical techniques, patient selection, and insurance coverage among these VATS alternatives are quite difficult to have evidence-based comparison (*Table 1*). Shows the summary based on our interpretation.

For lung cancer surgery, several controversies exist concerning RATS (8), including the high cost, the increased number of utility wounds, and the need for skilled assistants to perform stapling for bronchus and pulmonary vessels. However, with the advances in new instrumentation, especially the endocutter, and the reduced size of the robotic arm which has avoided collisions during surgery, the role of RATS in lung cancer has exceeded our expectations. Although non-intubated VATS did not represent an improvement in surgical technique, it has the advantage of reduction in airway trauma caused by standard double-lumen endotracheal intubation. Furthermore, both the introduction of vagus nerve blockade to inhibit cough reflex and the insertion of an epidural catheter to reduce pain emphasize the need for team work between chest surgeon and anesthesiologist (9,10) during this technique.

Due to high cost limitations associated with RATS or the discomfort associated with mediastinal movement during non-intubated VATS, single-port VATS is another option for chest surgeons who are familiar with the conventional 4-, 3- or 2-ports VATS. In this review, we will assess the various uses of single-port VATS, especially for lobectomy.

Current evidence

Single-port surgery has been adopted in several surgical fields, especially in colorectal and gynecologic training programs (11). In 2004, Rocco *et al.* reported their pioneering work with pulmonary wedge resection through single-port VATS (12). Thereafter, more and more chest surgeons used single-port VATS for pulmonary resection, including wedge resection (12), segmentectomy (13-15), lobectomy (16-19), pneumonectomy (20,21), and pleural surgery (including pleural biopsy and pleural resection or decortication) (22), for both benign or malignant disease (*Table 2*). Lobectomy plus radical mediastinal lymph node dissection remain the “gold standard” for resectable lung cancer. However, pneumonectomy or segmentectomy/wedge resection may be executed based on lung cancer status, according to oncological principles or clinical considerations. Between 2012 and 2013, Gonzalez-Rivas *et al.* shared their innovative experiences with single-port VATS lobectomy, segmentectomy, and pneumonectomy for lung cancer (13,14,17-21). They also explained, in detail, the procedure and necessary equipment for meticulous application of single-port VATS. However, this was only one report from a single institution. The advantages and disadvantages of single-port VATS *vs.* conventional 2-, 3-,or 4-ports VATS, especially for lobectomy or segmentectomy of lung cancer, deserved further re-appraisal.

Our experiences at the Koo Foundation Sun Yat-Sen Cancer Center

We began performing 3-ports VATS lobectomy in 2005, and shifted to 2-ports VATS lobectomy in 2007. As described by Rocco *et al.* (12), surgeons always stand in front of the patient while performing VATS, in contrast to conventional open thoracotomy. Concerning the 2-ports VATS lobectomy that we perform, one port is used for instrument insertion (utility port, 3-5 cm in length, retracted by wound protector) and the other port is used for camera scope insertion (scope port, 1 cm in length, kept by trocar). A 30-degree camera scope was applied

Table 2 Summary of the specific issues regarding single-port VATS

Issues of single-port VATS		Reported articles
Pioneer	How to do it	(12)
History/evolution review	Conventional to single-port VATS	(7,16,23)
Geometric configuration	Cranio-caudal perspective	(12,24)
Clinical application		(22)
Clinical diagnosis	Wedge resection/biopsy	(12,25)
Lung cancer/tumor	Wedge resection	(12)
	Segmetectomy	(14,15)
	Lobectomy/sleeve lobectomy	(15,17-19,26)
	Pneumonectomy	(20,21)
Pneumothorax		(12,25,27,28)
Empyema		(29)
Lymph node dissection	Overall number/areas	(19)
	Lobe specific	(15,30)

VATS, video-assisted thoracoscopic surgery.

Figure 1 Two ports VATS—Transection of right superior pulmonary vein.

Figure 2 Single-port VATS—Transection of left superior pulmonary vein.

to our VATS. Actually, during 2-ports lobectomy, we insert multiple instruments into the utility port, which is the training basis for single-port VATS lobectomy. During upper lobe lobectomy, the straight endocutter is usually shifted to the camera port for the division of superior pulmonary vein, and all other instruments plus thoracoscope are inserted through the utility port (*Figure 1*). More specifically, if we can insert the endocutter through the same wound, i.e., the utility port, it becomes a single-port VATS. The application of the curved endocutter plays an important role in this specific procedure (*Figure 2*).

We began single-port VATS lobectomy in December 2010 (30). The first case we performed was actually a single-port segmentectomy for a centrally located carcinoid tumor over the left common basilar segment of the left lower lung. Because this patient had chronic obstructive pulmonary disease (COPD) with poor lung function, we shifted our tentative single-port VATS lobectomy to a segmentectomy, and this may represent the first single-port VATS segmentectomy reported in the literature (15,30). Despite the severely adherent anthracotic segmental lymph nodes, we completed the procedure smoothly and successfully. Since that time, we have been capable of single-port VATS anatomic lung resection. However, during that period, the concept of single-port VATS lobectomy or segmentectomy was neither popular nor well accepted. Most chest surgeons performed VATS lobectomy through 2-, 3-, or 4-ports procedures, or through a needle scope. Inevitably, however, a small utility wound is necessary for surgical specimen retrieval. Based on the need to reduce surgical trauma, we began our single-port VATS lobectomy/segmentectomy program, depending on careful case selection, the need for resident training, or sufficient surgical time without a tight schedule. Between November 2010 and May 2012, we retrospectively collected 19 cases of single-port VATS lobectomy/segmentectomy at our institute, and we shared our experiences with an emphasis on patient safety and surgical skill during radical lymph node dissection. This preliminary experience demonstrated the feasibility of single-port VATS lobectomy and radical lymph node dissection for benign pulmonary disease and early-stage lung cancer (15).

In Dr. C.C. Liu's practice, single-port lobectomy has become the standard procedure for lung cancer surgery, if there is no chest wall invasion or obvious hilar structural invasion. The size of the tumor is seldom a contraindication, since the larger the tumor, the larger the utility wound needed. Usually, the incision is approximately 3 cm in length if the tumor diameter is less than 3 cm.

Our collection of cases totals 63 single-port VATS lobectomies and 24 segmentectomies. The conversion rate from single-port VATS was low (3.45%, 3 in 87, converted to 2-ports VATS because of adhesion/anthracotic lymph nodes) and no surgical mortality occurred. Post-operative recovery was similar to traditional 2-ports VATS lobectomies.

The concept of minimally invasive surgery is not only preferred for reduction in the size of the external wound but also for reduction in inner trauma, including the extent of tumor resection and lymph node dissection. Therefore, sub-lobar resection (especially segmentectomy) for early stage lung cancer is crucial (31). Regarding the resection planes used in segmentectomy, we prefer the endocutter stapler to seal off air leakage rather than electrical coagulation (32). The segmental structures, including segmental artery, bronchus and veins, are dissected towards the hilum and then divided. The dissected lymph nodes and the resection margins deserve special mention. They are examined by experienced pathologists through frozen section to guarantee a complete resection. One of our patients harbored a ground glass opacity (GGO) lesion over the basal segment of the lower lobe, which proved to be lung cancer during intra-operative pathological diagnosis. The basal segmentectomy was converted to lobectomy due to a close resection margin. At present, we have already performed 24 segmentectomies using endocutter stapler to divide the intersegmental planes. Compared with conventional cauterization along the intersegmental plane and for ligation of branches from intersegmental veins, endocutter stapler is much easier to use. Although transient postoperative lung atelectasis with subsequent fever is not inevitable, this procedure does reduce the incidence of prolonged or delayed air leak (33). With regards to conventional segmentectomies, e.g., superior segmentectomy for the lower lobe, lingular segmentectomy, trisegmentectomy of left upper lobe (lingular sparing) and common basal segmentectomy of lower lobe, they can all be executed using a single-port technique. We have also begun lobe-specific lymph node dissection for early stage lung cancer. It not only reduces the degree of mediastinal trauma and saves more time, but also lessens the complications related to extensive lymph node dissection (15).

OR setting

We use the same setting as used in traditional VATS in our group.

Anesthesia

General anesthesia with double lumen endotracheal tube intubation is applied for right sided procedures. For left sided procedures, in contrast, single lumen endotracheal tube intubation with endobronchial blocker is applied, especially when left subcarinal lymph node dissection is required. A low tidal volume of approximately 350 mL with a PEEP at a setting of approximately 5 mmHg is preferred. Central venous catheter insertion is not our routine. Intercostal nerve block with bupivacaine is injected by the surgeon along the utility wound [including one more intercostal space (ICS) up and down] at the end of surgery.

Patient positioning

We use the same position as used in traditional VATS.

Instruments

Scanlan® VATS instruments, laparoscopic grasp, laparoscopic needle holder, knot pusher, and harmonic scalpel are the main instruments used during single-port VATS. We prefer to use longer instruments to avoid their possible collision due to crowding during manipulation. The surgical field can be viewed clearly through a 10 mm (preferred) or 5 mm 30 degree endoscope. The utility wound is retracted by wound protector (XS in size).

Incision

We prefer to create the utility wound at the sixth ICS that crosses the anterior axillary line for the following reasons:

(I) For upper lobe lobectomy, this incision is away from the superior pulmonary vein and provides adequate space for applying the endocutter;

(II) For lymph node dissection, this incision allows for easier subcarinal lymph node dissection, especially when we encounter a bulky bronchial tree caused by double lumen tube with an inflated balloon or a relatively rigid bronchus;

(III) Such an incision avoids hypersensitive areas or avoids causing paresthesia involving the breast, particularly the nipple, because the nipple is innervated by 4^{th} intercostal nerve;

(IV) The incision may be shifted more laterally along the sixth ICS in female patients, and along the fifth ICS only for left upper lobe $LB_{1+2,3}$ trisegmentectomy for early lung cancer and lobe specific lymph node dissection and the upper mediastinum lymph nodes, rather than the subcarinal lymph nodes.

Handling of instruments

To achieve a smooth surgical procedure, the long curved sucker (Scanlan®) is manipulated by the surgeon's left hand, and the hook, laparoscopic or Scanlan® dissectors are manipulated using his right hand. Such a combination of long straight and long curved instruments can minimize their collision and interference during surgery. Generally, the entire single-port VATS procedure is similar to traditional 2-ports VATS, except for the application of the endocutter through a narrower space that requires more skill. Adequate dissection and release of the surrounding soft tissues of the vascular structures are important steps that provide sufficient space for insertion of the endocutter blade during conventional 3- or 2-ports VATS. The Endo-GIA was originally designed for gastrointestinal anastomosis, rather than pulmonary vascular structures. We feel that it is a problem of instrument design rather than a problem with technique. The newly designed curved-tip endocutter is a useful option when performing division of a vessel, especially the superior pulmonary vein.

Camera scope handling

An experienced cameraman is crucial for a successful single-port VATS lobectomy, and a 30-degree camera scope (10 or 5 mm) is recommended. After an initial inspection of the surgical field from the eagle view through the camera, an impression of the anatomic landmarks should be fully realized. The surgeon can re-adjust the settings to facilitate the exposure and dissection. Usually the surgeon will choose the best position for performing the surgical procedure, and then bring in the camera to take advantage of the 30-degree lens to provide the best view. Every step should be under direct vision in order maintain safety, especially during dissection and application of the endocutter to the great vessels. Concerning the relative positions inside the utility port, grasp and camera scope are usually maintained in the upper part of the port and the surgeon's instruments are in the lower part during dissecting process. However, during application of the endocutter or other specific procedures, a dynamic change in position may be necessary in order to command a clearer view and perform a safer procedure (*Figure 2*).

VATS lymph node dissection

Lymph node dissections on the right side of the mediastinum and left upper mediastinum are similar to traditional 2-ports VATS procedure (*Figures 3,4*). Although usually not difficult, it requires more time and patience to perform. However, the left subcarinal area can be challenging. We developed a special method, called the Liu's maneuver, to facilitate exposure of the left subcarinal space. We placed a non-elastic bandage above the inferior pulmonary vein to hook on the left lower lobe bronchus; thus, the lung parenchyma and hilum can be pulled away from the aorta and esophagus. With this maneuver, we obtain a clearer view of the carina, bilateral main bronchi, bilateral inferior pulmonary veins, pericardium, and esophagus along with right and left vagus nerves, right lung and right mediastinal pleura. In our early series using this maneuver, the average number of dissected lymph nodes for lung cancer was 23, similar to traditional VATS (15).

Learning curve, education, and training

Regarding learning curves, we went through a process similar to that of Diego Gonzalez-Rivas (6,16). As shown in his review articles, he also shifted from 3-ports to 2-ports and then to single-port VATS lobectomy. As a result, this process could be a training model for those who had VATS experience and who wanted to shift to single-port

Figure 3 Relative positions between the surgeon and cameraman during single-portright superior mediastinal lymph node dissection.

Figure 4 Single-port VATS for right subcarinal lymph node dissection.

VATS lobectomy, and for the new learner starting VATS lobectomy.

However, for the new learner without VATS experience, we are not certain about the need for a shift from 3-ports to 2-ports and then to single-port VATS. This question is similar to questions regarding the training required for traditional VATS. An open procedure is not absolutely necessary for the trainee to learn VATS. Similar to Diego Gonzalez-Rivas's group, we found that trainees without previous VATS experience are more open to new ideas and settings using single-port VATS. Actually, they accept these procedures and perform them better and more easily than experienced VATS surgeons who have already performed multiple ports VATS.

There is insufficient supporting data concerning the learning curve associated with VATS. Some thought that experienced VATS surgeons harbored a basic concept for VATS, and thus they could reach the plateau of the learning curve much quicker. However, if we take the Cases/Time curve into consideration when predicting the learning curve, perhaps the new learner will reach the learning plateau quicker than I did as it took me two years to pass the learning curve by accumulating more than 30 cases, which was really slow going in the beginning! This was not due to the difficulty of the technique, but rather the difficulty in making the determination whether or not to do it. To quote a well-known proverb:

The Difficulty lies, not in the new ideas, but in escaping from the old ones

——By John Maynard Keynes

The aggressive mind of the chest surgeon plays an important role in promoting the rapid development of commercial equipment necessary for single-port VATS, including the single-port wound protector, articulating instruments, harmonic scalpel, various sized straight or curved endocutter staplers, and higher resolution camera scopes with less scopic diameter. The mutual interaction between the desire of the surgeon and new manufacturing designs is the stimulus for advances in VATS.

More and more single-port VATS symposiums and conferences are held worldwide. Specific training programs on single-port VATS are also available. Furthermore, there are many single-port VATS videos, including trouble shooting for incomplete fissures, anthracotic lymph nodes, sleeve resection/bronchoplasty, bleeding, etc. These videos are available over the internet through YouTube.

Careful patient selection by the chest surgeon, for either benign or malignant disease, plays an important role when starting a single-port VATS lobectomy program. A single port VATS lower lobe lobectomy can be accomplished as easily as traditional VATS if there are no anthracotic nodes in the hilum nor incomplete fissures. The chest surgeon can then gradually expand his expertise to include all patients with early-stage lung cancer, if there are no specific contraindications.

In conclusion, we have reviewed the feasibility and safety of single-port VATS lobectomy for early-stage lung cancer. Single-port VATS is just another variant of VATS surgery in the modern era. More time and effort is need to procure sufficient evidence to show that single-port VATS is more beneficial to patients compared with standard techniques, in terms of less trauma and less postoperative pain, without compromising ontological outcome.

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Uniportal video-assisted thoracoscopic lobectomy: Zhongshan experience

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Historical note

Uniportal video-assisted thoracoscopic (VATS) is an emerging technique in the field of thoracic surgery. Since the report on uniportal thoracic surgery by Rocco in 2004, the topics on pneumothorax, pleural biopsy, and lung wedge resection using uniportal VATS have shown promising results (1). In 2011, Gonzalez *et al.* reported their experience on thoracoscopic lobectomy through single port, which was the first published study on major lung resection (2,3). Following that were the manuscripts on complicated cases using uniportal sleeve or even double-sleeve lobectomy within very short periods of time (4). The emerging technique, as an ever-progressive procedure, further pushed the advancement of thoracic surgery (5,6).

Up to date, with growing evidence on feasibility and safety, uniportal VATS was world-widely welcomed. In a recent report from Dr. Venuta, uniportal VATS was even well practiced by hands without VATS experience (7). Meanwhile, there remained a large number of medical centers in which uniportal VATS lobectomy was never ever practiced, due to technical difficulties. In this chapter, we aimed to describe uniportal VATS lobectomy that was conventionally performed in an Eastern center, which might help facilitate a good beginning in practice this technique.

Indications

The indications of uniportal VATS lobectomy are merely equal, if not the same, to multiportal VATS lobectomy. The benign indications for lobectomy include carcinoid tumors, fungal and bacterial infections, chronic bronchiectasis, tuberculosis infection of the lung, and congenital malformations. In the cases of malignancy, pre-operative examination including electrocardiogram (EKG), pulmonary function, chest computed tomography (CT) scan, bronchoscope, and brain magnetic resonance imaging (MRI) would be administered to exclude the candidates for curative surgery. The stage I-II patients in together with some surgically resectable stage III cases would be included in uniportal VATS lobectomy.

Anesthesia and analgesia

All patients would receive a combination of epidural and general anesthesia, and were provided with patient-controlled analgesia (PCA) postoperatively. After intravenous induction, each patient was intubated with a double-lumen endotracheal tube to accomplish single lung ventilation. All patients were extubated at the end of surgery and transferred to the ward. Local anesthesia to the incision using 0.2% bupivacaine is recommended during the wound closure.

Positioning

Generally, the patient was kept in a folding knife gesture (with the cranial side slightly raised up and caudal side pushed down) in lateral decubitus position (*Figure 1*). Intra-operatively, the surgeon and the assistant stood on the abdominal side of the patient. The assistant stood at the

Figure 1 The patient position during uniportal VATS. VATS, video-assisted thoracoscopic surgery.

Figure 2 The incision for uniportal VATS LUL lobectomy. VATS, video-assisted thoracoscopic surgery; LUL, left upper lobe.

foot-stool. The entire procedure was performed under the screen observation.

Incision

In uniportal VATS lobectomy, the surgical resection around hilar would be the major part to the whole procedure. Since there would be only one port available, the optimal distance between hilar and the port would facilitate the lobectomy. Besides, the limited width of the incision would interfere the surgical instruments when passing through the incision, and the hilar as well, which required an additional angel between the incision and the hilar. So the role of incision positioning should take both the distance and angle into the consideration. Due to the anatomic variation, the hilar would be positioned close to the level of 4th-5th intercostal space. It would be helpful to locate the hilar according to CT scan before operation. Conventionally, an incision (<3.5 cm) would be made in the anterior axillary line along 4th intercostal space (*Figure 2*) for upper lobe resection and 5th intercostal space for middle and inferior lobe resection.

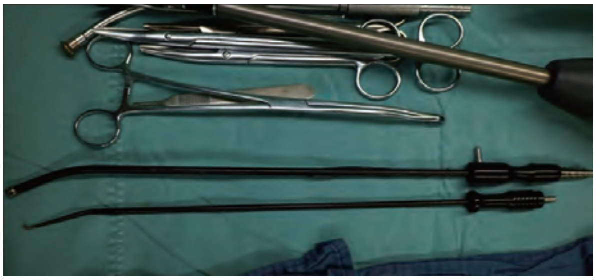

Figure 3 The designed surgical instruments for uniportal VATS. VATS, video-assisted thoracoscopic surgery.

A soft plastic wound protector was applied to the incision without rib-spreading procedure. The protector minimized iatrogenic touch during the introduction of thoracoscope to the surgical field, especially in the cases of obesity patients with thick subcutaneous fat tissues. A 10-mm 30 degree thoracoscope would be positioned in the superior side of the incision during the whole procedure. The designed surgical instruments (*Figure 3*), in together with the harmonic shear (Ethicon Endo-Surgery Inc, Cincinnati, OH, USA) or hook electro-cautery were applied during the procedure.

Thoracic exploration

In uniportal VATS lobectomy, the geographical view differed from multiportal VATS, while the thoracic cavity required carefully exploration to identify any unexpected invasion or metastasis. Since the incision was located at the anterior axillary line close to the anterior part of the hilar. The posterior part of the hilar, and diaphragm were far from the surgical incision. Therefore the identification of incidental lesion at these locations remained important before the confirmation of the lobe resectability.

Management of the hilar vessels

The procedure continued from the diaphragm exploration to the taken down of the inferior pulmonary ligament. Usually, care must be taken not to injure the inferior pulmonary vein. The lobectomy around hilar included the identification and dissection of the three primary vascular structures: the pulmonary artery, the superior pulmonary vein, and the inferior pulmonary vein. Venous drainage of each lobe is confirmed, and any anatomic anomalies are identified. The order of dissection and transection differed

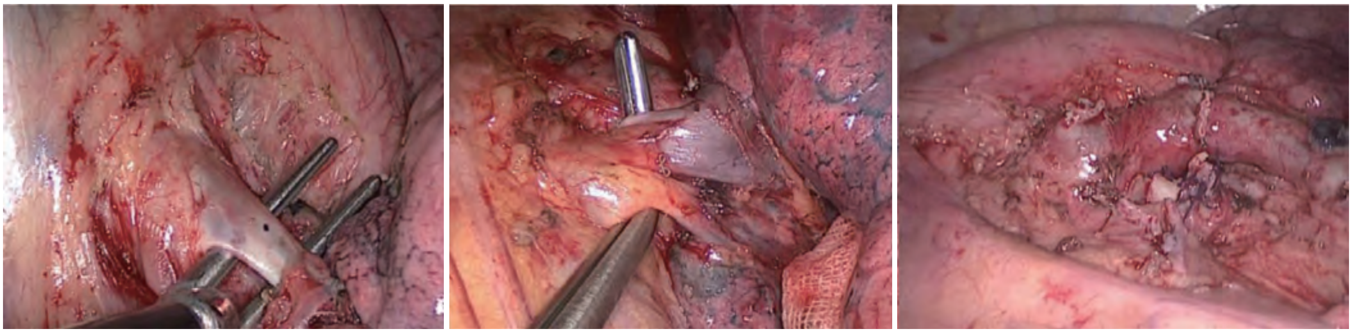

Figure 4 The dissection order of the uniportal VATS left-upper lobectomy. The apical branch of pulmonary artery, and the superior pulmonary vein and the left upper bronchus were dissected in order (Shown in the video of *Figure 5*).

in upper and lower lobectomy (detailed below). Cautery can be used on the posterior aspect of the hilum, but care must be taken anteriorly to avoid thermal injury to the phrenic nerve.

Management of the fissure

In uniportal VATS, a complete or incomplete fissure makes the difference between a very simple resection and a tedious and difficult one. Similar to the multiportal VATS, complete fissures allowed identification of the pulmonary artery as a landmark to begin dissection. Otherwise, the fissureless technique would be considered to deal with the fissure as the last step during the surgical resection of the target lobe. In dissecting the fissure, make sure that the staple line covered both surfaces of the lung and no remaining parenchymal is left after firing the staple. Besides, an uncertain staple line might be tested for air leak and oversaw strengthen.

Upper lobectomy

Previously, upper lobectomy using VATS technique was considered more difficult in compared with lower lobectomy. The dissection of truncus anterior branch of pulmonary artery remained as the challenging part during the upper lobectomy. Besides, if the surgery started from the dissection of major fissure, which was not always well developed, would increase the difficulty towards lobectomy. On the contrary, in uniportal VATS upper lobectomy, the surgery usually started from the dissection around the hilar, and truncus anterior artery was usually kept as the first main vessel to be dealt with. The dissection order was modified to facilitate the whole procedure. After the dissection of truncus anterior artery, the superior pulmonary vein and

Figure 5 Uniportal VATS upper lobectomy with mediastinal lymph node dissection (8). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/507

upper bronchus would be exposed, and the dissection would be easy. The artery, vein, and bronchus were divided and dissected separately using an endo-linear stapler (Covidien, Mansfield, MA, USA or Ethicon Endo-Surgery Inc, Cincinnati, OH, USA) (*Figures 4,5*) (8).

Lower lobectomy

In the cases of lower lobe lesions, the dissection order varied according to the development of the major fissure. When the oblique fissure developed well, the basal and the posterior branch could be mobilized easily. The procedure would be followed by dissection of the lower bronchus and then the inferior pulmonary vein. Since the incision was located at the 5th intercostal space, which was close to the major fissure, the dissection along the fissure was facilitated without turning over the lower lobe.

When the fissure was not well developed or the lesion was close to the fissure, it would be easier to start the dissection from the inferior ligament. The inferior pulmonary vein was switched to the first main vessel during the whole procedure. The procedure was similar to the "single direction lung resection" described by Dr. Lunxu Liu and associates (9). In that case, the surgeon and assistant would change their positions to facilitate the dissection along the inferior ligament.

Middle lobectomy

Usually, a lesion located in the middle lobe would have higher incidence to be invasive to the upper or lower lobes, so it would be important to explore the whole thoracic cavity before the lobectomy. The uniportal VATS middle lobectomy through 5th intercostal space was a standard procedure. The dissection of the middle lobe pulmonary vein usually came as the first structure, while the identification and dissection of the vein remained challenging using endoscopic staplers. Because the stapler had a restricted curve to pass through both the incision and the middle pulmonary vein, while the ligation of the vein might be an alternative during the middle lobe lobectomy. The surgery went on sequentially with the dissection of middle lobe bronchus and the artery.

The specimen was taken out in the specimen bag (Ethicon Endo-Surgery Inc, Cincinnati, OH, USA). In the cases of large size tumor, Dr. Sihoe suggested to dissect one rib to facilitate the take-out, which would be an alternative during the uniportal VATS lobectomy. A 28-Fr chest tube was inserted at the end of the operation, and the chest tube would be removed in the cases there was no air leakage and the volume of drainage was less than 200 mL per day 24 hours post-operatively.

Conversions

In multiportal VATS, the conversion to thoracotomy was not considered as failure to the procedure. Meanwhile, the uniportal VATS required learning curve to reach a stable plateau of performance. Therefore, the application of additional port or even thoracotomy would be helpful when the operation ran into difficulty. The severe thoracic adhesion, major bleeding or lymph node invasion could be the main reasons to do the conversion.

Learning curve

Every surgical procedure required certain case volumes to reach the plateau of performance. At this point, the uniportal VATS lobectomy was not an exceptional. As most surgeons turned to uniportal VATS could have some experience on minimally invasive surgery, the difficulty relied mostly on how to pass the staplers through the inter-space among the mediastinal vessels. Sometimes the lobe should be contracted towards different directions to match the endo-cutter, and the assistant surgeon would therefor play an important role throughout the surgery. Since the surgeon and the assistant stood at the same side during the operation, with the better training opportunities, the learning curve for this demanding procedure might be shortened in spite of the difficulties mentioned above.

Future prospective

Uniportal VATS, is not the happy ending in thoracic surgery. Beside its rapid progression, there remained a lot of questions to answer. Its uncovered benefits and drawbacks over traditional VATS, its possible improvements, and less invasive peri-operative managements could be the future topics. A comparison between uniportal versus multiportal VATS using high-level methodology is therefore required. With the development of surgical minds and instruments, uniportal VATS would have done more to the patients.

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Single-port video-assisted thoracoscopic surgery lung resection: experiences in Fujian Medical University Union Hospital

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Abstract: Video-assisted thoracoscopic surgery (VATS) is currently a better choice than thoracotomy for lung resection, and then single-port VATS has been increasingly applied in clinical settings with the improvements in both endoscopic instruments and surgical skills. Our center began to perform single-port VATS lobectomy in May 2014 and had performed all sort of lung resection in 168 patients till December 2014, including wedge resection, routine lobectomy, sleeve lobectomy, segmentectomy and pneumonectomy. All these procedures were successfully performed without any severe complication. We believe the single-port VATS lung resection is a safe and feasible procedure after surgery practice.

Keywords: Single-port; video-assisted thoracoscopic surgery (VATS); lobectomy; segmentectomy

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Developments in single-port video-assisted thoracoscopic surgery (VATS)

The single-port VATS was initially reported by Migliore *et al.*, who applied this technique in the diagnosis and treatment of noncomplex pleural disease (1).With the advances in thoracoscopic equipments and surgical skills, this technique has gradually applied in routine VATS and even for the surgical treatments of more complicated thoracic diseases. In 2011, Gonzalez *et al.* reported the single-port VATS lobectomy based on their extensive experiences (2). With the constant improvement of thoracoscopic techniques and development of surgical instruments, more and more thoracic surgeons have performed the single-port VATS lung resection. This technique has become a major developmental trend in minimally invasive surgery.

Single-port VATS in Fujian Medical University Union Hospital

In 2004, the single-port VATS was initially applied for pleural biopsy in our center. Subsequently, it was applied for thoracic sympathectomy, pleurodesis, and resection of pulmonary bullae. Since May 2014, it has been applied for the radical resection of lung cancer and then for more complicated surgeries such as segmentectomy and bronchoplastic procedures. In October 2014, sleeve lobectomy and pneumonectomy by single-port VATS were successfully performed in our center. Currently, the single-port VATS technique has been applied for almost all the traditional VATS lung surgeries including wedge resection, routine lobectomy, bronchoplasty, sleeve lobectomy, segmentectomy, and pneumonectomy.

Implementation of single-port VATS in Fujian Medical University Union Hospital (*Tables 1-3, Figure 1*)

Operative position during single-port VATS: placed in a 90° lateral decubitus position on the healthy side

See *Figure 2*.

Table 1 Implementation of single-port VATS in Fujian Medical University Union Hospital from May to December in 2014 (n=168)

Procedures	Number
Wedge resection	43
Segmentectomy	28
Routine lobectomy	93
Sleeve lobectomy	3
Pneumonectomy	1

VATS, video-assisted thoracoscopic surgery.

Table 2 Implementation of single-port VATS lobectomy and mediastinal lymph node dissection for non-small cell lung cancer in Fujian Medical University Union Hospital from May to December in 2014 (n=82)

Procedures	Outcomes
Tumor location	
Right upper lobe	31
Right middle lobe	7
Right lower lobe	16
Right middle & lower lobe	2
Left upper lobe	15
Left lower lobe	11
Pathologic type	
Minimally invasive adenocarcinoma	14
Invasive adenocarcinoma	56
Squamous cell carcinoma	8
Adenosquamous carcinoma	2
Carcinoid	1
Mucoepidermoid carcinoma	1
Tumor size (cm)	2.1±1.3
Tumor stage	
0	1
Ia	39
Ib	17
IIa	10
IIb	9
IIIa	6
Operation time (mins)	173.5±36.3
Intraoperative blood loss (mL)	90.0±54.6
Total number of lymph node dissection	22.4±9.4
Intrapulmonary lymph nodes	8.2±4.1
Mediastinal lymph nodes	14.3±7.6
Post-operative chest drainage duration (days)	4.3±1.6
Post-operative hospital stay (days)	7.4±4.3

VATS, video-assisted thoracoscopic surgery.

Table 3 Implementation of single-port VATS segmentectomy in Fujian Medical University Union Hospital from May to December in 2014 (n=28)

Procedures	Outcomes
Range of surgical resection	
Right lung	11
S1	2
S2	3
S3	1
S1 + S2	1
S6	3
S7 + S8 + S9 + S10	1
Left lung	17
S1	1
S2	2
S1 + S2	1
S1 + S2 + S3	6
S3 + S4 + S5	1
S4 + S5	2
S6	1
S7 + S8	1
S7 + S8 + S9 + S10	2

VATS, video-assisted thoracoscopic surgery.

Figure 1 Operative scene.

Design of the incision

The surgical incision (3.0-4.5 cm in length) was created at the 4th or 5th intercostal space at the anterior axillary line, depending on the patient's height and weight as well as the lesion location. In most cases, the incision was made at the 5th intercostal space (*Figure 3*).

Figure 2 Operative position.

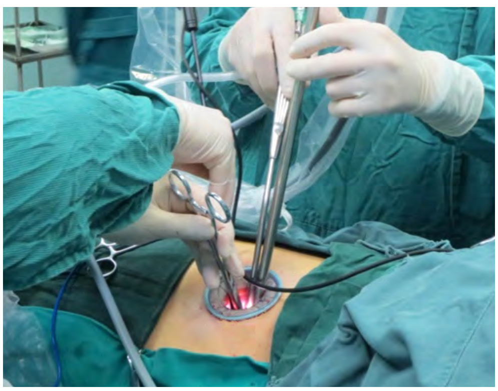

Figure 3 Surgical incision.

Figure 4 Single-port VATS right upper lobectomy (3). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/554

Figure 5 Single-port VATS right middle lobectomy (4). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/555

Surgery video

Single-port VATS lobectomy

Right upper lobectomy (*Figure 4*)

Before the surgery, patient was pathologically confirmed to be with invasive adenocarcinoma. Right upper lobectomy and mediastinal lymph node dissection were then performed. The steps of single-port right upper lobectomy were as follows: after thoracic cavity exploration, the pleura facing the right superior pulmonary vein was opened in front of hilum to expose the upper lung branch of the superior pulmonary vein and then dissociated the hilum. After the right upper lobe bronchus being exposed, removed the lymph nodes surrounding the bronchus. After a sufficiently long bronchus was dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected. Dissected the main pulmonary artery to expose its branches in the right upper lobe, which were also transected using the linear stapler. The upper lobe branch of the superior pulmonary vein was transected using the linear stapler. Finally, divided the hypoplastic pulmonary fissures using the ultrasonic scalpel.

Right middle lobectomy (*Figure 5*)

Non-peripheral pulmonary nodules were found in the right middle lobe of this patient. Since it was difficult to perform wedge resection in this case, right middle lobectomy was performed instead. After thoracic cavity exploration, the middle lobe branch of the right superior pulmonary vein was dissociated firstly, which was then transected after ligation with silk thread at the proximal end. The right middle pulmonary artery was exposed at the junction of interlobular fissures and then transected using the

Figure 6 Single-port VATS right lower lobectomy (5). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/556

Figure 7 Single-port VATS left upper lobectomy (6). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/557

Figure 8 Single-port VATS left lower lobectomy (7). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/558

linear stapler. After the right middle lobe bronchus being dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected. Finally, divided the hypoplastic horizontal fissure using the linear stapler.

Right lower lobectomy (*Figure 6*)

The patient had right lower lung cancer, which was pathologically confirmed to be invasive adenocarcinoma after the pre-operative CT-guided lung puncture. Right lower lobectomy and mediastinal lymph node dissection were then performed. After thoracic cavity exploration, exposed the pulmonary artery at the junction of interlobular fissures. After the posterior section of the oblique fissure being sufficiently opened, dissected the arteries in the basal and dorsal segments of the right lower lobe and then transected them with the linear stapler. Divided the hypoplastic posterior section of the oblique fissure using the linear stapler. Dissociated the right inferior pulmonary vein, and then transected it with the linear stapler. After the right lower lobe bronchus was dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected.

Left upper lobectomy (*Figure 7*)

The patient was found to be with a peripheral nodule in the left upper lobe. At first, wedge resection was performed using the linear stapler to remove the nodule, which was intra-operatively confirmed to be invasive adenocarcinoma by frozen pathology. Then, radical resection of left upper lobe was performed. The inferior pulmonary ligament was dissociated till the inferior pulmonary vein level. The superior pulmonary vein was showed in front of the hilum and then lifted with silk thread. After the hilum being released, dissected the interlobular fissure to expose the pulmonary artery trunk. Divided the posterior section of the oblique fissure using the linear stapler. After the trisegemental branches of the left pulmonary artery being exposed, transected them using the linear stapler, followed by the transection of the left superior pulmonary vein. Transected the lingular artery branches using the ultrasonic scalpel after its proximal end being ligated with silk thread. Divided the anterior section of the oblique fissure using the linear stapler. After the upper left lobe bronchus being dissociated, it was clamped with the linear stapler. Since the inspection showed that the residual lungs were well dilated, the bronchus was then transected.

Left lower lobectomy (*Figure 8*)

In a patient with peripheral pulmonary nodule in his left

Figure 9 Single-port VATS right upper lobe bronchial sleeve lobectomy (8). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/559

Figure 10 Single-port VATS right upper lobe apical segmentectomy (S1) (9). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/560

lower lobe, wedge resection and then left lower lobectomy and mediastinal lymph node dissection were performed, during which the nodule was confirmed to be invasive adenocarcinoma by frozen pathology. The steps of single-port left lower lobectomy were as follows: the inferior pulmonary ligament was dissociated till the inferior pulmonary vein level. Dissociated the inferior pulmonary vein. Dissected the interlobular fissure to expose the pulmonary artery, during which the pulmonary artery should be carefully protected. Dissected the hypoplastic posterior section of the oblique fissure with the ultrasonic scalpel and dissociated the arteries in the basal and dorsal segments. Transected the left inferior pulmonary vein with the linear stapler and then transected the arteries of the basal and dorsal segments. After the left lower lobe bronchus being dissociated, it was clamped with the linear stapler. Since the inspection showed that the residual lungs were well dilated, the bronchus was then transected.

Right upper lobe bronchial sleeve lobectomy (*Figure 9*)

In a patient with central non-small cell lung cancer (NSCLC), bronchoscopy showed that the tumor had invaded the right main bronchus. Right upper lung bronchial sleeve lobectomy was then performed. This video mainly introduced the single-port VATS bronchial sleeve lobectomy. After the thoracic cavity exploration, transected the right superior pulmonary vein and artery with the linear stapler, followed by the dissection of mediastinal lymph nodes, transection of azygos vein, and finally bronchial sleeve resection. The right main bronchus that had been invaded by the tumor underwent the sleeve resection. Since the intra-operative frozen section analysis for the two bronchial stumps showed negative results, bronchial anastomosis was further performed. Continuously suturing using a single 3-0 prolene suture (a 4-quadrant suturing technique) was applied. With the first suture made in the inner side of the bronchial wall and knotted outside the bronchus, a continuous suture was made on one quarter of the circumference on both sides and drawn to reduce the tension, followed by further continuous sutures to cover the entire circumference, with a final knot at the outer side of the wall to complete the anastomosis. Leak testing was conducted following the anastomosis, in which no leakage was detected up to an airway pressure of 30 cmH_2O (2.94 kPa).

Single-port VATS segmentectomy

Right upper lobe apical segmentectomy (S1) (*Figure 10*)

Firstly, the right superior pulmonary vein was dissociated towards the distal end, and the apical segment of the vein was identified. Meanwhile, the artery of the apical segment was dissociated. Since the vein and artery of the apical segment were very close to each other, they were transected together with the same linear stapler. Then, pulled downward the right upper lobe to dissociate the apical segmental bronchus. The apical segmental bronchus was clamped with vessel smooth forceps, then the lungs were dilated to confirm the border of the apical segmental lung tissues. Divided the bronchus using the linear stapler. Finally, removed the apical segment using the linear stapler along its border.

Right upper lobe anterior segmentectomy (S3) (*Figure 11*)

The patient was found to be with a benign lesion in his anterior segment of the right upper lobe. The horizontal fissure was poorly developed. Firstly, the horizontal fissure

Figure 11 Single-port VATS right upper lobe anterior segmentectomy (S3) (10). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/561

Figure 12 Single-port VATS right upper lobe apicoposterior segmentectomy (S1 + S2) (11). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/562

Figure 13 Single-port VATS right lower lobe dorsal segmentectomy (S6) (12). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/563

was opened with a linear stapler. Then, the right superior pulmonary vein was dissociated towards the distal end. After each branch of the pulmonary vein being dissociated and confirmed, transected the anterior segmental branch using the linear stapler. Transected the anterior branch of the right pulmonary artery with the linear stapler after dissociating it carefully. Then, pulled backwards the right upper lung to dissociate the anterior segmental bronchus along the deep surface. The anterior segmental bronchus was clamped using vessel smooth forceps, then the lungs were dilated to confirm the borders of the anterior segmental lung tissues. Divided the bronchus using the linear stapler. Finally, removed the lung tissue along the borders of the anterior segment.

Right upper lobe apicoposterior segmentectomy (S1 + S2) (*Figure 12*)

Firstly, the posterior mediastinal pleura was opened and the posterior oblique fissure was divided using electric hook, followed by the dissociation and transection of the artery and vein of the posterior segment. Then the apical segmental artery was dissociated and then transected with the linear stapler. The right upper lobe bronchus was dissociated from the posterior side, and then the bronchus of the apicoposterior segment was dissociated. The bronchus of the apicoposterior segment was clamped with vessel smooth forceps, then the lungs were dilated to confirm the borders of the apicoposterior segmental lung tissues. Divided the bronchus of the apicoposterior segment using the linear stapler. Then, the vein of the apical segment was dissociated from the anterior side, ligated with a 1-0 silk suture, and finally transected using the ultrasonic scalpel. Finally, removed the apicoposterior segment using the linear stapler along its borders.

Right lower lobe dorsal segmentectomy (S6) (*Figure 13*)

The patient was found to be with multiple nodules in the right lung. There was a 10 mm nodule at the dorsal segment of the right lower lobe. Since wedge resection was not suitable, resection of the dorsal segment was performed. Opened the posterior oblique fissure and the posterior mediastinal pleura to dissociate the artery of the dorsal segment along the pulmonary artery trunk. The artery of the dorsal segment was then transected using the linear stapler. Pulled downwards the right lower lobe to dissociate the dorsal segmental bronchus. Searching for the segmental bronchus was often interfered by its surrounding lymph nodes (station 13). Therefore, removal of the station 13 lymph node could make the dissociation of the segmental bronchus easier. Divided the dorsal segmental bronchus

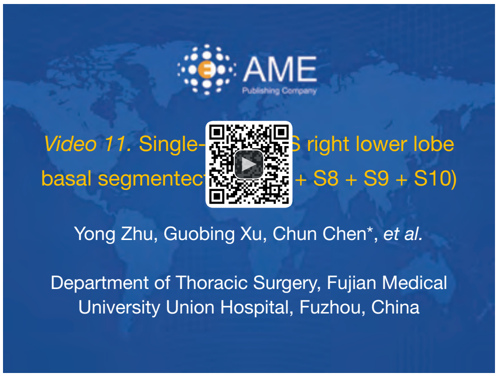

Figure 14 Single-port VATS right lower lobe basal segmentectomy (S7 + S8 + S9 + S10) (13). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/564

Figure 15 Single-port VATS left upper lobe posterior segmentectomy (S2) (14). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/565

Figure 16 Single-port VATS left upper lobe apicoposterior segmentectomy (S1 + S2) (15). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/566

using the linear stapler. Before the transection of the dorsal segmental bronchus, the lungs were dilated to confirm the borders of the dorsal segmental lung tissues. Then, transected the dorsal segmental vein using the linear stapler. Finally, removed the dorsal segment using the linear stapler along its borders.

Right lower lobe basal segmentectomy (S7 + S8 + S9 + S10) (*Figure 14*)

The patient had a ground glass opacity at his basal segment of the right lower lobe. The tumor sized about 10 mm and could not be removed by wedge resection. Firstly, dissociated the vein and artery of the basal segment, and then transected them using the linear stapler. Pulled backwards the lower right lung to dissociate the basal segmental bronchus. The basal segmental bronchus was clamped with vessel smooth forceps, then the lungs were dilated to confirm the borders of the basal segmental lung tissues. Divided the basal segmental bronchus using the linear stapler. Finally, removed the lung tissue along the borders of the basal segment.

Left upper lobe posterior segmentectomy (S2) (*Figure 15*)

The patient had a ground glass opacity at the posterior segment of the left upper lobe. Firstly, opened the posterior oblique fissure to dissociate the posterior segmental artery. This artery was ligated with a 1-0 silk suture and transected using the ultrasonic scalpel. Then, dissociated the posterior segmental bronchus. Clamped it with vessel smooth forceps, then the lungs were dilated to confirm the borders of the posterior segmental lung tissues. Divided the posterior segmental bronchus using the linear stapler. Finally, removed the lung tissues with the linear stapler along the borders of posterior segment.

Left upper lobe apicoposterior segmentectomy (S1 + S2) (*Figure 16*)

Firstly, dissociated left superior pulmonary vein toward its distal end, and then the apical and posterior segmental branches were confirmed. Divided the posterior oblique fissure, dissociated the arteries of the apicoposterior segment and then transected the arteries and veins of the apicoposterior segment using the linear stapler. The left upper lobe was pulled forwards, and then the bronchus of the apicoposterior segment were dissociated. The bronchus of the apicoposterior segment was clamped with vessel smooth forceps, then the lungs were dilated to confirm the borders of the apicoposterior segmental lung tissues. Divided the bronchus at the apicoposterior segment using the linear stapler. Finally, removed the lung tissues of the apicoposterior segment using the linear stapler.

Figure 17 Single-port VATS left upper lobe trisegmentectomy (S1 + S2 + S3) (16). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/567

Figure 18 Single-port VATS left upper lobe lingular segmentectomy (S4 + S5) (17). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/568

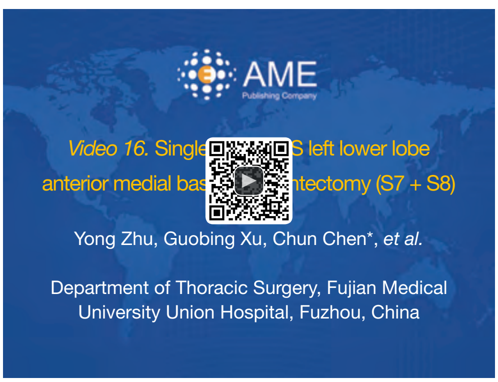

Figure 19 Single-port VATS left lower lobe anterior medial basal segmentectomy (S7 + S8) (18). VATS, video-assisted thoracoscopic surgery. Available online: http://www.asvide.com/articles/569

Left upper lobe trisegmentectomy (S1 + S2 + S3) (*Figure 17*)

Firstly, opened the anterior and posterior mediastinal pleura to dissociate the veins, then the arteries of the trisegment. Transected the veins of the trisegment using the linear stapler. The posterior segmental artery was ligated with a 1-0 silk suture and transected with the ultrasonic scalpel, and the remaining arteries were handled using the linear stapler. Then the bronchus of the trisegment was transected with the linear stapler. Finally, removed the lung tissues of the trisegment along their borders. During the surgery, the lung tissues of the proper segment were confirmed using two methods: method A—the trisegmental bronchus was clamped firstly before lung dilation; thus, the undilated lung tissue was the proper segment; method B—the lung was dilated firstly, followed by the clamping of the trisegmental bronchus, thus, the unclapsed lung tissue was the trisegment.

Left upper lobe lingular segmentectomy (S4 + S5) (*Figure 18*)

At first, opened the oblique fissure to expose the pulmonary artery trunk. However, no lingular segmental artery was found. Further dissection showed the variation of the lingular artery, which arose from the proximal end of the left pulmonary artery and then entered the lingular segmental lung tissue after passing the frontal side of the left upper lobe bronchus. Then, the lingular segmental bronchus, vein, and artery were handled one by one. Finally, removed the lung tissues of the lingular segment along its borders.

Left lower lobe anterior medial basal segmentectomy (S7 + S8) (*Figure 19*)

Firstly, opened the anterior oblique fissure to dissociate the anterior medial basal segmental artery ,which was then transected using the linear stapler. After being exposed, the anterior medial basal segmental bronchus was clamped with vessel smooth forceps, then the lungs were dilated to confirm the borders of the anterior medial basal segmental lung tissues. Divided the anterior medial basal segmental bronchus using the linear stapler. Dissociated the left inferior pulmonary vein to the distal end to identify its branches. The anterior medial basal segmental vein was then transected using the linear stapler. Finally, removed the lung tissue of the anterior medial basal segment along its borders.

Single-port VATS pneumonectomy (*Figure 20*)

The patient with bronchiectasis in the whole left lung was admitted to our hospital due to recurrent hemoptysis. Left

Figure 20 Single-port VATS pneumonectomy (19). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/570

pneumonectomy was then performed. Firstly, opened the anterior and posterior mediastinal pleura to thoroughly dissociate the left pulmonary artery and vein and the left main bronchus. Afterwards, the left inferior pulmonary vein, left superior pulmonary vein, left pulmonary artery trunk, and left main bronchus were transected using the linear stapler one by one.

Discussion

Along with the advances in thoracoscopic techniques, VATS instruments, and minimally invasive concepts, the number of incisions made during VATS has decreased from 3 or 4 to 1. The application of the single-port VATS in more complicated procedures including lobectomy (2,20), segmentectomy (21), pneumonectomy (22), sleeve lobectomy (23), and pulmonary artery angioplasty (24) have also been reported. Compared with the conventional triple-port complete VATS, the single-port VATS no longer use the auxiliary port at the posterior axillary line and the observation port at the midaxillary line. The 4th or 5th intercostal space at the anterior axillary line is relatively wide, with fewer muscle layers at the chest wall; therefore, it has high elasticity, and bleeding at this site can be easily stopped. Incision at this area will cause milder injury and pain and thus has fewer impacts on the patient's feelings and activities. During the single-port VATS, however, both the operational instruments and endoscope pass in and out from the same port and therefore may interfere with each other; in particular, it is difficult to expose the lesions located at the dorsal side or near the diaphragm, making the operations more challenging. Thus, the beginners should operate via multiple ports firstly before using a single port. In our center, the VATS teams had rich experiences in performing three-port VATS lobectomy (25,26), which laid a solid foundation for the adoption of the single-port VATS.

Our recommendations include:

(I) Incision selection should be based on a specific lesion. The incision should be a bit far away from the lesion, so as to avoid the mutual interference among the instruments. Typically, the incision is often located at the 5th intercostal space; for patients with a chunky body, the 4th intercostal space will be more feasible;

(II) The surgical instruments should be thin and long, with multiple joints or cornered design, so as to save the incision space to avoid the mutual interference among surgical instruments and the "arrow effect" during the maneuvers; also, the use of such instruments is helpful to lower the operational difficulty, increase the surgical smoothness, and shorten the surgical duration;

(III) A close cooperation between the camera-holding assistant and the operator is particularly important. Typically, the camera-holding assistant stands opposite to the operator, maintaining the thoracoscope over the incision. Such a position decreases the body interference between the camera-holding assistant and the operator, and leaves the majority of the incision space to the operator. Since the single-port VATS is performed via the sagittal plane and through the tail-head approach, the eyes and hands are used at the same level during the operation; thus, an observation from tail to head should be avoided. The impacts of the quality of camera-holding on the VATS can be reflected in multiple facets including the comfort of the operator, the smoothness of the surgery, the operational duration, the surgical viewing, and the operational safety. A qualified assistant must have flexible camera-holding skills, be familiar with the detailed surgical procedures, understand the operational habits of the operator, and have rich teamwork experiences;

(IV) During the operation, vascular injury due to excessive extraction should be avoided. Meanwhile, the surgical field should be adequately exposed, and forced insertion of the stapler should be avoided. Due to the surgical angles, the vessels (in particular the two upper lung veins) should be thoroughly dissociated to ensure a safe transection;

(V) For patients who are scheduled for segmentectomy, the lesion should be repeatedly located before and during the surgery. In our center, the lesion is located by lung CT three-dimensional reconstruction or by thin-slice CT scan before surgery in combination with finger palpation during the surgery;

(VI) In our earlier practices, we routinely placed a chest tube for the resection of the middle or lower lobes; for the resection of the upper lobes, two chest tubes were placed along the surgical incision. Now we are using a modified method: a drainage tube is placed along the surgical incision, and then an Abel drainage tube is placed by acupunture at the 8th or 9th intercostal space along the posterior axillary line. This new method can shorten the chest tube duration and reduce pulmonary complications. Also, the Abel drainage tube is more comfortable for the patient and can adequately drain the pleural fluids; it can be indwelled for a longer period of time and thus reduce the rate of chest tube replacement.

In summary, all the single-port VATS procedures were sucessfully performed in our center. No perioperative severe complication or death was noted. Nevertheless, the middle- and long-term efficacies of these procedures for lung cancer still require evidences from further follow-up. In our view, the single-port VATS is safe and feasible, and thus warrants further clinical applications.

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From open to single port video assisted thoracoscopic lobectomy: a stepwise and return progression of the experience from Department of Thoracic Surgery, General Hospital of Guangzhou Military Command of P.L.A

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Introduction

Department of Thoracic Surgery, General Hospital of Guangzhou Military Command of P.L.A was founded in 1954, and the first lobectomy using standard posterolateral thoracotomy was performed in the same year. For about half a century, more than 5,000 open lobectomy have been performed at the department. With the wide acceptance of video assisted thoracoscopic surgery (VATS) lobectomy all over the world, more than a thousand cases of multiport VATS lobectomy have been performed at our department. Since 2013, without any training and operation observation, single port VATS lobectomy has been successfully developed after the reading of a series of papers by Dr. Gonzalez-Rivas, and nearly 200 single port VATS lobectomy have been performed at our department up to now. Moreover, we have developed our own unique surgical skills and process without any major intra-/and post-operative complications. In order to verify the advantages of single port, we launched a prospective study to compare the short and long term outcomes between multiple and single port VATS lobectomy recently. Here, we firstly introduce the evolution of lobectomy approach at our department, and give the story how we develop surgical approach from open to single port VATS step by step. Then, the characteristic of single port lobectomy and our unique experience will be described. We think single port VATS lobectomy is a kind of return progression from open lobectomy with the same surgical vision and technique maneuver. At last, we will discuss a few potential improvements of single port lobectomy and give a glimpse into the future.

Single port VATS approach was firstly elaborated by Dr. Rocco from Division of Surgery, the National Cancer Institute, Naples, Italy. Since 2004, Rocco and colleagues (1-3) described their technology and initial experience of single port VATS in pulmonary wedge resection and mediastinal nodal biopsy in a series of papers. It has been a prevalent trend around the world after 2012, when Dr. Gonzalez-Rivas firstly reported his wonderful endeavor in single port VATS lobectomy with radical lymphadenectomy for non-small cell lung cancer (NSCLC). Nowadays, more and more surgeons are interesting in how to develop this relative complicated technique. In this paper, we introduce our experience and some tips and tricks in single port VATS lobectomy.

The evolution of surgical approach for lobectomy at our department

Traditional open surgical approach [1954-2000]

In 1954, Department of Thoracic Surgery was founded in General Hospital of Guangzhou Military Command of P.L.A by a prominent surgeon Dr. Weijie Ou (*Figure 1A*).

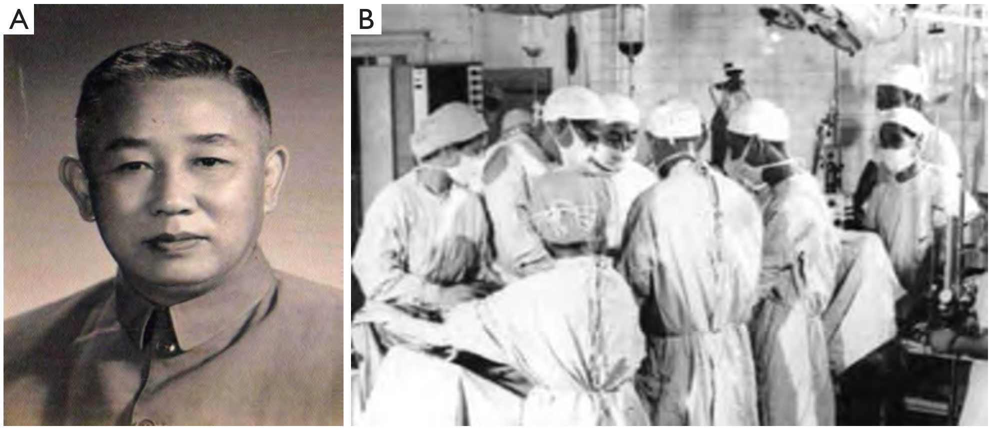

Figure 1 (A) Dr. Weijie Ou [1920-1997], founder and first director of our department; (B) lobectomy in our department in the early time.

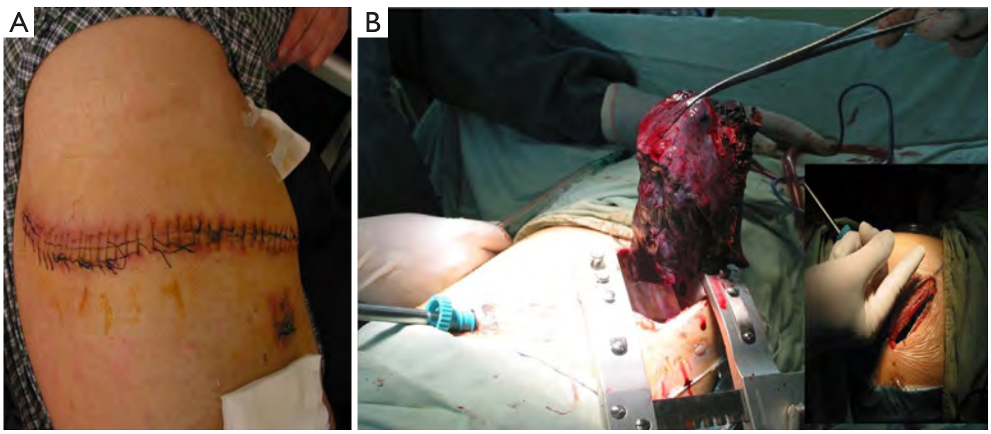

Figure 2 (A) Apperance of chest wall after standard posterolateral thoracotomy, we can see the almost 35 cm long incision and the drainage port below; (B) lobectomy through video-assisted thoracoscopic subaxillary minithoracotomy. The incision is longer than 10 cm.

At almost the same time, the first lobectomy through standard posterolateral thoracotomy was performed at our department (*Figure 1B*). At that time, it was one of the several centers that could be qualified for major pulmonary surgery in southern China. Since then, thousands of patients with lung diseases have regained their health in our department. During half a century, the main surgical approach for lobectomy was the standard posterolateral thoracotomy at our department (*Figure 2A*).

Muscle sparing thoracotomy [2000-2003]

Based on the abundant experience on lobectomy using traditional thoracotomy, we were adapted to muscle sparing thoracotomy fast and well around 2000. In general, muscle sparing thoracotomy includes subaxillary minithoracotomy (*Figure 2B*, the common way we did) and auscultatory triangle thoracotomy. Though the assumption that muscle sparing thoracotomy resulting in less pain than conventional open surgery was debated (4,5), the smaller incision leading to a better cosmetic result is obvious. The approach was still attractive before VATS become widespread. It should be pointed out that conventional open operation and muscle sparing thoracotomy coexist at our department during this period.

Video-assisted thoracoscopic surgery (VATS) [2003-]

If muscle sparing thoracotomy was the eve of minimally invasive thoracic surgery, the use of thoracoscopy truly opened the era of minimally invasive thoracic surgery. With the experience of VATS in pneumothorax, mediastinal diseases and pulmonary wedge resection for nearly 10 years, we applied VATS in lobectomy from 2003. Since then,

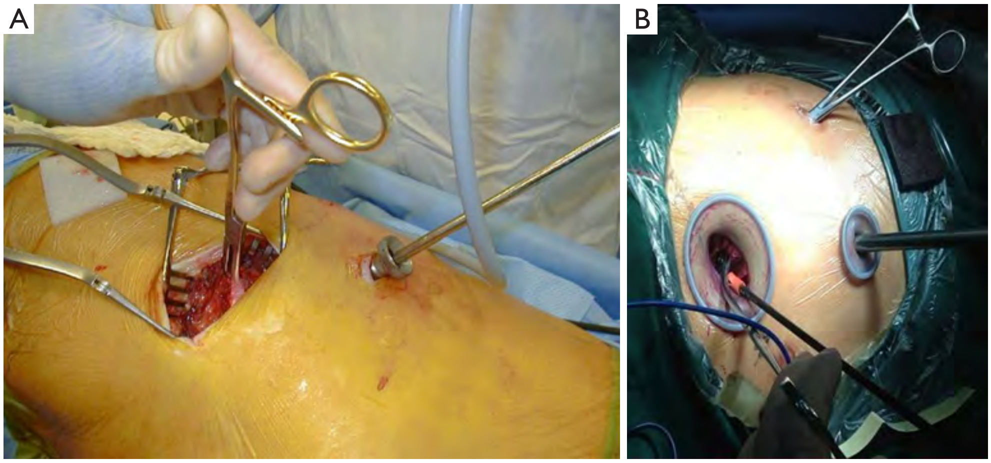

Figure 3 (A) Hybrid VATS lobectomy: the length of incision is shorter than *Figure 2B*. Meanwhile, a minimal invasive rib retractor is still used to expose thoracic cavity; (B) complete VATS lobectomy through the typical 3-port. The length of utility incision is about 3-6 cm without rib retractor, but a wound protector. A 1-cm auxiliary is used to help expose the tissue. Another 1-cm incision is used to insert thoracoscope, here we use a small wound protector instead of trocar. VATS, video assisted thoracoscopic surgery.

VATS lobectomy has been applied in our unit more and more widely, and the development of VATS lobectomy at our department can be broadly divided into three phases: hybrid VATS, complete VATS and single port VATS.

Hybrid VATS lobectomy (after 2003)

Before 2005, the main approach for lobectomy at our department is hybrid VATS. In our view, hybrid VATS contains muscle-sparing minithoracotomy using rib retractor to spread intercostal (incision, 8 to 10 cm) and a 10-mm incision to insert thoracoscopy (*Figure 3A*). The perspective of a surgeon comes from the combination of genuine direct vision and visualization of video screen. It is the primary development stage of VATS lobectomy at our unit. In this stage, this hybrid method made the surgeons adapt to the perspective and operation under thoracoscope. In addition, almost every complicated procedure including double sleeve pulmonary resection could be performed using this hybrid method. Most important, we completed almost all lobectomy by handmade maneuver (including the suture and ligation of vessels) instead of surgical instruments like stapler. This hybrid VATS lobectomy not only reduces medical cost but also improve our surgical skills which facilitate the transition of single port lobectomy from multiple ports.

Complete VATS lobectomy (after 2006)

In 2005, Dr. McKenna and colleagues (6) reported their experience of VATS lobectomy with 1,100 cases and published in *Annals of Thoracic Surgery* in 2006. Based on their description, the typical design includes (*Figure 3B*): a 10-mm incision placing trocar through the 7th or 8th intercostal space in the midaxillary line, a 1-cm auxiliary incision in the 7th intercostal space in the posterior axillary line, and a 3 to 6 cm utility incision (without using rib retractor, but wound protector) directing lateral from the vein for upper lobectomies or one intercostal space lower for middle or lower lobectomies. Strictly speaking, all procedures should be seen only through the visualization of video. The method they used became known as complete VATS (c-VATS).

Almost at the same time, we successfully performed c-VATS lobectomy, too. The first case we performed was right middle lobectomy (*Figure 4*) in October, 2005. Notably, the case involved in a very complex procedure: to manage the severely adhesive pulmonary vein safely, partial resection of pericardium was performed under c-VATS. It was inseparable from the long history of open surgery and experience accumulated in hybrid VATS for us to be able to handle such a difficult procedure. Besides, one of the unique features of our VATS lobectomies could be seen from the video, thanks to the experience accumulated by conventional thoracotomy as mentioned before, we had been used to the handmade surgical maneuver without any instruments.

Since 2006, endoscopic instruments, including instrumentation with both proximal and distal articulation, modern articulated staplers have been brought in our department. With the development of our technology, the majority of pulmonary lobectomies can be done under complete VATS. In this process, we tried consciously to transform the typical three or four ports to two ports (single utility port). That's one small step, one giant leap for techniques and concepts. For 3-port approach, not only the optical plane that requires a torsional angle, but also the cooperation and hands operation both are separated. With aspect to 2-port approach, however, both hands operation and cooperation are performed through the same one port. Through this approach, operators could practice the single port operation. One can suppose that it's the run-up for single port VATS.

Single port VATS lobectomy (after 2009)

We performed the first single port VATS in 2009. Initially, it was used for minor operations, such as pneumothorax, thymusectomy or sympathectomy. At that moment, special instruments (*Figure 5A,B*) for single port surgery designed by a Chinese company (Liuyedao, Inc., Yuyao, China) were used. However, the instruments were firstly designed for single port laparoscopic surgical procedures. Thus, it should be pointed out now that the instrument has limitations for single port pulmonary lobectomy. Because the instrument is overlong and wrist-controlled, it is not convenient for complex pulmonary surgery. Nevertheless, this process provided us valuable practice to experience single port operation.

Since 2013, without any training and operation observation, single port VATS lobectomy has been successfully developed after the reading of a series of papers by Dr. Gonzalez-Rivas, and nearly 200 single port VATS lobectomies have been performed at our department up to now. Moreover, we have developed our own unique surgical skills and process without any major intra-/ and post-operative complications. Nowadays, more than 40% lobectomies at our department can be performed using single port VATS. All types of lobectomies can be performed by us expertly, including lobectomy, bilobectomy and sleeve lobectomy. And here, we would like to present a complete single port VATS right upper lobectomy we performed (*Figure 6*). It is a complicated large tumor with diameter of 9 cm.

Just like the evolutionary process from the ape to the modern man, the progression of the approach for pulmonary lobectomy at our department is step by step from long incision to multiple small ports and eventually to the single port (*Figure 7A,B*). In our opinion, single port or uniportal technique is the final evolution stage in these minimally invasive surgical techniques. It is the theory of evolution that is reflected in minimally invasive thoracic surgery, which is bound to happen as time progressed.

Figure 4 Right middle lobectomy: the first case of c-VATS lobectomy we performed in October, 2005 (7). C-VATS, complete video assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/551

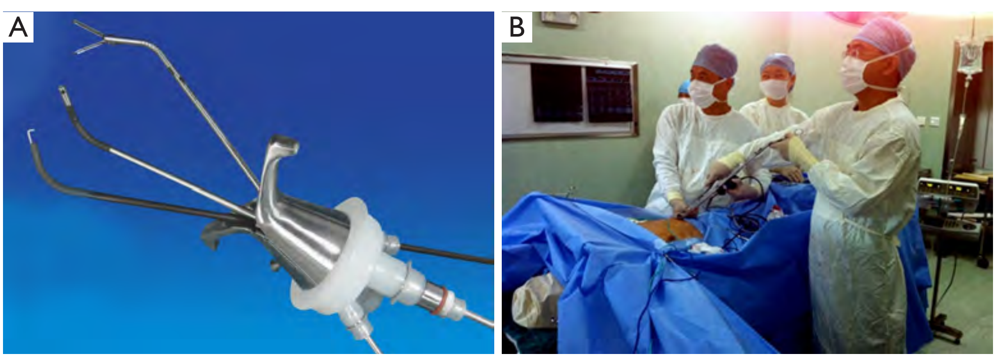

Figure 5 (A) Special instruments for single port surgery (Liuyedao, Inc., Yuyao, China), including a single hole puncture device, non-invasive grasping forcep, separating pliers and electric hook; (B) intraoperative image using the special instruments (Liuyedao, Inc., Yuyao, China).

Because the visual perspective and surgical maneuver of single port lobectomy are same with the open or hybrid VATS lobectomy, we call this evolution from open to single port as "return progression".

Our experience of single port VATS lobectomy

Theoretically, single port VATS lobectomy has its potential advantages. Firstly, instruments are parallel to thoracoscope, providing a similar angle of view as for open surgery, i.e., a sagittal, caudocranial perspective. Obviously, it contributes to flat one's learning curve from open surgery to single port VATS. Then, trocar is not needed to introduce the lens. It may reduce the postoperative pain and paresthesias mainly because of the squeezing between trocar and ribs. Recently, a study found that the pain and recovery are comparable after either uniportal or multiport video-assisted thoracoscopic lobectomy. Though the study indicated that single port VATS lobectomy is non-inferior to multiport lobectomy in the first 24 postoperative hours, it was a non-randomized and retrospective clinical trial based on only one centre. In the future, larger prospective trials are needed to address whether there is difference in the outcome of pain scores of a longer period in the postoperative course. On the other hand, however, disadvantages exist inevitably. Firstly, because of the narrow space from single port, the view of operators is obstructed, as well as their operation is restricted. These lead to bad exposure and difficulty in node dissection or stopping bleeding. Secondly, it is hard to coordinate among instruments, as well as the cooperation with thoracoscope assistant, which leading to unavoidable interference of the thoracoscope and the instrumentation. Thirdly, to some extent, single port VATS lobectomy challenges the personal habits and skills of who has already been adapted in multiport surgery.

Figure 6 Uniportal VATS right upper lobectomy (8). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/552

Currently, single port lobectomy has been reported as safe and effective, with low postoperative morbidity and mortality (9,10). Is it ready to declare that single port VATS can replace the status of multiport surgery? In our opinion, one should consider that single port VATS is not a denial of conventional VATS surgery, but a beneficial supplement. For selected cases, those with severe adhesions for an example, multiport VATS or conventional open surgery may be more effective and safe than single port surgery.

It must be pointed out again that available studies were non-randomized and retrospective because of the late arrival of single port VATS. The previous results were obtained based on weak evidence. Furthermore, with the development of single port technology and instruments, the disadvantages mentioned above should be overcome, which could be deduced from the process history of multiport

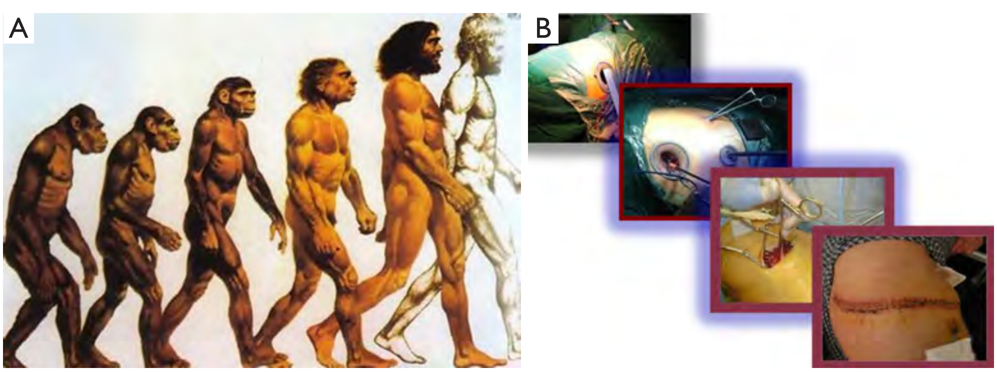

Figure 7 (A) History of human evolution; (B) evolution history of the approach for pulmonary lobectomy at our department.

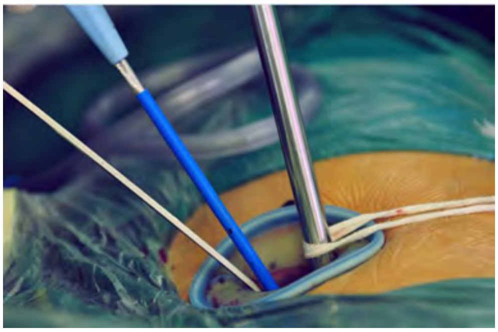

Figure 8 The general position of camera and stabilization. The lens is sticked to the upper side of incision. A string is used to eliminate camera shake.

Figure 9 The common instruments we used in single port VATS lobectomy, including ultrasound scalpel, articulated stapler, non-invasive grasping forceps, oval forceps, separating pliers, electric hook, and vascular clamp. VATS, video assisted thoracoscopic surgery.

VATS lobectomy. To explore the potential advantages of single port VATS lobectomy, a retrospective and prospective clinical study to explore the short-term effects (e.g., pain, lung function, chest tube duration, hospital stay and complications, etc.) among hybrid VATS lobectomy, complete VATS lobectomy and single port VATS lobectomy is conducted in our department now. Early results indicate that paresthesias in single port arm seem to be lower than the others, with no difference of pain and complications. We believe that similar clinical trials are ongoing around the world. However, it is more time that is needed to get results. Currently, an effective way to encourage progress is the exchange of experiences among units, which can help find our problems and promote solutions. Therefore, in this stage, summary of individual experience becomes very important. The experiences of our department in single port VATS lobectomy will be summarized as follows.

Position of camera and stabilization

Unlike traditional multiport VATS, it is unnecessary to use a trocar for the thoracoscope, which is one of the potential principles of single port VATS lobectomy to relieve pain. To ensure enough space for operation, we think, assistant should stick the lens to the upper side (the posterior part) of incision most of the time. Operator will have enough room to complete the surgical procedure in this situation. In addition, a string is used to eliminate camera shake, as well as lighten assistant's load. The classical appearance is presented in *Figure 8*.

Instruments

Nowadays, there is a set of specific adapted instruments for single port lobectomy, including the common high definition 30° thoracoscope, articulated staplers, and instruments with proximal and distal articulation. However, based on a range of practices we get from the long history of our conventional lobectomy, we are very skilled at using conventional instruments (*Figure 9*). For example, vascular clips or sutures and ligations are commonly used when handling the vessels, just like in open or hybrid VATS lobectomy. For small pulmonary lacerations, we are accustomed to choose sutures, but not staplers. For patients, more medical costs will be saved by using conventional instruments. In addition, a unique experience of us is that we use short-handled instruments widely. We think that may contribute to providing a stable triangular space, as well as avoiding inadvertent collisions.

Incision

To our knowledge, the common location of the incision for single port VATS lobectomy is 4th or 5th intercostal space in the anterior position. Gonzalez-Rivas *et al.* (11) tended to recommend the 5th intercostal space. Indeed, that provided better angles for hilar dissection and appropriate length for the insertion of staplers. Nevertheless, we use 4th intercostal space more than 5th intercostal space. The incision is about 3-5 cm long, the same size as the utility incision we use in multiport VATS technique (*Figure 10*). Though it is a little harder to insert staplers than 5th intercostal space, it is closer to the hilar. Because of the unique development history of our department as mentioned above, we are used to sutures or insert vascular clips (traditional open surgery procedures), not articulated

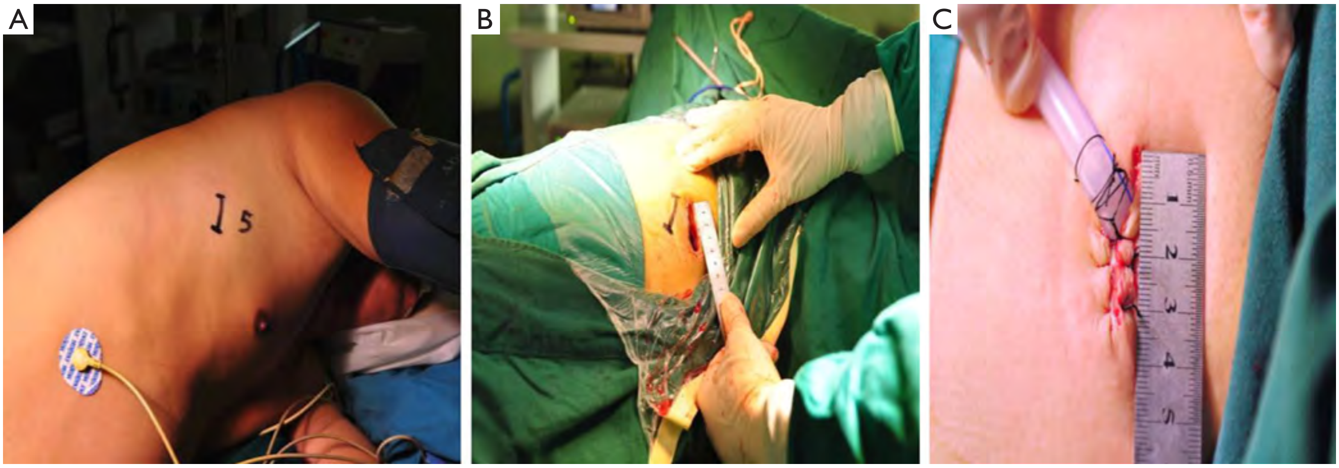

Figure 10 Location and length of the incision for single port lobectomy at our department. 4th intercostal space in the anterior position is common used, and the length is about 3-5 cm.

Figure 11 General position of operating personnel in our department for single port lung resection. Operator and the assistant who handle the thoracoscope are positioned in front of the patient. The other assistant who helps exposure the target tissue and instrument nurse are at the posterior of patient.

staplers. Moreover, in severe circumstances, operator is able to handle the accidental bleeding during surgery as soon as possible.

Position of operating personnel

In view of narrow operation space of single port surgery, a coordinated, effective positional programme is urgently needed. In general, surgical team members include three surgeons and one instrument nurse, as we can see from *Figure 11*. The operator and the assistant who handle the thoracoscope must to be positioned in front of the patient in order to have the same thoracoscopic vision and movements. And the assistant is better to stand below the operator. The other assistant who helps exposure the target tissue should be at the posterior of patient. The instrument nurse is also located at the posterior side of patient. It must be explained that the position we described above is general aspect. A competent operator will be able to make a change flexibly based on the actual situation.

Management of accidents

Operative accidents, including severe adhesion, bleeding, pulmonary laceration, etc., happened occasionally. Among them, bleeding is a common but sometimes life-threaten complication during surgery. When facing such situation, we recommend that operator should make a prompt decision to transform single port to multiport (*Figure 12*). Especially when the single port VATS lobectomy is still in developing stage around the world now, don't do something for the sake of doing it. The safety of patients is the first, technical exercises the second. The practice also applies to some other accidents. In our opinion, management of accidents represents the ability of operator. A good operator can make an appropriate decision quickly and decisively.

Single port VATS lobectomy is another innovation in the minimally invasive thoracic surgery. Different methods of painting is a good analogy for single port VATS and open lobectomy (*Figure 13A,B*). Imaging that the traditional Chinese landscape painting is the open lobectomy, while the single port VATS lobectomy be the inside-bottle painting. The process of traditional Chinese landscape painting is painting the background before details. Instead, the inside-bottle painting is painted by the accumulation of details. The two methods are mostly opposite. For this reason, single port VATS lobectomy is the new challenges of thoracic surgery. In order to deal with the single port VATS lobectomy better, operators should renew their concepts, operating skills and surgical process.

Future prospects of single port VATS lobectomy

Currently, single port VATS lobectomy has shown as an irresistible trend in the minimally invasive thoracic surgery. However, there are still many imperfect fields which need further improvement. Hence, here we will discuss a few notable future prospects based on the development situation among units and the practical experiences of ourselves.

Figure 12 Transform single port to multiport VATS to manage bleeding. VATS, video assisted thoracoscopic surgery (12).
Available online: http://www.asvide.com/articles/553

Improvement of instruments

Nowadays, though the modern instruments can be competent with single port VATS lobectomy basically, the further improvements are needed.

The first one is the articulated stapler. Recently, the use of 360° rotation of the shaft is an encouraging progress. However, the existing problem is that the stem is too thick to move flexible in single port's narrow surgery space, leading to more instrument interference and obstruction of view. Given this, a thinner stem is urgently needed with reservation of available features. According to the development of modern materials science, we believe that it is not a dream to deliver such the technology.

Another one is the high definition 30° thoracoscope. The same existing problem is the thick stem, too. Certainly, one could also design a thinner stem thoracoscope as a solution. However, some authors (13) have described a remote wireless cameras which can be 'hung' onto the inside of the chest wall or held against the inner chest cavity by a magnetic anchoring and guidance system (MAGS, *Figure 14A,B*), a way they used to facilitate laparoscopic single port surgery. To our knowledge, the main limitations now are the battery life issues (insufficient power reserve capacity for surgery) and deficiency of wireless data transmission (leading to image instability). In the near future, the development of energy science and radio science may address the problems.

Indeed, improvement of instruments will facilitate the single port VATS lobectomy well. Nevertheless, more frequently use of modern specific adapted instruments, disposable medical instruments in particular, leads to the increase of cost inevitably. As a well-established thoracic department, in most cases, we are good at using traditional instruments to complete most of the single port lobectomy procedures. Thus,

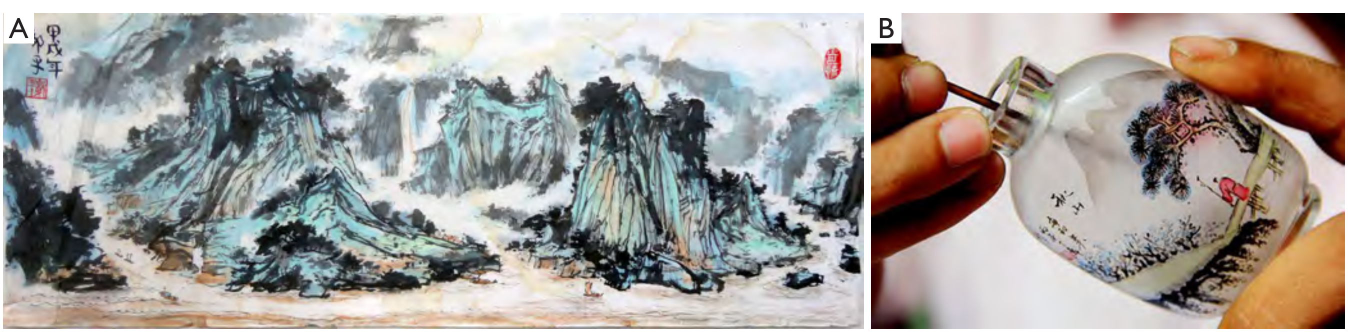

Figure 13 (A) Painting process of traditional Chinese landscape painting is painting the background before details (Available online: http://www.dfmsj.com/Sj/ShowProducts-47-121.html); (B) painting process of the inside-bottle painting (Available online: http://www.duitang.com/people/mblog/222929285/detail/).

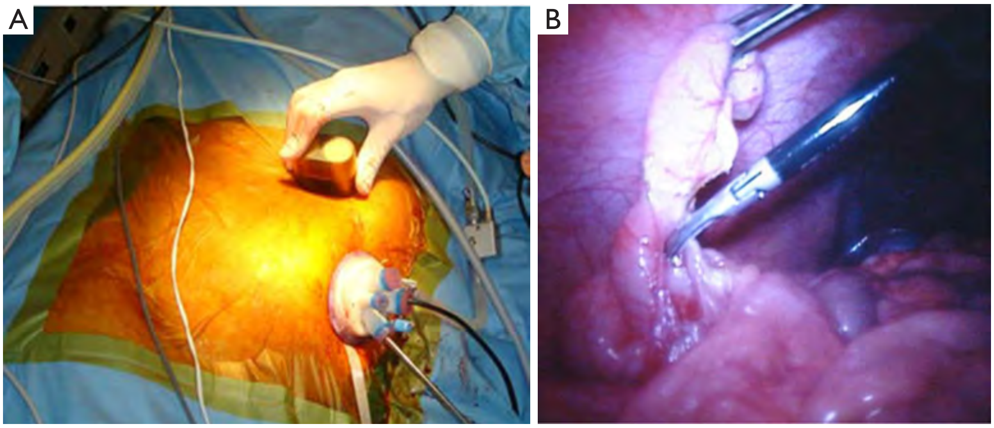

Figure 14 (A) Deployment of magnet on anterior abdominal wall during nephrectomy (13); (B) internal MAGS camera view of appendix with internal LED illumination and ultrasonic shears dividing the appendiceal mesentery (13). MAGS, magnetic anchoring and guidance system; LED, light emitting diode.

Figure 15 The robot is "outside" of the patient (Available online: http://www.mountainside-medical.com/blog/da-vinci-latest-robotic-surgery/).

our technical ability to use traditional instruments expertly in VATS lobectomy will be a beneficial complement.

Robotic single port VATS

After the advancement of VATS, the development of the surgical robot (Intuitive, Da Vinci, Inc, Sunnyvale, CA, USA) has been in the ascendant for a decade. Initially, the major applications have been for pelvic surgeries. It was not until 2006 that Park *et al.* reported their initial practice of robotic lobectomy (14). After that, previous reports (15,16) demonstrate the safety of robotic lobectomy. Nowadays, more and more thoracic units in China have introduced the robotic device and technology.

Actually, the main advantage of robotic operation is that the robotic arms cover seven degrees of freedom enabling wristed movement for surgery. However, as we can notice from *Figure 15*, the robot is 'outside' of the patient, which is similar to the operating principle of human beings. Due to the feature of current system design, it is certain that multiple ports are required. But actually, the robotic platform is designed to mimic open surgery, matching the

Figure 16 A new insertable robotic end-effectors platform (IREP, Columbia University, USA) (17). (A) The cylindrical profile with the diameter of only 15 mm before opened up; (B) the robot opens up with camera and arms when it is inserted into the thoracic cavity.

Figure 17 (A) Ultrasonography device with detail of characteristics that make the probe useful for single-access video-assisted thoracic surgery (VATS); (B,C) in particular, the articulating end contributes to refinement of lung scanning (19).

original intention of single port VATS. To perform robotic lobectomy through single port approach, a good solution is to design an inserted robotic system. The operation body, including camera, robot arms, should be inserted into the thoracic cavity through a single small incision. Fortunately, a new insertable robotic end-effectors platform (IREP, Columbia University, USA) (17) has been designed and constructed for single-port access surgery. The IREP is designed as a cylindrical profile which has the diameter of only 15 mm (*Figure 16A*). After being inserted into the thoracic cavity, the robot opens up with camera and arms (*Figure 16B*). One could realize that it is the duplicate for existing single port VATS.

Still, several problems remain in robotic lung resection (18), including: (I) the learning curve is often unclear at this stage of adoption, resulting in potential harm; (II) the robotic platform does not provide tactile feedback, leading to possible off-screen damage; (III) robotic-assisted lobectomies cost seems to be higher than thoracoscopic procedures. Due to the sustaining innovations of products and concepts, however, the robotic single port lobectomy is feasible now in theory.

Localization of small lung nodules

Currently, the precise resection for small lung nodules, especially small nodules and those with low solid component, mainly depends on the accurate preoperative localization, including CT-guide hookwire localization, methylene blue staining etc. Actually, operator could assess the accuracy of preoperative localization by touching the target tissue in multiport VATS. Though operators could apply traditional preoperative computed tomography-guided hookwire localization to single port VATS lobectomy, there is an issue that the inability to palpate the lung to identify invisible lesion because of the narrow space of single port. Thus, it is more difficulty than multiport VATS in assessing tumors though a single port.

To solve the problem above, scholars carried out various attempts. Rocco and colleagues (19) reported the use of intraoperative articulating ultrasound probe in single port VATS lung resection (*Figure 17*). It is a laparoscopic 10-mm ultrasound probe (B-K Medical, Herlev, Denmark) which can be inserted through the single port. Once the lesion is identified, it will be marked with electrocautery and then, a wedge resection can be performed. Moreover, an advanced multimodality image-guided operating room (AMIGO, *Figure 18*) was used in minimally invasive thoracic surgery in 2013 by Prof. Raphael Bueno's group at Harvard University, Brigham and Women Hospital, Boston (20). It is a good attempt that should be concerned. On one hand, preoperative hookwire localization can be performed in the same room just before operation. On the other hand, similar to the principle of percutaneous coronary intervention (PCI), a real-time on-table scan can be performed without inserting hookwire.

In our opinion, with the speedy development of productivity, science and technology, all the problems will

Figure 18 (A) Advanced multimodality image-guided operating room used to perform image-guided video-assisted thoracic surgery; (B) the adjacent control room and; (C) in this case uniportal (single-port) video-assisted thoracic lobectomy (20).

be solved appropriately in the near future. Nowadays, discovery of the clinical issues and formation of novel notions are the most important things.

Conclusions

Currently, more and more reports identify the feasibility and safety of single port VATS lobectomy. However, there is no reliable evidence to demonstrate the potential superior short and long term effects of single port approach for the reason that it is a newer technique. As accumulation of experience and many ongoing clinical trials among the units (including ours), confirmation of the advantages of single port VATS is just around the corner. Needless to say, along with the development of devices and concepts, there is no doubt that it is an exciting and intriguing future.

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Uniportal video assisted thoracoscopic lobectomy: going directly from open surgery to a single port approach

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Abstract: Uniportal video-assisted thoracoscopy (VATS) has gaining a special place in the thoracic surgery scenario; nowadays even major pulmonary resections can be performed through this approach. We hereby review our initial experience with uniportal VAT lobectomy, performed passing directly from the open approach to a single port approach. We attempted 26 lobectomies through VATS with a single incision of about 5 cm and 22 of them were completed: eight left lower lobectomies, six right upper lobectomies, five left upper lobectomies and three right lower lobectomies. At pathological staging all but four patients were stage I; three patients were $T_2N_1M_0$ and one had a micrometastasis in a lymph node of station 7 ($T_1N_2M_0$—Stage IIIA) and they all underwent adjuvant chemotherapy. No perioperative mortality was observed. One patient had a myocardial infarction in the first postoperative day requiring placement of four stents and another one required thoracentesis after drainage removal. The mean time for drainage removal was 3 days and the length of hospitalization was 4.2±1.1. Pain as measured by the visual analogical scale (VAS) scale was graded as 4.9, 2.6 and 0.5 during the first postoperative day, at discharge and after 1 month respectively.

Keywords: Uniportal thoracoscopy; single port thoracoscopy; pulmonary lobectomy; lung resection; video-assisted thoracoscopy (VATS); lung cancer

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During the last three decades video-assisted thoracoscopy (VATS) has completely changed the approach to surgical treatment of thoracic disorders. This procedure has been increasingly proposed to perform procedures with increasing technical complexity: from sympathectomy to major lung resections, including bronchial sleeve resections (1) with a technique almost identical to that used in open surgery (2). The increasing complexity of the surgical procedures performed with this minimally invasive approach has been accompanied by the reduction in the number of incisions (ports), from three to two to a single one (3). Also lung resections can now be performed with a single port video assisted approach, even in awake patients (4) and complete ambulatory setting. However, it was only recently that a robust series of patients undergoing major lung resection (lobectomy and pneumonectomy) was published showing encouraging results (5,6). This approach, although technically demanding, has completely changed our minimally invasive view. In terms of accuracy, efficacy and safety the uniportal approach is certainly comparable to the standard multiple port VATS, but the geometric configuration of the approach is completely different (7). The use of a single port favors a translational approach of VATS instruments along a sagittal plane; it enables the instruments to move in the direction of two parallel lines on that plane and approach the target lesion from a cranio-caudal perspective. This allows bringing the operative fulcrum inside the chest, in a fashion similar to open surgery (7). These geometrical and ergonomic advantages are accompanied by the obvious reduction of surgical trauma with a single port incision of 4-5 cm, and the consequent reduction of postoperative pain.

We hereby review our initial experience with uniportal VAT lobectomy, performed passing directly from the open approach to a single port approach.

Patients and Methods

From December 2012 to February 2014 we performed 26 lobectomies through VATS with a single incision of about 5 cm without rib spreading (with the exception of first two patients, when we used an Alexis retractor) in patients with lung cancer. Only patients with clinical stage I or II lung cancer were considered for this minimally invasive approach. The incision was made anteriorly, at the level of the 5th intercostal space. Complete mediastinal lymphadenectomy was performed removing all the accessible lymph node stations as for the open procedure. Preoperative workup included routine blood tests, cardiac assessment, pulmonary function tests, arterial blood gas analysis, chest X-ray and total body computed tomography (CT) scan. In patients scheduled for a video-assisted approach, the completeness of fissures was carefully evaluated at CT scan, although its radiological absence was not considered a contraindication. Sixteen patients were women (61.5%) and ten were men (38.5%); the mean age was 63.4±12 years (range, 39-76 years). Fifteen patients (58%) were active or former smokers and six (23%) had a previous history of cancer (breast and bowel) treated with surgery and adjuvant chemotherapy. Eight patients (30%) presented an increased cardiovascular risk (previous myocardial infarction, arrhythmia, high blood pressure). In the majority of cases (22/26, 85%) a preoperative diagnosis of lung cancer was obtained with fine needle CT guided biopsy or fiberoptic bronchoscopy; in the other four patients (15%) intraoperative frozen sections were obtained to confirm diagnosis before performing lobectomy. The telescope was a 30 degrees 10-mm high definition scope. In all patients complete mediastinal lymph node dissection was performed after the lobectomy. At the end of the procedure the wound was infiltrated with naropine and lidocaine and postoperative analgesia was administered with an elastomeric pump loaded with morphine. Postoperative pain was assessed using the visual analogical scale (VAS) based on colorimetric graduation administered to patients during the first and third postoperative day, at discharge and after 1 month.

Results

No perioperative mortality was observed. In four patients (15.3%), we were unable to complete the operation with the uniportal approach: in two cases conversion to thoracotomy was required because of bleeding from the Boyden artery during right upper lobectomy and in another patient for a massive hemothorax due to a subclavian artery injury related to central vein catheter misplacement during induction of anesthesia; in another patient undergoing right lower lobectomy the procedure was converted in a 2-port approach because of widespread pleural adhesions. We completed eight left lower lobectomies, six right upper lobectomies, five left upper lobectomies and three right lower lobectomies. Adenocarcinoma was the most frequent histologic type (67%). At pathological staging all but four patients were stage I; three patients were $T_2N_1M_0$ and one had a micrometastasis in a lymph node of station 7 ($T_1N_2M_0$—stage IIIA) and they all underwent adjuvant chemotherapy. The operatory time was 160.7±39 minutes (range, 110-220 minutes). One patient had a myocardial infarction in the first postoperative day requiring placement of four stents and another one required thoracentesis after drainage removal. The mean time for drainage removal was 3 days and the length of hospitalization was 4.2±1.1. Pain as measured by the VAS scale was graded as 4.9, 2.6 and 0.5 during the first postoperative day, at discharge and after 1 month respectively.

Discussion

Since video-assisted thoracoscopic lobectomy (VATS) was first reported in 1993 (8,9), many advances in minimally invasive surgery have been proposed. The instrumentation and technology completely changed; now we have dedicated surgical instruments specifically designed for thoracoscopy. The numbers of ports have been progressively reduced, and after Rocco published his report on uniportal VATS, there was a rise of interest for single port VATS lobectomy. There are certainly some advantages with this approach; particularly, since only one intercostal space is involved, some authors reported a decrease in postoperative pain when minor procedures are performed (10); this might speed recovery and return to work. However, no such data are yet available for the lobectomy population of patients. On the other hand, it has been clearly demonstrated that pulmonary lobectomy is feasible and is safe when performed through a single port approach, even in patients with incomplete fissures (11); also complete mediastinal lymph node dissection can be performed in the same way it is done through an open approach or through multiple port VATS. However, long-term survival data in patients undergoing pulmonary lobectomy are still lacking. Also more complex procedures like pneumonectomy (12) and bronchial sleeve resections (1) have been reported and are technically feasible with the uniportal approach.

From the technical point of view the use of thoracoscopic linear staplers certainly helps to section the vessels, although in some situations other solutions need to be adopted; particularly, we have found useful the use of a TA vascular stapler to close the upper pulmonary vein when there are technical difficulties to do it with the linear one (13). Also the use of self-locking clips (14) and energy delivering devices helps to speed the procedure.

The single port approach has been thoroughly studied also from the geometrical point of view (7), and striking differences have been found when compared to the standard three port VATS. In fact, the geometric configuration of the latter approach generates interference with the optical source, the telescope; this creates a plane with a torsion angle unfavorable on the flat 2-dimensional vision that we currently have. On the other hand, the uniportal approach allows a translational approach of instruments along a sagittal plane. As a consequence, this enables VATS instruments to draw two parallel lines on that plane, bringing them to approach the target (the lesion to be resected) from a caudo-cranial perspective achieving a projective plane. This allows the surgeon to bring the operative fulcrum inside the chest to reach the lesion in a way more similar to open surgery (7).

Our initial experience confirms the feasibility and safety of this approach. The converted cases were all within the first 10 procedures and since then no other conversion to open surgery occurred. There is certainly a learning curve that might be a little longer if the operating surgeon and his team move straightforward from open surgery to the uniportal approach, without progressively reducing the number of incision. However, if the uniportal approach has been previously considered and used for minor procedures and lesser resections (sympathectomy, surgery for pneumothorax, wedge resections) the learning curve would be certainly shorter. Training at centers with major experience might be crucial to speed the process.

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From open surgery to uniportal VATS: asturias experience

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Objective: Uniportal video-assisted thoracic surgery (VATS) resections are of increasing interest in many thoracic surgery departments. This study shows our initial experience in uniportal VATS anatomical resections in direct transition from posterolateral thoracotomy.

Patients and methods: We retrospectively reviewed the 82 files of patients on whom anatomical pulmonary resection via uniportal VATS was attempted in our department by a single surgeon experienced in VATS for almost all purposes except major pulmonary resections. Demographic data of patients, smoking habits, chronic obstructive pulmonary disease (COPD), presence of cardiopulmonary comorbidities, general characteristics of pulmonary lesions, preoperative FEV1, intraoperative findings, operative time, postoperative-drain-time, hospital-stay-time, successfully completed or converted to thoracotomy, intraoperative and postoperative complications and 30-day mortality were recorded. The patients were chronologically divided into two groups for analysis (A: operated on in the first year; B: operated on after the first year). We compare our results with the largest published experience in anatomical resections by uniportal VATS started from multiport technique and anterior thoracotomy in order to identify the feasibility of this transition.

Results: From January 2012 to January 2014, 82 uniportal VATS anatomical pulmonary resections were attempted. Of these 82 resections attempted, 74 (90.2%) were completely carried out. The median drain-time and hospital-stay-time were 3 days, and 4 days for the first year of experience and 2 and 3 days for the second year of experience respectively. The most frequent intraoperative complication was bleeding in 10 (12.1%), of these 8 occurred in the first year of experience (group A). In 8 (9.75%) cases conversion to thoracotomy widening the incision was needed for different reasons, of these 6 occurred in group A. The most frequent minor complication was chest tube reinsertion in 12 (14.6%) patients. There were no major complications or mortality in the first year of experience (group A). Two cases of mortality in the 8^{th} and 15^{th} postoperative day respectively occurred in group B in two patients with serious comorbidities.

Conclusions: Uniportal VATS for anatomical resections is a feasible and safe technique with good results even if experience is started in direct transition from open surgery, on condition that general recommendations for an initial VATS program were observed. Specific training courses with experts are also necessary. Patient selection is crucial. The number of procedures necessary to obtain appropriate experience may be similar to those reported for transition from open surgery to multiport technique.

Keywords: Video-assisted thoracic surgery (VATS); minimally invasive pulmonary resection; lung resection; non-small-cell lung cancer (NSCLC)

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Introduction

Single port major pulmonary resections are very popular worldwide and interest is growing in many thoracic surgery departments. It probably represents a less invasive approach to operate non-small cell lung cancer.

It has been proven to be a feasible and safe procedure when performed by surgeons experienced with double-port technique and anterior thoracotomy (1,2) but there is no evidence whether it is possible to perform a direct transition from posterolateral thoracotomy to the single port with as satisfactory postoperative results as with the transition from multiport technique.

In January 2012 a uniportal video-assisted thoracic surgery (VATS) program for major pulmonary resections was started at the Asturias University Central Hospital. This article presents the results of our learning curve period for uniportal VATS anatomical resections in a direct transition from open surgery to single-port. The focus of this study was to analyze and compare the results of our initial experience in direct transition from open surgery to uniportal VATS with the reference data from the results of the published best initial experience in the transition from multiport technique to uniportal VATS (3) in order to identify the feasibility and safety of this transition.

Patients and methods

We retrospectively reviewed the files of patients on whom anatomical pulmonary resection via uniportal VATS was attempted between January 2012 and January 2014 in the Department of Thoracic Surgery of Asturias University Central Hospital by the unique surgeon with VATS experience in the department, assisted by residents of thoracic surgery (4). The approval for this study was provided by the institutional ethical review board of the said hospital, and all patients provided written informed consent before operation.

Variables

We recorded: demographic data of patients, smoking habits, chronic obstructive pulmonary disease (COPD), presence of cardiopulmonary comorbidities, general characteristics of pulmonary lesions, preoperative FEV1, intraoperative findings, operative time, postoperative-drain-time, hospital-stay-time, successfully completed or converted to thoracotomy, intraoperative and postoperative complications and 30-day mortality.

The preoperative assessment according to the protocol of the tumor board routinely included: blood test, bronchoscopy, thoracic computed tomography (CT), and pulmonary function performed by spirometry or additional functional test in high-risk patients. PET-CT was made in cases of N2 suggested by CT. We made two groups of patients for analysis: A—patients operated on in the first year of experience (January 2012 to December 2012), and B—patients operated on in the second part of experience (January 2013 to January 2014).

As reference data, we select the results published in the largest case-series in uniportal VATS major resection (3).

Selection criteria

The indication criteria for uniportal VATS approach were the same as for open surgery except for lesions affecting chest wall or impossibility to extract without rib spreading.

Surgical technique

The patients were positioned in lateral decubitus as for posterolateral thoracotomy. The lung blockade was obtained using a double lumen tube and continuous suction is applied to the non ventilated bronchus. A 4-5 cm incision was made in the 5th intercostal space. Rib retractor was not used in any case. A wound protector is used in some particular patients. A 10 mm/30° camera was used for vision. Some specific Scanlan instruments (ref 9009-738SC, 9009-828, 9009-240, 9909-225, 9909-227, 9909-920, 9909-203) was used in combination with standard VATS instruments.

Following specific technical recommendations for uniportal VATS, the hilar vessels and bronchus were dissected and transected in a particular order using stapler devices (ECHELON FLEX™) and clips (Hem-o-lok®). Fissureless technique was applied if absent or uncompleted fissures were found. No section of pulmonary ligament was made in any case. A special bag was used for the extraction of the resected lobe. Mediastinal lymph nodes were dissected completely. The intercostal spaces were infiltrated with bupivacaine in all cases. A 24F chest tube was positioned through the incision in the upper part of the pleural space.

Statistical analysis

All the data are reported as mean, median or frequencies, with associated interquartile ranges (IQR), 95% confidence intervals (CI), and P values calculated. Categorical data, both nominal and ordinal, were compared between groups using Fisher's χ^2 (exact) test. A probability value of less than 0.05 was considered to be statistically significant. SPSS, version 20.0 (IBM Corp) was used for the statistical analysis.

Results

From January 2012 to January 2014, 82 uniportal VATS

Table 1 Surgical time during learning curve

Surgical time	Group A (min)	Group B (min)	Reference data (1) (min)
Highest	366	300	360
Lowest	60	60	60
Mean	211	150	154

anatomical pulmonary resections were attempted in the department of thoracic surgery by a single surgeon. In the first part of the experience (January 2012-Dec 2012) 40 resections were attempted, of them 36 (90%) were completed by uniportal VATS. In the second part of experience (January 2013-January 2014) 42 resections were attempted and 40 (95.2%) were completed. Therefore, of the 82 resections attempted, 74 (90.2%) were completely carried out including: left upper lobectomy in 21 patients, left lower lobectomy in 18 patients, right upper lobectomy in 18 patients, middle lobectomy in 2 patients, right lower lobectomy in 12 patients, lingulectomy in 1 patient, middle & lower bilobectomy in 1 patient, and pneumonectomy in 1 patient.

The general characteristics in two groups were similar: the mean age was 61±14 for group A and 62±12 for group B. Mean FEV1 was 87±19 for group A and 85±19 for group B.

Of 82 patients, 76 (92.6%) were selected for resection because of a diagnosis of non-small lung cancer.

One third of patients could be considered to be relatively complex case for an initial program of VATS because of: strong pleural adhesion in 25 (30.4%) cases, silicoanthracotic adherent lymph nodes in 26 (31.7%) cases, incomplete or fused fissures in 26 (31.7%) cases, pneumoconiosis in 16 (19.5%) cases, tumor size larger than ≥5 cm in 10 (12.1%) cases, preoperative global FEV1 less than 50% in 4 (4.8%) cases.

The mean surgical time during the learning curve was 211 min for group A and 150 min for group B (*Table 1*).

The median drain-time and hospital-stay-time were 3 and 4 days for the first year of experience, 2 and 3 days for the second year of experience respectively. In the multivariable analysis we identify pneumoconiosis and level of training as significant factors for higher operative and postoperative time.

Comparisons between multiple variables with drain-time and hospital-stay-time are described in *Table 2*.

The most frequent intraoperative complication was bleeding in 10 (12.1%) patients (*Table 3*) but only 2 patients of group B had this complication. Conversion was required in 6 patients of group A and 2 patients of group B. Of the 82 patients 23 (28%) had some minor postoperative complication. Of these, chest tube reinsertion was the most frequently observed in ten patients of group A but only two patients of group B because a decreased incidence of postoperative residual pleural effusion (*Table 4*). There were 3 (3.65%) major complications, all of them in group B. In this group there were two perioperative deaths: (I) a right upper bilobectomy for a 5 cm long tumor in a 76-year-old man with preoperative FEV1 of 42% because of a pneumoconiosis with massive pulmonary fibrosis (the poorest pulmonary function in this study population) who died of respiratory failure on the 12th postoperative day. This patient was one of the four conversions to thoracotomy because of technical difficulties. (II) a left upper lobectomy in a 76-year-old man with high cardiovascular risk because of a triple coronary bypass, and previous right upper lobectomy with simultaneous left upper lobe wedge resection with adjuvant chemotherapy and radiotherapy treatment for synchronous lung cancer, with limited pulmonary function (preoperative FEV1: 70%) who died the day he was discharged from hospital after an optimal recovery because of a neurologic cause on the 8th postoperative day.

Relations between multiple variables with complications are outlined in *Table 5*.

Discussion

Single-port major pulmonary resections are very popular worldwide and interest is growing in many thoracic surgery departments. It probably represents a less invasive approach to operate on non-small cell lung cancer.

This technique has been proved to be a feasible and safe procedure when performed by surgeons experienced with double-port technique and anterior thoracotomy (1-3) but probably that particular experience is not really necessary to start a uniportal VATS program. We have hypothesized that a uniportal VATS program for major resections could be started with similar recommendations published by Petersen for a multiport VATS program (5,6): 1—large experience in open lobectomy; 2—experience in performing more than 100 minor VATS procedures; 3—attendance at formal courses in VATS lobectomy; 4—selection of the patients; 5—introduction of the element of resection step-by-step; and 6—making a prospective data collection.

A uniportal VATS program was implemented at Asturias

Table 2 Comparison between multiple variable and time

Features of resections	Operative time; median (range)	Drain time; median (range)	Stay time; median (range)
Type of resection			
Upper	196±60.21	4.92±4.4	4.71±4.5
Lower	171.29±60.23	4.03±2.6	4.75±6.8
	P=0.083	P=0.353	P=0.287
Side			
Right	182±56.41	3.95±2.5	4.03±5.53
Left	191±71.28	4.95±4.2	5.35±5.91
	P=0.59	P=0.192	P=0.071
Strong adhesions			
No	207.64±70.28	4.39±3.88	4.63±5.26
Yes	178±60.23	4.68±2.75	4.96±5.26
	P=0.168	P=0.911	P=0.195
Incomplete fissure			
No	185±46.3	3±7.4	3±4.2
Yes	206±84	3±3.2	4±1.5
	P=0.306	P=0.862	P=0.884
Pneumoconiosis			
No	184.40±63.65	4.13±3.6	4.72±6.2
Yes	195.76±67.80	5.48±3.14	4.76±3.85
	P=0.673	P<0.05	P<0.05
Adherent adenopathies			
No	180.39±63.68	4.24±3.63	4.69±6.18
Yes	210.05±63.60	5.26±3.26	4.84±4.1
	P=0.093	P=0.164	P=0.095
Level of training			
First year	213±61.03	5.25±7	6.50±7.6
Second year	161±57.49	3.73±2.5	3±18
	P<0.05	P<0.05	P<0.05

Table 3 Intraoperative complications

Intraoperative complications	Group A (N=40)	Group B (N=42)
Bleeding	8 (20%)	2 (4.7%)
Required conversion	5	1
No required conversion	3	1
Suture failure	6 (15%)	1 (2.3%)
Bronchial	2	0
Vascular	4	1
Surgeon error	3 (7.5%)	0 (0%)
Involuntary bronchial section	2	0
Involuntary arterial section	1	0
Insuperable technical difficulties	3 (7.5%)	1 (2.3%)
Conversions to thoracotomy	6 (15%)	2 (4.7%)

University Central Hospital, in a direct transition from posterolateral thoracotomy by a single surgeon very experienced in posterolateral but not in anterior approach for open lung resections.

The analysis of data shows several differences between group A and B in terms of surgical time, postoperative drain time, hospital-stay-time, minor and major complications. Indeed, mean surgical time was reduced after the 40 first cases (group B) by 61 min. In a similar way, the median of postoperative drain time and hospital stay time was reduced by 1 day. Therefore, group B had similar postoperative outcomes to patients in the reference studies in those particular items. Minor complications in group B were also similar to the reference study except for a small increase rate in patients requiring reinsertion of chest tube (5%/3.2%).

Table 4 Postoperative complications in VATS completed resections

Postoperative complications	Group A (N=34 patients) (%)	Group B (N=40 patients) (%)	Reference data (1) (N=97 patients) (%)
Minor complications			
Reinsertion of chest tube	29.4	5	3.2
Wound infection	11.7	0	2.1
Prolonged air leak (>5 d)	14.7	7.5	8.6
Rehospitalization	14.7	2.5	No referred
Major complications			
Respiratory failure	0	2.5	0
Reoperation	0	0	2.1
Mortality (30 d)	0	5	0

Table 5 Comparison between multiple variables and complications

Features of resections	Complications (%)	P
Level of training		
1st year	14 (73.69)	P=0.005
2nd year	5 (26.31)	
Sex		
Male	14 (73.68)	P=0.148
Female	5 (26.32)	
Smoker		
Yes	13 (22.73)	P=0.910
No	6 (26.7)	
COPD		
Yes	11 (57.9)	P=0.005
No	8 (42.10)	
Hard adhesions		
Yes	14 (73.68)	P=0.64
No	5 (26.31)	
Cardiovascular disease		
Yes	12 (63.16)	P<0.23
No	7 (36.84)	

Major complications were found in 3.6% of patients but only in group B including two cases of 30 d-mortality in this group. In our study we included a considerable amount of relatively complex cases for initial VATS program. We found this reason responsible for increased rates of complications in both groups. Additionally, in the multivariable analysis, we found COPD and the level of training as the only significant factors for complications (P=0.05).

The results of the second part of our experience are in concordance to results of others authors and reference data except for 30 d-mortality (*Table 6*). However we found these deaths associated with an inadequate selection decision more than with a technique-related cause, because of an overestimation of the benefits of the technique in these patients. As a result, we consider that patient selection is crucial to prevent complications.

From the results of group B of patients we may consider that our learning curve from open surgery to uniportal VATS has required 40 resections. This is very similar to that reported for multiport technique (5,6). In this period of time we had no major complications and a very assumable rate of minor complications, so we found this transition feasible, safe and concordant with the transition from open surgery to multiport technique if patients are properly selected.

Our study has several limitations. Indeed, this is a small, retrospective and descriptive study of a single-surgeon's practice. Reference data used for comparison include the global results of the two first years of experience. This can lead to underestimate the particular results of the second year of experience in comparison with our group B of patients.

Conclusions

Direct transition from open surgery to uniportal VATS for major pulmonary resections has been in our experience feasible and safe with good results. We founded this approach may be closer to conventional operation technique as compared to traditional thoracoscopic technique. It is probably important that the surgeon has to be very experienced in open resections and has completed more than 100 minor VATS procedures. Specific training courses

Table 6 Literature review

Author (reference)	N	Conversion rate (%)	NSCLC (%)	No. of incision	Length stay (days); mean/median	Morbility (%)	Mortality (%)
McKenna *et al.* (7)	1,100	2.5	92	3	4.8/3	15	0.8
Yim *et al.* (8)	214	0.9	79	2	6.8/NR	22	0.5
Roviaro *et al.* (9)	171	5.3	83	4	NR/NR	8.7	0.6
Walker *et al.* (10)	159	11.2	100	4	NR/6	NR	1.8
Swanson *et al.* (11)	128	13	N/R	2-4	3/NR	NR	NR
Solaini *et al.* (12)	105	5.7	95	4	6.2/NR	2.3	NR
Gonzalez-Rivas *et al.* (3)	102	2.94	74.50	Single port	NR/3	NR	0
Sugi *et al.* (13)	50	4	96	4	NR/NR	NR	NR

NR, not reported.

with experts and proper patient selection process are also necessary. The number of procedures necessary to obtain appropriate experience may be similar to those reported for transition from open surgery to multiport technique. It is recommendable to be conscious that conversion to thoracotomy at the correct time during learning curve indicates prudence not failure. Until there are other similar experiences, our results should be interpreted with caution.

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Uniportal VATS: the first German experience

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Background: The acceptance of uniportal video-assisted thoracic surgery (VATS) for minor and major thoracic procedures is growing in Europe. This study presents the first experience with uniportal VATS in Germany.

Methods: In a retrospective study of prospectively collected data, 56 uniportal VATS were analyzed between 06/2012 and 06/2014. The technique was used for diagnostic aims, pleurectomies, wedge resections, segmentectomies and major resections. All procedures were performed without rib spreading. Patients' demographic data, preoperative and postoperative management as well as results were analyzed.

Results: A total of 42 patients (75%) were males. The mean age was 59.2±15 years. The uniportal VATS procedures included one or multiple wedge resections in 30 cases (53.6%), major resections in 9 cases (16.1%), anatomical segment resections in 6 cases (10.7%) and other indications in 11 cases (19.6%). The median operation time was 252, 114, 88 and 73 minutes for major resections, anatomical segment resections, wedge resections and other indications, respectively. There were three conversions in two cases of major resections and in one anatomical segmentectomy. The mean chest tube duration was 3.4±2.1 days. The mean hospital stay was 8.3±5.3 days for the whole group.

Conclusions: Uniportal VATS is a feasible and safe technique for various indications in thoracic surgery. The perioperative results are promising. It can be performed by thoracic surgeons experienced in the postero-lateral thoracotomy approach.

Keywords: Video-assisted thoracic surgery (VATS); uniportal VATS; single-port thoracic surgery; minimally invasive thoracic surgery

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Introduction

The development of video-assisted thoracic surgery (VATS) over the past two decades has led to a significant shift in the management of an increasing number of thoracic pathologies. The procedure gained acceptance due to its clinical benefits in comparison to the conventional thoracic procedures, this is true too for the economic context (1-6). VATS is associated with less pain, decreased general complications and shorter hospital stay (7,8). VATS reduces surgical trauma and maintains the oncological principles of traditional open procedures (9). VATS leads to a fast postoperative recovery which allows the earlier administration of adjuvant therapy when necessary (10-13). A further development of the 2-3 trocar VATS with a utility incision for major lung resections is the uniportal VATS. The first description of this technique took place in 1998 and concerned a series of six patients, five wedge resections and one foreign bodies removal (14). This paved the way for the development of more complex uniportal procedures for a range of thoracic and mediastinal pathologies. This first progress of uniportal VATS was mainly pioneered by

Table 1 Demographic date of the patients

Variable	No. of patients (%)
Age (years)	59.2±15
Sex	
Male	42 (75.0)
Female	14 (25.0)
Comorbidity	
Diabetes mellitus	5 (8.9)
COPD	12 (21.4)
TBC/aspergilloma	4 (7.1)
Lung fibrosis	3 (5.3)
Pulmonary hypertension	6 (10.7)
Cardiac disease	26 (46.4)
Renal dysfunction	11 (19.6)
Liver cirrhosis	3 (5.3)
Other cancer	37 (66.1)
Previous chemotherapy/radiotherapy	15 (26.8)

Prof. Gaetano Rocco from the National Cancer Institute, Naples, Italy. Between 2003 and 2006, uniportal VATS was performed for pleural effusion, pleurodesis, pleural and mediastinal biopsies, lung wedge resections, and mediastinal pathologies (15-17) A milestone was the first report on a major lung resection with radical lymphadenectomy for non-small cell lung cancer (NSCLC), by Dr. Gonzalez-Rivas from Coruña University Hospital in Spain (18), followed by complex uniportal VATS lung resections including pneumonectomy, segmentectomy, bronchoplastic procedures and chest wall resection (18-21). The latest development was a lobectomy in a non-intubated patient by uniportal VATS (22). The implementation of uniportal technique into the clinical practice is spreading globally. Especially, a strong trend in research and practice of uniportal VATS is ongoing in Asia (23). The initial clinical outcomes and short-term results are encouraging, and more long term data is awaited (23,24).

The purpose of this study was to critically analyze the first preliminary experience on uniportal VATS in Germany, in order to contextualize it internationally and understand its benefits and disadvantages.

Patients and methods

Between June 2012 and June 2014, a retrospective study from prospectively collected data was performed for patients undergoing a uniportal VATS procedure. 56 Patients were included in this study. The demographic data of the patients are present in *Table 1*. The first operations were performed together with Dr. Gonzalez-Rivas. This study was approved by the review board at the Charité - Universitätsmedizin Berlin and Charité Kompetenzzentrum für Thoraxchirurgie, and all patients provided written informed consent before operation. The main endpoint of this study was the feasibility of this technique for thoracic surgeons mainly performing a postero-lateral thoracotomy approach for major lung resections but experienced in minor VATS procedures. The outcome of uniportal VATS in terms of morbidity, 30 days mortality, conversion rate, operative time and hospital stay was studied.

Surgical technique

The patients were placed in a right or left sided position as for the postero-lateral thoracotomy but with modification of the arms' position (*Figure 1A*). All procedures were performed under general anesthesia with single lung ventilation. The 3-5 cm single incision was placed in the 5^{th} intercostal space. There was no rib spreading used. The 5 mm or 10 mm 30° scope camera was introduced in the upper part of the incision (*Figure 1B*). Nodule identification was performed through digital palpation under camera view in all cases where it was necessary. The incision allowed the introduction of more than two instruments beside the scope simultaneously. No additional skin incisions were made for any purpose such as placement of thoracoscope, graspers, or drains. A complete radical lymphadenectomy was performed in all patients with NSCLC. The surgeon and his assistant stand both in front of the patient. All tumor specimens were removed with an Endobag. At the end of the operation, one 24 or 20 Fr chest tube was inserted in the posterior part of the incision and was sutured to the anterior and posterior margins of the uniportal skin incision (*Figure 1C*). No additional incisions were made for the chest tube placement.

Postoperative management

The postoperative management applied an established Fast-Track concept of the thoracic surgery department. Most of the patients were admitted to an intermediate care unit and later on the same day to the normal ward. The mobilization and physiotherapy of the patients began on the operation day. Some of the patients received an epidural catheter while

Figure 1 The uniportal VATS technique: (A) patient positioning; (B) the incision placed in the 5th intercostal space, and the scope in the upper part of the incision; (C) chest tube inserted in the same incision at the posterior part.

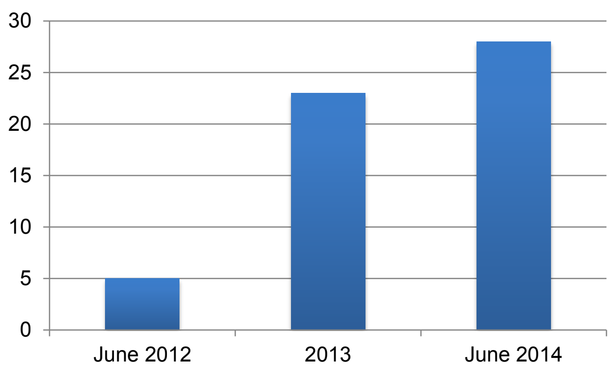

Figure 2 Development of the uniportal VATS at the Charité - Universitätsmedizin Berlin.

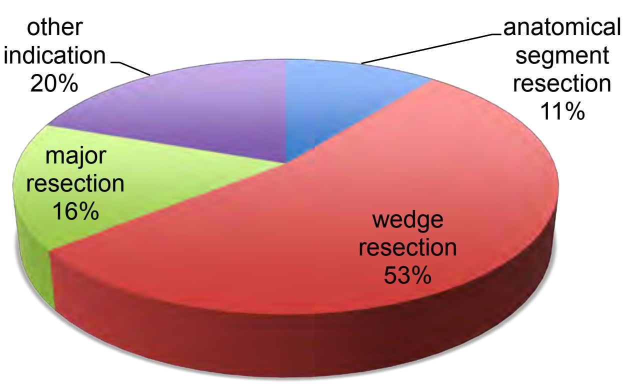

Figure 3 Spectrum of the uniportal VATS.

the others received an opiate pain medication. Thoracic X-ray was performed on the operation day and on the first postoperative day. The thoracic drainage was removed without clamping with normal X-ray findings, nor air leak and secretion below 200 mL within 24 hours. No patient was discharged with a chest tube *in situ*.

Statistical analysis

Parametric data are presented as mean values. SPSS v19 (SPSS Inc, Chicago, IL, USA) software was used and the significance level for all analyses was set at a P value of less than 0.05.

Results

Spectrum of the uniportal VATS

The uniportal VATS was introduced in the Charité department of thoracic surgery in June 2012 together with Dr. Gonzalez-Rivas. Until June 2014, there were 56 uniportal VAT procedures performed for different indications (*Figure 2*). There were 42 (75%) males and the mean age was 59.2±15 years. The 1 (41.1%), 2 (7.1%) and 3 (5.4%) wedge resections were the main procedures, being performed in 30 patients (53.6%). The 9 (16.1%) major lung resections included, 1 lower bilobectomy, 3 right upper, 4 right lower and 1 middle lobectomy. There were 6 (10.7%) anatomical one or more segment resections. The 11 (19.6%) other procedures included mainly pleurectomies, biopsies and lymphadenectomies (*Figure 3*). There were two conversions, in two cases of major resections. In one case the patient had a history of tuberculosis and there was a complete thoracic and mediastinal adhesion. In the other case, the lung resection was performed in a uniportal VATS technique but the lymphadenectomy was performed through a thoracotomy. In one anatomical segmentectomy the incision was enlarged, and a 12-cm thoracotomy with rib spreading was performed.

Operation time

The operation time was calculated from skin incision until wound closure. The operation time included also the time which was necessary for the frozen sections for histological

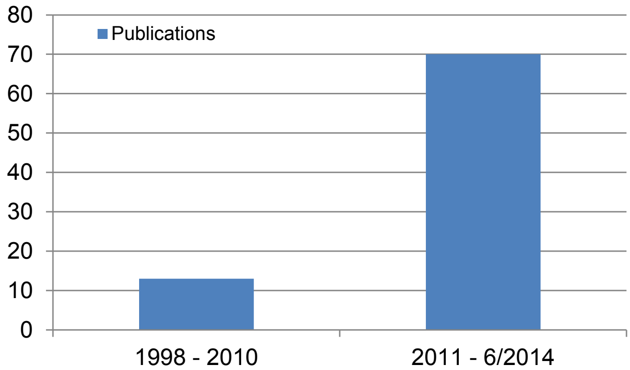

Figure 4 Literature growth of the uniportal VATS.

examination. The median operation time for major lung resections, anatomical segment resections, wedge resections and others was 252, 114, 88 and 73 minutes, respectively.

Histology

In 14 (25%) of the patients, the histological finding was NSCLC. The other histological findings included different lung metastases, aspergillum, or no malignancy in 19 (33.9%), 2 (3.6%) and 21 (37.5%) of the patients, respectively. All tumors were completely resected (R0).

Perioperative morbidity and mortality

There were three revisions due to postoperative hemothorax. In two of these patients, a wedge resection was performed after adhesiolysis, and one of them was suffering from Child B liver cirrhosis while the other had previous heart transplantation and was under anti-coagulation due to lung artery embolism. The third patient had a severe pulmonary hypertonia and underwent a pleurectomy with adhesiolysis. In two patients, a postoperative pneumonia was noticed and successfully treated. One patient developed a pneumothorax after removal of the chest tube. In this patient, placement of a new thoracic drainage was necessary. Non-surgery related mortality was recorded on the 18th postoperative day by a patient who suffered from severe cardiac disease with preoperative ejection fraction of 10-15%.

Postoperative management

The thoracic drainage was removed with a secretion volume below 200 mL. The chest tube was removed after a mean of 3.4±2.1 days. Two postoperative lung fistulas were successfully treated conservatively. The mean hospital stay was 8.3±5.3 days.

Discussion

Uniportal VATS is becoming accepted worldwide for minor and major procedures to treat thoracic and mediastinal pathologies (23,24). The initial results are promising and the technical feasibility has been shown (24) To date, there are no results of randomized controlled trials to compare the role of minimally invasive techniques and open procedures. However, the non-randomized evidence has shown that minimally invasive techniques in thoracic surgery are feasible and associated with less postoperative morbidity and fast recovery allowing the begin of adjuvant therapy when necessary without delay (13,25,26). The 1 and 3 years survival of patients after VATS is at least equivalent to open procedures, with a trend towards better survival at 5 years with a VATS approach (7,8). Despite the 16 years experience with this technique, there were only 13 published cases with uniportal VATS until 2010. From 2011 till June 2014, there were 70 publications after the first report on Uniportal lobectomy (10) (*Figure 4*).

The uniportal VATS program was started at our institution in June 2012. The 3-port VATS was the standard procedure for minor procedures whereas the postero-lateral thoracotomy was the standard approach for major resections. The operations were performed according to the availability of the instruments and experience of the thoracic surgeon with a learning curve. Patient selection was not limited to low risk individuals. There were 1, 12, 38 and 5 patients with "The American Society of Anesthesiologists score" I, II, III and IV, respectively. Most of the patients had four or more comorbidities. This is reflected in the prolonged hospital stay despite the removal of the chest tube. A limiting factor was the unavailability of the special instruments for the technique with proximal and distal articulation as reported in other centers (20). Only four major lung resections were performed with these instruments while the other operations were performed with various endoscopic and conventional instruments. This resulted in a prolonged operation time. Certainly, the use of such instruments for retraction and dissection during uniportal VATS major lung resection is possible but far from optimal (23,27). Specifically designed uniportal VATS instruments are available with slight curvature and narrower shaft to allow for a smaller incision and reduced instrument fencing (19). All procedures were performed as pure uniportal VATS approach without the use muscle spreading. Only in one patient there was a use of an extra 5-mm port for the camera. Our report represents the first German experience with uniportal VATS in a heterogeneous group demonstrating feasibility with low conversion rate and morbidity.

Various technical aspects are of importance for the uniportal VATS. The procedure can be optimally learned under the supervision of a team experienced with it. The development of a uniportal VATS program requires special instrumentations and previous general experience in VATS and could be even performed by thoracic surgeons experienced in postero-lateral thoracotomy approach. Furthermore, randomized controlled studies are necessary to compare the uniportal VATS with other techniques in terms of lymph node dissection as well as mid and long term results, which will influence the future of uniportal VATS in Germany.

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Lobectomy

Uniportal video-assisted thoracoscopic lobectomy in the animal model

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Abstract: We introduce the training on uniportal video-assisted thoracoscopic (VATS) lobectomy in sheep. This animal model is helpful to learn the different view, the importance of lung exposure and the key points of the instrumentation. In this article we present three videos with the left upper lobectomy, the left lower lobectomy and the right upper lobectomy in the sheep.

Keywords: Video-assisted thoracoscopic lobectomy (VATS lobectomy); uniportal VATS; VATS training; VATS animal model

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Introduction

Video-assisted thoracoscopic (VATS) lobectomy in the animal model is very helpful in surgeons training, particularly in a new approach as the uniportal. It allows to know the different visualization with the camera through the same incision and learning the keypoints of the instrumentation (1,2).

The best animal model in our experience is the sheep, due to its anatomy.

The Technological Center

Our technological center is located near to the hospital and is managed by a veterinarian, with great experience in training courses, not only for thoracic surgery, but also general surgery, vascular surgery, microsurgery.

The training hall has eight surgery tables with a ventilator and monitorization. The vet is helped by another two vets and two assistants. They are responsible for the general anesthesia, selective intubation of the sheep, and the posterior control during the surgery. The center has also simulators to practise sutures in artificial tissues or animal tissues (*Figure 1*).

The animal model

The anatomy of the sheep is in our opinion the most similar to the human model. We use adult sheep, six months old and with an average weight of 25-28 kg.

We recommend starting with the left upper lobe, because it is a small lobe, and so the exposure is easier. The lingula is long, needing frequently to be positioned in the posterior part of the hemithorax.

After the upper lobectomy, the left lower lobectomy is easier because the artery and the bronchus are exposed in the fissure. For this reason, we suggest the students to try to do the lobectomy from the inferior aspect of the lung, after dividing the pulmonary ligament.

In the right side, the anatomy is a little different from human. The cava vein is bigger, and the pulmonary arterial branches are behind it. The upper lobe has a tracheal bronchus. The upper and lower veins are hidden behind the cava vein too.

The sheep is positioned in the lateral decubitus with a rol or a small pillow under the thorax (*Figure 2*).

The uniportal utility incision

The best place is in the fourth intercostal space, in the lateral part of the hemithorax and in front of the tip of the scapula. Three or four centimeters are enough.

Instruments

We use a 30º-10 mm camera and most of the time we place

Figure 1 Surgery hall in The Technological Center.

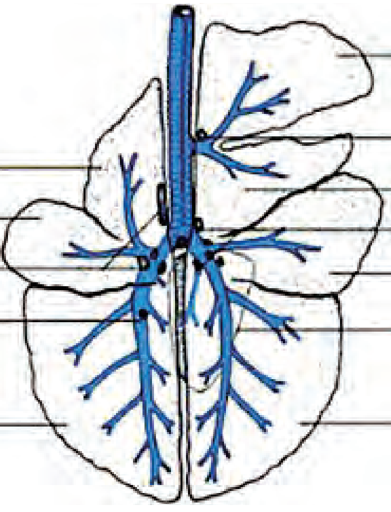

Figure 2 Lung's anatomy in the sheep.

it in the posterior angle of the incision.

For the dissection we recommend Scanlan instruments, with proximal and distal articulation: thin lung grasper, dissector, scissor. The long curved suction is helpful to expose and sometimes to dissect the hilar structures.

The staplers are the same as in human surgery, and frequently they are too big to divide the vessels. In this case the vascular clips are the solution.

Energy devices are helpful to divide the mediastinal pleural, the hilar tissue around the bronchus and the pulmonary ligament.

The left upper lobectomy (*Figure 3*)

The surgeon is positioned in the upper part of the thorax.

The camera is introduced through the incision and placed in the posterior angle.

The upper lobe is retracted to posterior with a lung grasper by the assistant, and then the hilar structures are visible.

The mediastinal pleura is opened.

The upper vein is dissected and divided with vascular clips, because the angle for a stapler is not good. The lingular vein is dissected and divided too.

It is important to be careful with this dissection because these vessels are thin and fragile.

The next step is to open the mediastinal pleura up to the posterior aspect of the arterial trunk. Now we can dissect and divide the artery or the lobar bronchus. We recommend to use a silk for the reference of the bronchus, to make the introduction of the stapler easier. This avoids the lesion of the lingular artery, located behind the bronchus.

The final step is the fissure (Fissure-less technique), that is divided with one or two staplers. The lobe is removed and you can use a protective bag.

Figure 3 Left upper lobectomy in the sheep (3).
Available online: http://www.asvide.com/articles/324

Figure 4 Left lower lobectomy in the sheep (4).
Available online: http://www.asvide.com/articles/325

Figure 5 Right upper lobectomy in the sheep (5).
Available online: http://www.asvide.com/articles/326

The left lower lobectomy (*Figure 4*)

The surgeon is positioned in the inferior part of the thorax, because the camera must be directed to the pulmonary ligament.

The lung is exposed to the upper part of the hemithorax with one or two lung graspers, since it is a big lobe.

The pulmonary ligament is very long. It is divided with the electronic devide or the cautery up to the lower vein.

This vein is then easily dissected and divided with a vascular stapler.

Many adhesions to the esophagus are divided up to the bronchus.

The basilar arterial trunk is dissected and divided with big vascular clips or a vascular stapler.

The final step is the dissection of the bronchus, that it is divided with a stapler.

The lobe is removed.

The right upper lobectomy (*Figure 5*)

The anatomy of the right lung is different from humans and the pulmonary resections are more difficult. One problem is the big cava vein.

The surgeon is positioned in the upper part of the thorax.

After opening the utility incision, the camera is placed in the posterior angle.

The upper lobe is retracted to the back.

The mediastinal pleura is opened.

Two or three veins are dissected separately and divided with vascular clips, because they are small.

Then you can find two arteries. They are dissected and divided with vascular clips.

The trachea is exposed and we recommend dividing first the fissure with two staplers.

The posterior mediastinal pleura and tissues are divided and the tracheal bronchus is exposed. It is dissected and transected with a stapler.

The lobe is removed.

The right lower lobectomy

It is the most difficult. The cava vein is big and the lower pulmonary vein is hidden behind it.

The lobe is retracted to the upper part of the pleural cavity with one or two lung graspers.

The long pulmonary ligament is divided with the energy device or the cautery. It is helpful to separate the cava vein with a small sponge stick.

The lower vein is then dissected and transected with a stapler.

The arteries are located in the anterior aspect of the lobe and they can be divided with vascular clips.

The tissue in the posterior face of the lobe is dissected and divided to expose the bronchus.

The bronchus is divided with a stapler. The lobe is removed.

Discussion

Although VATS lobectomy has been demonstrated to be safe and effective, the technique is not widely. This may, in part, reflect difficulty in acquiring appropriate skills (6).

This minimally invasive technique places special demands on the surgeons. Using simulation-based training on artificial models or animals has been proposed to overcome the initial part of the learning curve (7,8).

Surgical simulation may be able to facilitate a more rapid and safe introduction into surgical practice without exposing the patient to unnecessary risk. There are number of relevant issues regarding simulation in thoracic surgery: computer-based, animal or tissue block (9,10). The virtual reality platform would be a good starting point for novice thoracic surgeons (11,12). The porcine model can then be used once surgeons gain some operative experience and will facilitate the development of fine dissection skills of hilar vessels (13).

Simulation may be able to replace some of the case numbers required to achieved proficiency in a complex operation, but this requires that the simulation environment have high fidelity and be challenging, constantly testing the learner's growing cognitive an technical skills (14).

Our experience with five courses in The Technological Center allows us to affirm that the sheep is an excellent model in VATS lobectomy training.

Summary

The uniportal VATS approach is the most ergonomic approach and it provides you a direct view to the hilar structures and the fissure (15). But you must be confident with the lung exposure and the instrumentation. The bimanual instrumentation is very helpful and to define every step is the key.

The practice in the animal model is a good option to acquire these skills.

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Uniportal video-assisted thoracoscopic lobectomy

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Abstract: Over the past two decades, video-assisted thoracic surgery (VATS) has revolutionized the way thoracic surgeons diagnose and treat lung diseases. The major advance in VATS procedures is related to the major pulmonary resections. The best VATS technique for lobectomy has not been well defined yet. Most of the authors describe the VATS approach to lobectomy via 3 to 4 incisions but the surgery can be performed by only one incision with similar outcomes. This single incision is the same as we normally use for VATS lobectomies performed by double or triple port technique with no rib spreading. As our experience with VATS lobectomy has grown, we have gradually improved the technique for a less invasive approach. Consequently the greater the experience we gained, the more complex the cases we performed were, hence expanding the indications for single-incision thoracoscopic lobectomy.

Keywords: Video-assisted thoracic surgery (VATS); left lower lobectomy; right lower lobectomy; left upper lobectomy; right upper lobectomy; middle lobectomy; lymphadenectomy; lobectomies; less invasive approach

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Introduction

Video-assisted thoracic surgery (VATS) anatomic lobectomy for lung cancer was initially described two decades ago (1). Since then, many units have successfully adopted this technique, albeit its precise definition and description greatly vary between them (2).

The final step in the evolution of the technique is the use of a single-port approach. The uniportal access was described initially by Rocco and colleagues for minor thoracic and pulmonary procedures (3). The development of articulated staplers and purposely-designed instruments has helped to perform major pulmonary resections through a single incision approach. The first uniportal VATS lobectomy was described by Gonzalez-Rivas and colleagues, from Coruña University Hospital in 2010 (4). This chapter describes the technique for VATS single-port lobectomies.

Material

Although uniportal VATS lobectomy can be performed with conventional instruments, the use of especially adapted conventional material (such as instrumentation with both proximal and distal articulation, *Figure 1*), modern articulated staplers, vascular clips, high definition 30° cameras (The use of videolaparoscope with the distally mounted CCD design facilitates the instrumentation, *Figure 2*) and energy devices seems to be more fitted for successful single-incision lobectomy.

General aspects

The surgeon and the assistant must to be positioned in front of the patient in order to have the same thoracoscopic vision during all steps of the procedure and experience more coordinated movements (*Figure 3*).

Even though the field of vision is only obtained through the anterior access site, the combined movements of the thoracoscope along the incision will create different angles of vision (in this context, a 30 degree thoracoscope is recommended to achieve a panoramic view). The advantage

Figure 1 Adapted instruments with proximal and distal articulation.

Figure 2 High definition 30° thoracoscope.

Figure 3 Surgeons positioned in front of the patient watching the same monitor. The scrub nurse is located on the opposite side.

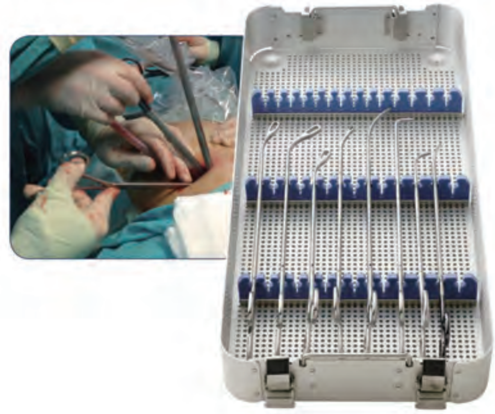

Figure 4 Uniportal set of specific adapted instruments.

Figure 5 Drawing showing the placement of incision.

of using the thoracoscope in coordination with the instruments is that the vision is directed to the target tissue, bringing the instruments to address the target lesion from a direct, sagittal perspective.

Instruments must preferably be long and curved to allow the insertion of 3 or 4 instruments simultaneously (*Figure 4*). Optimal exposure of the lung is vital in order to facilitate the dissection of the structures and to avoid instrument interference.

Under general anesthesia and double lumen intubation, the patient is placed in a lateral decubitus position as usual for a conventional VATS. The incision, about 4-5 cm long, is performed preferably in the 5th intercostal space in the anterior position (*Figure 5*). This location of the incision provides better angles for hilar dissection and insertion of staplers (*Figure 6*). This incision is the same size as the utility incision we use for double or triple port VATS technique to allow removal of specimen (*Figure 7*). There is no need to use a trocar for the thoracoscope.

It is helpful to rotate the surgical table away from surgeons during the hilar dissection and division of structures, and towards the surgeons for the lymph node dissection.

The vessels are usually divided by staplers but when the angle for vascular division is difficult for stapler insertion, the use of vascular clips (click aV, Grena®) or sutures is recommended (*Figure 8*).

For most of the surgical steps the thoracoscope is usually

Figure 6 Insertion of staplers during upper lobectomies (5). Available online: http://www.asvide.com/articles/34

Figure 7 Incision for left upper lobectomy (6). Available online: http://www.asvide.com/articles/35

Figure 8 Use of vascular clips during lobectomy (7). Available online: http://www.asvide.com/articles/36

placed at the posterior part of the utility incision working with the instruments in the anterior part.

For lower lobectomies the normal sequence of dissection is as follows: inferior pulmonary ligament, inferior pulmonary vein, pulmonary artery, bronchus and finally completion of the fissure. In case of upper lobectomies, the pulmonary artery is normally divided first, followed by vein, bronchus and fissure.

Figure 9 Single-chest tube placed in the posterior part of the incision.

When the lobectomy is completed, the lobe is removed in a protective bag and a systematic lymph node dissection is accomplished. The intercostal spaces are infiltrated with bupivacaine at the end of the surgery under thoracoscopic view. A single-chest tube is placed in the posterior part of the incision (*Figure 9*). We do not routinely employ epidural or paravertebral catheters.

Indications and contraindications

The indications and contraindication for uniportal VATS are similar as proposed by authors with experience in double or triple-port technique VATS (8).

The only absolute contraindications we consider are surgeon discomfort and huge tumors are not possible to be removed without rib spreading.

Surgical technique

Left lower lobectomy

The lobectomy may be technically different depending on whether the fissure is complete or not. If fissure is complete we try to dissect and staple the artery in the fissure. Sometimes, it is easier to individually divide the arterial branches of the superior and basilar segments. Upon retracting the lobe with a long curved grasper, we cut the pulmonary ligament to find the vein. The vein is dissected free and divided. Then, the lower lobe bronchus is exposed, dissected and stapled the same way as mentioned for the vein. The last step is to staple the fissure and remove the lobe in to a protective bag (*Figure 10*).

Figure 10 Left lower lobectomy (artery exposed in the fissure) (9). Available online: http://www.asvide.com/articles/37

Figure 11 Left lower lobectomy from bottom to top (10). Available online: http://www.asvide.com/articles/38

Figure 12 Right lower lobectomy with artery exposed in the fissure (11). Available online: http://www.asvide.com/articles/39

Figure 13 Right lower lobectomy from down to up (12). Available online: http://www.asvide.com/articles/40

In the presence on an incomplete fissure or no visible artery, the technique may change. The preferred method does not involve dissection within the fissure in order to avoid postoperative air leaks. In this case, the lobectomy must be performed from caudal to cranial leaving the fissure stapling as the last step (fissureless technique). Once the lobe is retracted cranially, the sequence of the dissection should be as follows: inferior pulmonary ligament; inferior vein; inferior bronchus. Subsequently, a plane is created between the bronchus and the artery; the artery is taken thus leaving the fissure to be developed last (*Figure 11*).

Right lower lobectomies

The strategy for right lower lobectomy is similar as for the left side but when the artery is exposed in the fissure, the origin of superior segmental artery must to be dissected in the posterior and superior portion of the fissure. The sequence is similar to left lower lobectomy (*Figure 12*).

For lobectomies when performed along a caudo-cranial axis, care must be taken to identify and avoid the damage of the bronchus or artery of the middle lobe. Once the inferior pulmonary vein has been stapled, the lower lobe bronchus is exposed, dissected and divided from its inferior aspect to its bifurcation with the middle lobe bronchus. Dissection of the bronchus with development of the plane between the bronchus and artery is performed leading to the visualization of the artery. We recommend removal of the interbronchial lymph nodes to better define the anatomy. Once identified, the segmental arterial branches to the lower lobe (basilar artery and superior segmental artery) are divided leaving the fissure to be finally stapled (*Figure 13*).

Left upper lobectomy

The operative sequence for left upper lobectomies is similar to conventional VATS. However, we recommend, when feasible, to divide the upper lobe truncus anterior first in order to facilitate division of the upper lobe vein (*Figure 14*).

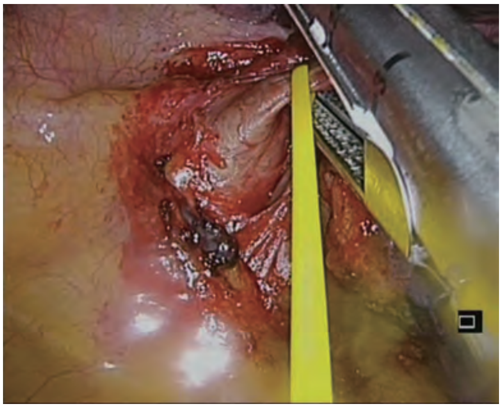

Figure 14 Division of upper arterial trunk as first step.

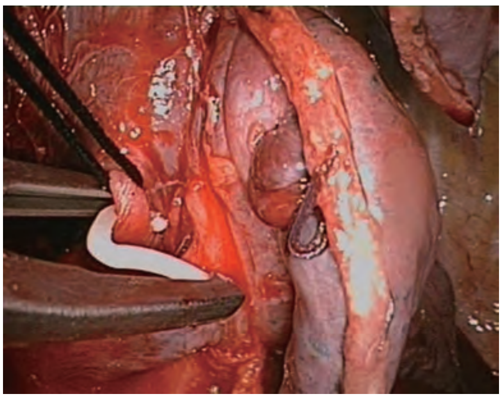

Figure 15 Use of vascular clips when the angle for staplers is not optimal.

Figure 16 Left upper lobectomy (fissureless technique) (13). Available online: http://www.asvide.com/articles/41

As a rule, for upper lobes we try to use staplers for all hilar structures. However, when there is no angle for stapler insertion or is difficult from the incision, we either use clips for vascular control (click aV, GrenaR) (*Figure 15*) or doubly ligates the vessels. We recommend to staple the fissure as the last step of the procedure, after dividing the hilar structures, from anterior to posterior (fissureless technique) (*Figure 16*).

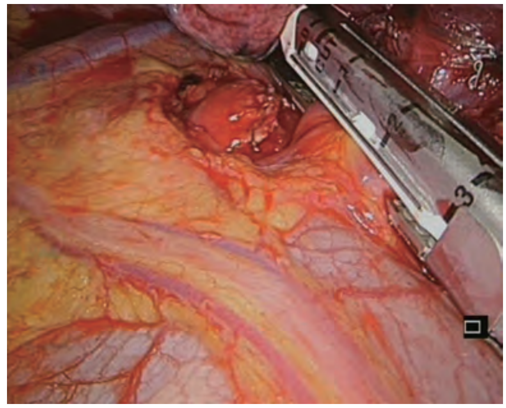

Figure 17 Division of the left superior pulmonary vein after division of truncus anterior.

The uniportal view facilitates the dissection and division of upper anterior and apical segmental trunks which are usually hidden by the superior vein when we use a conventional thoracoscopic view. We recommend to first divide the upper anterior and apical segmental trunk in order to facilitate the insertion of the endostaplers in the upper lobe vein. Once this arterial branch is stapled, the vein is easily exposed (*Figure 17*). It is important to dissect the vein as distal as possible for optimal stapler insertion. The use of curved-tip stapler technology facilitates improved placement around superior pulmonary vein and bronchus through a single incision (*Figure 18*). Another interesting option for management of the upper lobe vein is to open the fissure as the first step, from a hilar view and then dissect the plane between upper and lower vein, with identification of the bronchus and artery. The stapler is inserted over the artery, thereby dividing the fissure, and the lobe is mobilized to allow stapling of the vein from a different angle (*Figure 19*).

The management of bronchus during left upper lobectomies is more difficult because care must to be taken with lingular artery which lies usually behind the bronchus. We have 4 different forms to manage the upper lobe bronchus (*Figure 20*). The first option consists of exposing the lingular artery and subsequently dividing it in the fissure. At this point, the insertion of an endostapler for the bronchus is easy. In the second option a TA stapler is used for division of the left upper lobe bronchus in certain cases of incomplete fissure to avoid injury of the lingular artery (*Figure 21*). The third option entails dividing the bronchus with scissors

Figure 18 Use of curved tip stapler to facilitate division of upper vein (14). Available online: http://www.asvide.com/articles/42

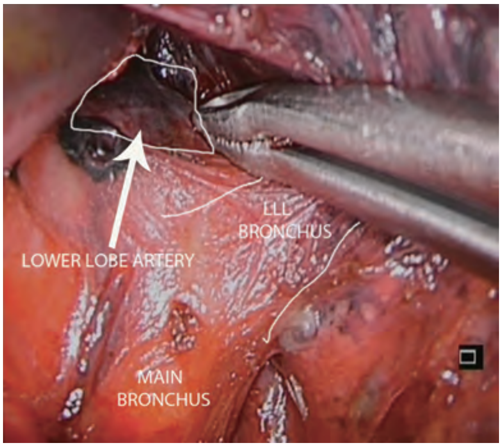

Figure 19 Division of anterior portion of fissure from a hilar view.

Figure 20 Different options for bronchus transection (15). Available online: http://www.asvide.com/articles/43

and closing it at the end of the surgery (by manual suture or by using a stapler). The final and fourth option focuses on inserting an endostapler after division of superior trunk (and optionally posterior ascending artery) and vein. This last option must be pursued only by experienced uniportal VATS surgeons.

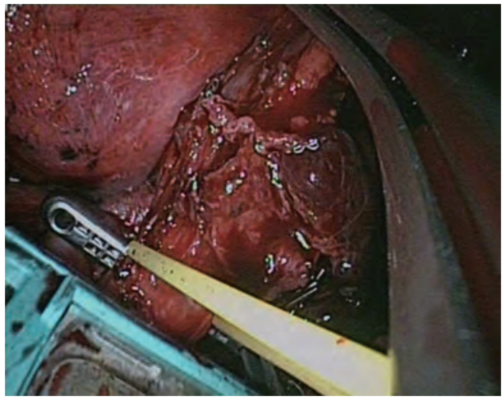

Figure 21 Use of TA linear stapler to transect the bronchus is case of complex fissure.

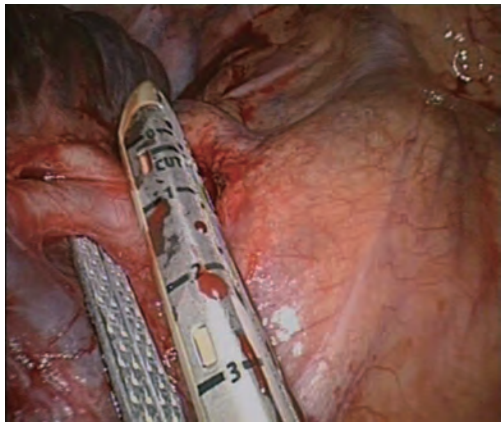

Figure 22 Division of boyden trunk as first step.

Right upper lobectomy

The surgical steps are similar to left upper lobectomy: anterior and apical segmental trunk, upper vein, posterior segmental artery, upper bronchus, fissure. We prefer to divide first the upper apico-anterior arterial trunk when possible (*Figure 22*) to help the insertion of staplers to the upper vein as described in the left upper lobe (*Figure 23*).

Sometimes it is helpful to partially divide the minor fissure as the first step (anvil of the stapler placed between the upper and middle lobe vein pulling the parenchyma into the jaws of the stapler) in order to get a better angle for the insertion the staplers to the upper vein. This maneuver will provide us with a much better field of vision to dissect and transect the RUL bronchus (*Figure 24*) or the ascending arteries.

The last step would be to complete the fissure (anvil of the stapler placed over the artery). After transecting the

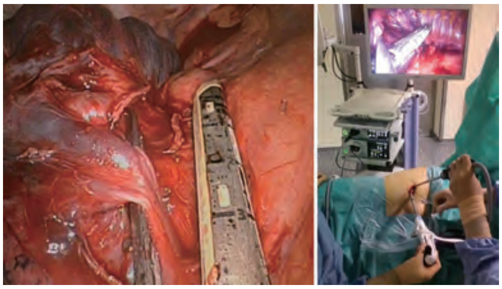

Figure 23 Division of upper lobe vein after arterial trunk is divided.

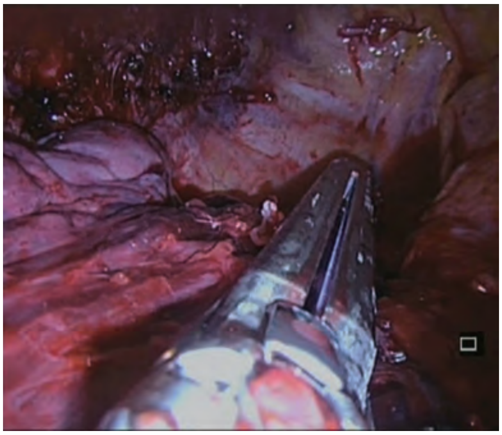

Figure 24 Division right upper lobe bronchus.

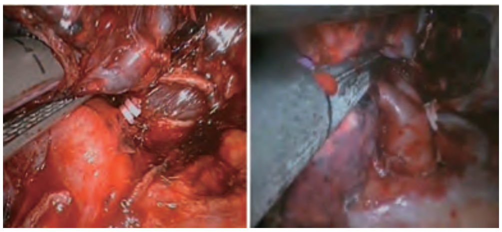

Figure 25 Division of the fissure in a right upper lobectomy from anterior to posterior as the last step of the lobectomy (fissureless technique).

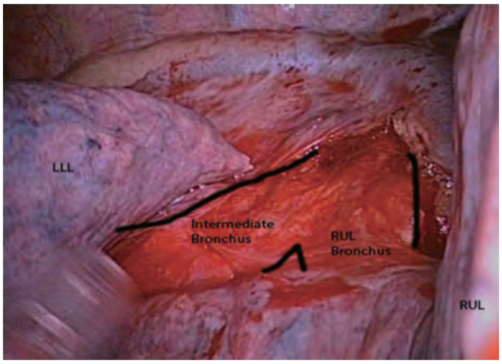

Figure 26 Exposure of posterior division of main right bronchus.

vein, artery and bronchus and after identifying the artery for the middle lobe, we can continue to divide the fissure by placing the stapler over the interlobar artery, pulling the parenchyma anteriorly making sure that the middle lobe artery is left out to the left side of the stapler. The vascular and bronchial stumps are kept out from the staplers jaws (*Figure 25*).

Occasionally, it is better to divide the bronchus after the division of the Boyden trunk to facilitate stapling of the upper lobe vein. We recommend first to expose the posterior bifurcation between the upper lobe and intermediate bronchus by dividing the posterior pleural reflection (*Figure 26*). This maneuver facilitates the following anterior bronchial dissection and subsequent insertion of staplers to divide the vein.

The use of vascular clips or tie off the vessels is helpful in the division of segmental branches of the pulmonary artery and vein. Except for the management of the bronchus, all vascular branches could be divided using clips rather than staplers.

Middle lobectomy

We recommend to perform the middle lobectomy from caudal to cranial: anterior portion of major fissure, vein, bronchus, artery, anterior portion of minor fissure and finally the posterior portion of fissure. The identification of medium (MLV) and lower lobe vein (LLV) indicates the location to place the stapler to divide the anterior portion of major fissure (the anvil of the stapler is placed between the MLV and LLV, and we pull the parenchyma into the jaws of the stapler). This maneuvre facilitates the dissection and insertion of stapler to transect the vein.

Once the vein is divided, the middle lobe bronchus is exposed, dissected and stapled. A ring forceps is then placed to exert traction onto the middle lobe, thereby exposing the middle lobe artery (medial segmental artery), which is then divided. Finally, the fissures are stapled (*Figure 27*).

Lymphadenectomy

A complete lymph node dissection can be performed with similar results as conventional VATS. For paratracheal dissection it is very helpful the anti-trendelenburg position because it naturally makes the lung “fall down”. For subcarinal dissection the trendelenburg position and the anterior table rotation facilitate the exposure. Preliminary division of the pulmonary ligament gives us a better access to the subcarinal space.

Figure 27 Middle lobectomy (16).
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Figure 28 Aortopulmonary window lymph node dissection (17).
Available online: http://www.asvide.com/articles/45

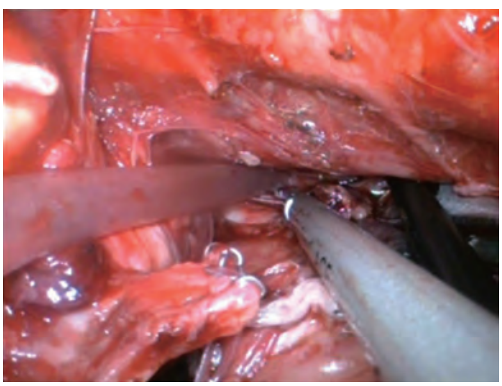

Figure 29 Left subcarinal lymph node dissection after left lower lobectomy.

Figure 30 Left subcarinal lymph node dissection (18).
Available online: http://www.asvide.com/articles/46

Figure 31 Right subcarinal lymph node dissection (19).
Available online: http://www.asvide.com/articles/47

The best location is to place the camera in the upper part of the incision. We can insert 3 or 4 instruments below the camera to complete the systematic dissection of the subcarinal space and paratracheal on the right side and subcarinal and aortopulmonary window on the left side (*Figure 28*).

For left subcarinal dissection, it is helpful to insert two 10 mm endopeanuts in the lower part of the utility incision to retract the aorta, esophagus and lung (*Figure 29*). This operation facilitates the dissection with instruments placed above the peanuts and below the camera (*Figure 30*).

For right subcarinal lymph node dissection, the esophagus and the intermediate bronchus must be separated to facilitate the procedure (*Figure 31*).

For paratracheal lymph node dissection, we recommend to carry out the procedure by opening the pleura inferiorly to the azygos vein, lifting the azygos vein and retracting the superior vena cava to the right side with an endopath instrument (*Figure 32*). This technique will create a plane that will allow us to successfully dissect the paratracheal space from an inferior approach (*Figure 33*).

For hilar and N1 station lymphadenectomy, it is

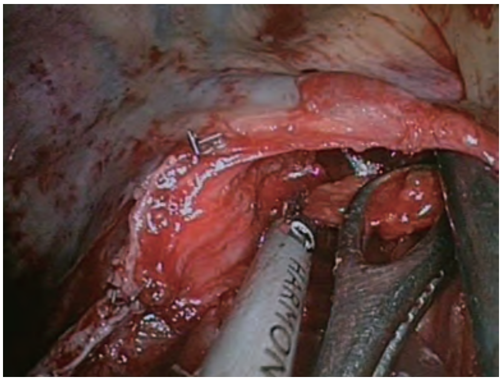

Figure 32 Surgical image of instrumentation during right paratracheal lymph node dissection.

Figure 33 Paratracheal lymph node dissection (20). Available online: http://www.asvide.com/articles/48

Figure 34 N1 station lymph node dissection after left upper lobectomy (21). Available online: http://www.asvide.com/articles/49

important to move and rotate the operating table posteriorly in order to place the lung in the back position. Bimanual instrumentation is crucial to achieve an accurate N1 radical lymph node dissection (*Figure 34*).

Results

Since June 2010, we have performed 222 uniportal VATS major pulmonary resections. All cases were performed by surgeons with experience in VATS surgery, especially in double-port technique for major pulmonary resections and single-port technique for minor procedures (wedge resections, pneumothorax, etc.). This series of patients included advanced NSCLC and complex major resections after chemo-radiotherapy induction treatment.

The overall conversion rate was 3.6%. The most frequent resection was right upper lobectomy (29.4%). The mean surgical time was 151.7±76 minutes (range, 60-310 minutes). After anatomical resection, a complete mediastinal lymphadenectomy was performed in patients with diagnosis of malignancy according to the oncological criteria already adopted in open surgery. The mean number of nodal stations explored was 4.4±1 (range, 3 to 7) with a mean of 14.6±6 (range, 5 to 38) lymph node resections. The mean tumor size was 3±2 cm (range, 0 to 9.8 cm).

The median chest tube duration was 2 days (range, 1 to 16 days) and the median length of stay was 3 days (range, 1 to 58 days).

Discussion

The VATS approach to lobectomy is not standardized. Although 3 to 4 incisions are usually made, the operation can be successfully carried out using only one incision.

Single-port pulmonary resections were initially described by Rocco and colleagues in 2004 (4). Since then they have published different articles on the single-port VATS technique (22,23) for diagnostic and therapeutic procedures, though not including lobectomies. We have adopted this single-incision technique and performed the initial major pulmonary resections by this approach (24,25). Currently we apply the single-port technique for most major resections including complex cases and advanced tumors (26).

The size of the utility incision performed is comparable to the ones commonly used for double (27) or triple-port approach (28). It is essential to accompany the movement of the camera in coordination with the surgical instruments. The use of high definition 30° thoracoscope with the distally mounted CCD design facilitates the instrumentation. The single-port technique provides a direct view to the target tissue. In comparison we feel that the conventional three-port creates an optical plane which requires a torsional angle that is not favorable with standard

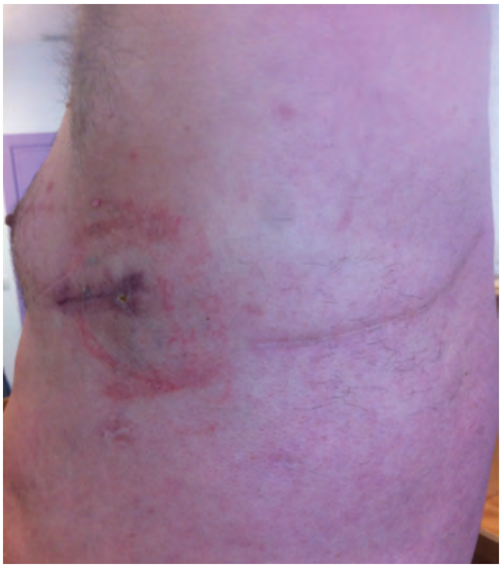

Figure 35 View of the single incison wound in a patient with a previous thoracothomy and double-port VATS. The patient was initially operated years ago by thoracotomy (wedge resection of a lower lobe metastasis). He was reoperated 3 years later by VATS 2 ports (atypical segmentectomy) and now reoperated by single incision to complete a lower lobectomy.

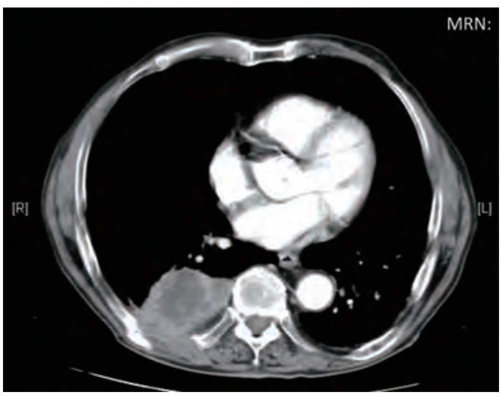

Figure 36 Lower lobe tumor with chest wall involvement operated by uniportal VATS for lobectomy and posterior incision for chest wall resection and reconstruction.

two-dimension monitors. The parallel instrumentation achieved during the single port approach mimics inside the maneuvers performed during open surgery. The uniportal view facilitates the dissection and division of the upper arterial trunk which is usually hidden by the superior vein when we use a conventional thoracoscopic view. For upper lobectomy, we recommend first dividing the upper lobe truncus anterior to facilitate dividing the upper lobe vein with an endo-stapler. Once the arterial branch is divided the division of the vein is much easier using the single-port approach. It is important to dissect the vein as distal as possible to optimise the passage of the stapler.

An advantage we have noticed is that we don't need the camera trocar to introduce the lens. By separating the soft tissue we can introduce the camera without trocar allowing us to have more flexibility and obtaining bigger and better angles of vision. Furthermore, we believe that by avoiding the use of the trocar the possibility of an intercostal nerve injury could be minimized. During the instrumentation we always try to avoid putting pressure over the intercostal bundle, putting it over the upper edge of the lower rib to avoid any contact with the nerve. We have the impression that our patients refer less pain when using this approach but we will try to demonstrate it in a further research with a larger patient population. Some authors have reported less postoperative pain and fewer paresthesias in patients operated for pneumothorax through a single incision, in comparison to the classical multiport approach (29).

Single-incision VATS is not only indicated to initial stages or easy cases. With gained experience the most complex cases can be performed in the same manner as with double or triple port approach (30). The previous experience in VATS is important to perform these advanced cases with success. We have performed lobectomies with strong adherences, re-VATS after thoracotomy (*Figure 35*), tumors with chest wall involvement (*Figure 36*) (31), cases after induction or radical chemo-radiotherapy, sleeve lobectomies (*Figure 37*) (32), vascular reconstruction (*Figure 38*), pancoast tumors, and huge tumors (*Figure 39*).

Recently, we have analysed our results comparing early stages of NSCLC with advanced tumors (>5 cm, T3-T4 or after induction therapy) operated by uniportal VATS (87 early stage tumors *vs.* 47 advanced tumors). Surgical time and number of lymph nodes were higher in advanced tumor group but postoperative outcomes were similar in both groups (chest tube duration, hospital stay and complications). Further analysis of survival for uniportal VATS lobectomy of advanced stage tumors is ongoing.

Despite the increasing adoption of the uniportal VATS approach worldwide, the technique for major lung resections should be learned by implementing dedicated educational pathways inclusive of wet labs and hands on courses as well as visiting experienced VATS centers. We expect further development of new technologies like electrosealing devices for all pulmonary structures, robotic arms that open inside

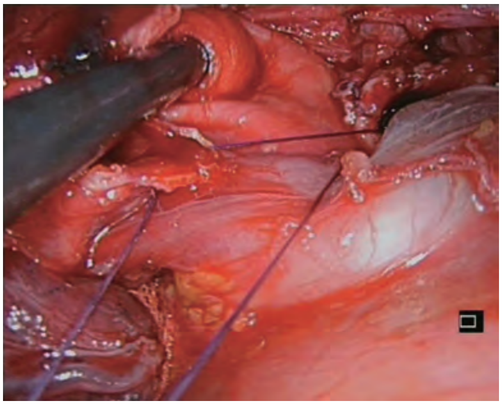

Figure 37 Sleeve anastomosis after left lower lobectomy.

Figure 38 Surgical instrumentation during vascular reconstruction.

the thorax and wireless cameras, which may allow the uniportal approach to become a standardized addition to the thoracic surgical armamentarium for major pulmonary resections in most thoracic departments.

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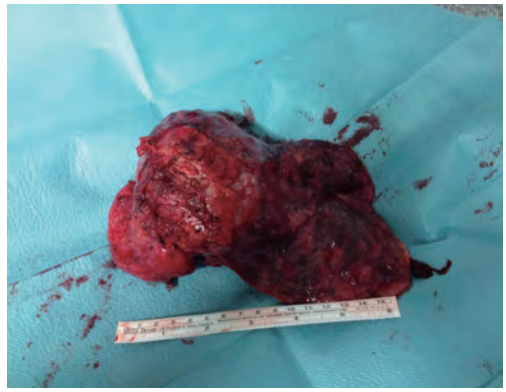

Figure 39 Huge tumor operated by uniportal VATS: bilobectomy and anatomic segmentectomy S6 (right upper lobe, middle lobe and superior segment of lower lobe were involved).

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Technique of uniportal VATS major pulmonary resections

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Abstract: The surgical approach to lung resections is evolving constantly. Since the video-assisted thoracoscopic surgery (VATS) anatomic lobectomy for lung cancer was described two decades ago, many units have successfully adopted this technique. The VATS lobectomy can be defined as the individual dissection of veins, arteries and bronchus, with a mediastinal lymphadenectomy, using a videothoracoscopic approach visualized on screen and involving 2 to 4 incisions or ports, with no rib spreading. However, the surgery can be performed by only one incision with similar outcomes. Since 2010, when the uniportal approach was introduced for major pulmonary resections, the technique has been spreading worldwide. This technique provides a direct view of the target tissue. The parallel instrumentation achieved during the single-port approach mimics the maneuvers performed during open surgery. It represents a less invasive approach than the multiport technique, and minimizes the compression of the intercostal nerve. As the surgeon's experience with the uniportal VATS lobectomy grows, more complex cases can be performed by using this approach, thus expanding the indications for single-incision thoracoscopic lobectomy.

Keywords: Minimally invasive surgery; video-assisted thoracic surgery (VATS); single-port lobectomy; uniportal video-assisted thoracic surgical resections

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Introduction

The uniportal access was initially described by Rocco *et al*., firstly for the management of minor procedures (1). Since 2010, when the uniportal approach was introduced for major pulmonary resections, the technique has been spreading worldwide.

This technique provides a direct view of the target tissue. The parallel instrumentation achieved during the single-port approach mimics the maneuvers performed during open surgery (1-3).

It represents a less invasive approach than the multiport technique, and minimizes the compression of the intercostal nerve.

The aim of this chapter is to establish the most important steps of the uniportal lobectomy and to reveal some useful tricks to perform the technique.

Operative technique

General aspects

Single-incision video-assisted thoracic surgery (VATS) lobectomy follows the oncological principles of major pulmonary resections by VATS: individual dissection of veins, arteries and lobar bronchus, likewise complete mediastinal lymphadenectomy with a video-assisted thoracoscopic approach, with no rib spreading (2-4). The procedure is performed by video-visualization.

The utility incision is usually placed in the 5^{th} intercostal space. The proper placement of the incision is crucial for good access to upper hilar structures and lymph node stations. No trocar and no rib spreader are required.

One of the key points is the adequate exposure of the lung, which is mandatory for every step. Also, the rotation

Figure 1 Uniportal instrumentation. Camera location (6).
Available online: http://www.asvide.com/articles/327

Figure 2 Video describing the use of energy devices, vascular clips and curved-tip staplers during the uniportal technique (7).
Available online: http://www.asvide.com/articles/328

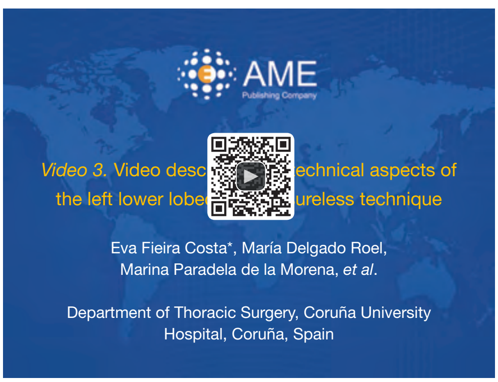

Figure 3 Video describing the technical aspects of the left lower lobectomy: fissureless technique (8).
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of the surgical table and the correct retraction of the parenchyma are essential to improve the exposure and to obtain different angles of view. Another key point is the bimanual instrumentation.

This approach provides a direct visualization of the target tissue (5). In addition, the surgeon and the assistant are placed in front of the patient, so they have the same field of vision and the coordination is better.

For most of the surgical steps, the thoracoscope is usually placed at the posterior part of the utility incision, working with the instruments in the anterior part (*Figure 1*).

Finally, the use of specific equipment (such as a 30º thoracoscope, instruments with proximal and distal articulation, energy devices, articulated staplers or vascular clips) is recommended (2,3). In fact, the use of vascular clips for proximal vascular control and energy devices for distal division of small vascular branches is recommended (*Figure 2*).

Lower lobectomy

The technique is different depending on whether the fissure is complete or not:

(I) If the fissure is complete, the sequence is as follows: artery, pulmonary ligament, vein, bronchus and fissure;

(II) In the fissureless-technique, the sequence could be: pulmonary ligament, vein, bronchus, artery and fissure. Another way would be starting the procedure by dividing the anterior portion of the fissure from the hilum, after the identification of the interlobar artery (the anvil of the stapler should be placed over the surface of the artery).

In the video, there is an example of the fissureless technique performing a left lower lobectomy, from down to up (*Figure 3*). After retracting the lower lobe posteriorly and superiorly, the vein can be dissected using the right angle clamp, so the stapler goes easily into place.

The most difficult step during this lobectomy is the dissection of the bronchus; care must be taken in order to avoid injuries in the basilar artery. An optimal plane must be created between the bronchus and the artery, to staple without tractions. Once the bronchus is transected, the artery can be divided. The last step is to complete the fissure.

On the right side, the right lower lobectomy is very similar. As in this video (*Figure 4*), firstly the pulmonary ligament is cut and the vein is dissected and stapled. In this case, the fissure is complete, so the artery can be easily exposed and divided. Sometimes, it is easier to divide the artery into basilar and superior segmental branches. Then the bronchus can be stapled; the last step is the fissure.

The sequence is different if a fissureless technique is performed: starting the procedure by cutting the pulmonary ligament and dissecting the vein. When the vein is divided,

Figure 4 Video describing technical aspects of the uniportal VATS right lower lobectomy (9).
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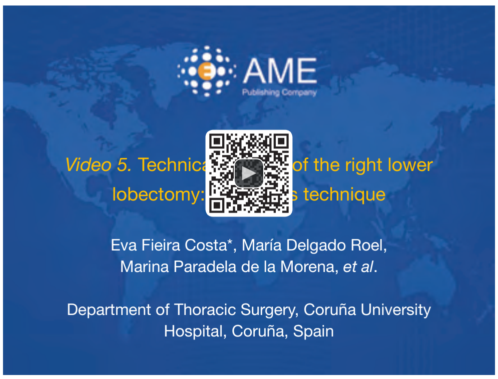

Figure 5 Technical aspects of the right lower lobectomy: fissureless technique (10).
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Figure 6 Video describing the technical aspects of the uniportal VATS left upper lobectomy (11).
Available online: http://www.asvide.com/articles/332

the bronchus is exposed and transected. Care must be taken to avoid injuring the bronchus or the artery of the middle lobe. After the section of the lower bronchus, the artery is identified and stapled. The fissure is the last step (*Figure 5*).

Figure 7 Technical aspects of the management of the left upper bronchus during the uniportal VATS left upper lobectomy (12).
Available online: http://www.asvide.com/articles/333

Left upper lobectomy

Probably, this is the most difficult lobectomy using the uniportal approach, especially when the fissure is not complete (*Figure 6*). We recommend dividing the arterial trunks before dissecting the vein. Once the artery is divided, the vein can easily be exposed. It is very important to dissect the vein as distal as possible to improve the angle for the insertion of the stapler.

During the management of the upper vein, we recommend stapling the anterior portion of the major fissure. At this point, the camera is placed in the anterior portion of the utility incision to provide a better view of the hilum. The use of tip-curved staplers is also recommended, to avoid major tractions.

When the remaining arterial branches are divided, the bronchus can be dissected. It can be transected at this point or left for the final step. In this video (*Figure 6*), we were able to identify the interlobar artery in the fissure; so the anvil of the stapler is placed over the surface of the interlobar artery and the fissure can then be stapled; it is the safest management of the fissure, avoiding vascular events. After this step, the fissure is completed and the bronchus divided.

Focusing on the management of the left upper bronchus, there are four different approaches to the bronchus transection (*Figure 7*):

(I) When the fissure is complete or the artery can be easily exposed, we recommend dividing the lingular artery in the fissure, and then the bronchus;
(II) If the fissure is not complete or the artery is hidden, a TA stapler can be used to divide it;
(III) Another way is the use of scissors and to close it later (using a stapler or manual suture);

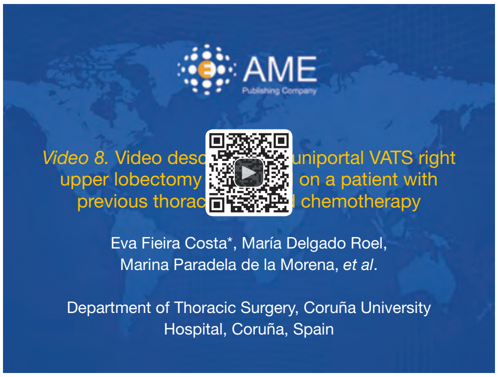

Figure 8 Video describing the uniportal VATS right upper lobectomy performed on a patient with previous thoracotomy and chemotherapy (13).
Available online: http://www.asvide.com/articles/334

Figure 9 Technical aspects of the uniportal VATS middle lobectomy (14).
Available online: http://www.asvide.com/articles/335

(IV) Finally, during the fissureless-technique, when the arteries and the vein have been stapled, the bronchus can be transected using an Endostapler. We only recommend this way for experienced VATS surgeons.

Right upper lobectomy

The steps for this lobectomy are very similar to those on the left side (*Figure 8*).

We recommend starting the procedure by dividing the anterior arterial trunk and then the vein. If the angle is no good, stapling the anterior portion of the minor fissure can provide a better retraction of the lobe, thus improving the angle.

When the artery and the vein are transected, the bronchus is divided and stapled and finally, the fissure. This last step is performed by placing the anvil of the stapler over the surface of the interlobar artery.

During the approach to the minor fissure, the camera is placed in the anterior portion of the utility incision and the instruments at the posterior. Perhaps, this is the only step in which the camera position is changed, but it provides a direct view of the hilum.

Middle lobe lobectomy

This lobectomy is usually performed from bottom to top. The sequence is as follows: anterior portion of the major fissure, vein, bronchus, artery and finally, the remaining fissure. Only when the fissure is complete or the artery can be easily exposed, the artery can be divided before the bronchus (*Figure 9*).

Due to the smaller branches, vascular clips are often used to divide the arterial branches in the middle lobectomy.

Comments

The uniportal lobectomy is a feasible, safe and an oncologic procedure in expert hands (4). To date, we have performed about 400 uniportal major pulmonary resections with good postoperative outcomes. Only one incision is used, which is less invasive than the multiportal technique. No trocar is used, so there could mean less compression to the intercostal nerve. The instrumentation is more anatomic and the visualization of the target is direct (5).

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Lobectomy

Uniportal complete video-assisted thoracoscopic lobectomy with systematic lymphadenectomy

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Abstract: Video-assisted thoracoscopic surgery (VATS) has permeated our thoracic surgical practice and now will develop in depth towards a next level of minimally invasive surgery (MIS). Irrespective of generation gaps and diversified perception within thoracic community, more and more surgical teams are adapting to the uniportal lobectomy. This video demonstrates a case undergoing uniportal VATS lobectomy with systematic lymphadenectomy for lung cancer. We here describe our technique for uniportal approach by using a combination of double-jointed and endoscopic instruments to combat the four major obstacles: (I) interference of the thoracoscope, stapler and the instrumentation in and out of the thoracic cavity? (II) whether the field of vision is enough or not without the other 1-3 ports to improve the exposure? (III) the optimal stapler introduction angle especially for upper and middle lobes resection? (IV) more importantly, the oncologic validity of uniportal procedures as well as the reduction of postoperative morbidity? We believe, uniportal VATS lobectomy with systematic lymphadenectomy is technically safe and feasible and alternative approach to conventional thoracoscopic lobectomy in lung cancer treatment. The issues of patient acceptability, the cosmetic and oncologic results, and cost-effectiveness remain to be determined in the future through multi-institution randomized controlled trials and long-term follow-up.

Keywords: Complete video-assisted thoracoscopic surgery (cVATS); uniportal; biportal; lobectomy; lung cancer; systematic lymphadenectomy; multiple nodules; oncologic outcome

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Introduction

When it comes to perspectives in complete video-assisted thoracoscopic surgery (cVATS), it has become a consensus in thoracic community that is to further reduce the number and the length of the incisions (1). In Jun 2011, Gonzalez Rivas first report uniportal cVATS lobectomy which becomes a milestone in the development history of VATS lobectomy (2). Perhaps the demand for increasingly more minimally invasive surgical approaches is even more important within the Chinese culture, uniportal VATS development has grown in popularity in mainland recently.

However, uniportal approach poses several major challenges to cVATS lobectomists (2): (I) interference of the thoracoscope, stapler and the instrumentation in and out of the thoracic cavity? (II) whether the field of vision is enough or not without the other 1-3 ports to improve the exposure? (III) the optimal stapler introduction angle especially for upper and middle lobes resection? (IV) more importantly, the oncologic validity of uniportal procedures as well as the reduction of postoperative morbidity? This video demonstrates a case undergoing uniportal cVATS lobectomy with systematic lymphadenectomy for lung cancer. We here describe our technique for uniportal approach by using a combination of double-jointed and endoscopic instruments.

Clinical data

A 64-year-old female presented with a 2.0 cm × 2.0 cm × 1.0 cm

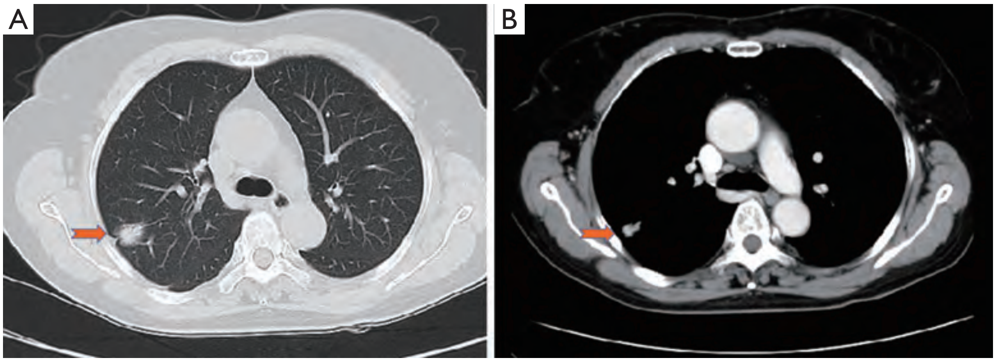

Figure 1 (A,B) A shadow in the right upper lobe.

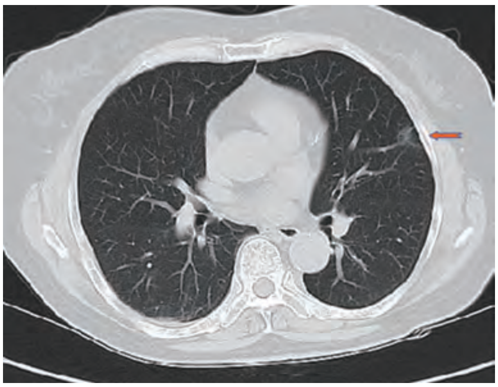

Figure 2 A GGO in the left upper lobe. GGO, ground glass opacity.

Figure 3 Uniportal cVATS lobectomy for lung cancer (3). Available online: http://www.asvide.com/articles/516

nodule in posterior segment of right upper lobe and a ground glass opacity (GGO) in the left upper lobe on computed tomographic (CT) (*Figures 1,2*) was admitted in our institute on March 16th, 2014. The patient underwent preoperative staging and cardiac and pulmonary function assessment. PET-scan indicates no signs of metastasis. Under general anesthesia with double lumen tube, the patient underwent uniportal cVATS lobectomy for right upper lung tumor on March 19th, 2014 (*Figure 3*). The final pathologic TNM staging is T1aN0M0 (IA). Regular follow up was initiated for the GGO in the left upper lobe.

Operative techniques

Patient positioning, placement of the single incision

The patient is positioned in full lateral decubitus position with slight flexion of the table at the level of the mid-chest, which allows slight splaying of the ribs to improve exposure in the absence of rib spreading. This is similar to conventional VATS procedures. All lobectomies and segmentectomies were underwent via the 5th intercostal space about 3.5-4.5 cm long. Plastic wound protector was not used now and soft tissues are retracted by silk only to prevent the lung from expanding when suction is used. The 30° 10 mm thoracoscope (5 mm ever used) is placed in the posterior part of the above incision and fixed by a rubber band (*Figure 4*).

Different stance for the operating personnel and instruments

We now use a combination of endoscopic and double-jointed instruments and some specially adapted for uniportal cVATS including long and short curved suction tube and ring forceps (*Figure 5*). An articulating endoscopic linear cutter is preferred.

The operator and the scope holder always stand anterior to the patient whether the operator stands caudally or cranially varies depending on the procedures in the lower or upper thoracic cavity. The first assistant stands

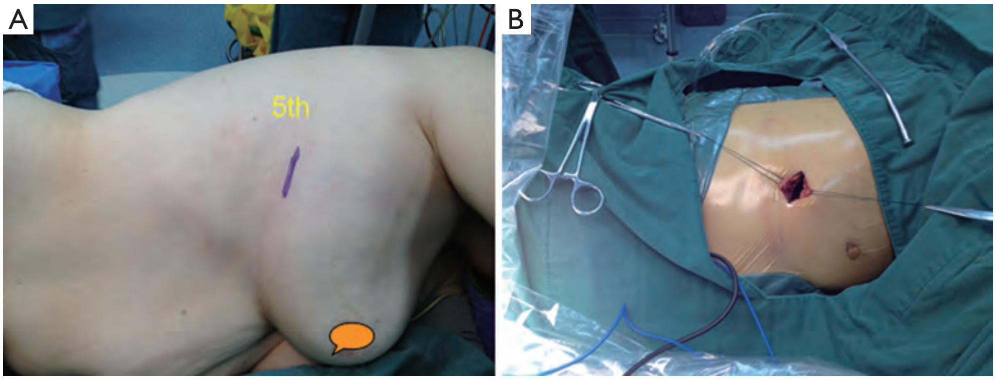

Figure 4 (A,B) The single incision is located in the fifth intercoastal space and retracted by silk.

Figure 5 A combination of double-jointed and endoscopic instruments.

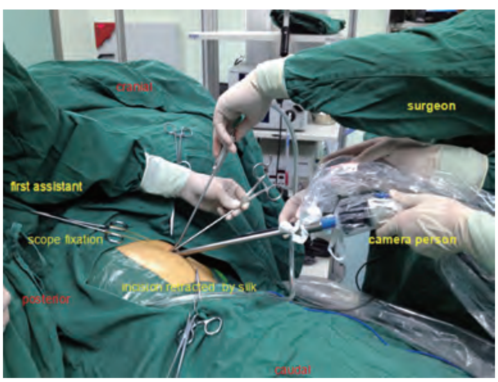

Figure 6 The intraoperative outer view showing different stance for operation personnel and instruments.

posteriorly responsible for the macro exposure. The surgeon always holds suction tube in the left hand for micro and dynamic exposure while in the right hand almost are the electrocautery or harmonic scalpel. From posterior to anterior at the incision level lies in turn the scope, the long curved ring forceps containing gauze for macro exposure, the energy devices and the suction tube (*Figure 6*).

Exploration

We begin the procedure with an exploration of the pleural cavity. The tumor is identified in the posterior segment of the right upper lobe. The frozen section analysis after wedge resection revealed infiltrating adenocarcinoma, so we proceed to right upper lobectomy with systematic lymphadenectomy.

Division and transection of truncus anterior artery

First cut open mediastinal pleura in the anterior hilum and underneath the arch of the azygos vein. Then dissect and indentify the gap between the superior pulmonary vein and truncus anterior artery. The lymph nodes are cleared at the same time. Dividing the truncus anterior artery first is often recommended in order to facilitate the insertion of the staplers for the upper lobe vein. We strongly recommend the use of silk ligation and hemolock in cases where the angle for stapler insertion is not optimal especially for the left upper lobectomy. The posterior ascending artery can be divided separately or at last together with the fissure.

Division and transection of superior pulmonary vein

The location of endostapler and the thoracoscope are interchangeable between two incisions in biportal approach. In uniportal approach, first dividing the artery is most commonly used. In unusual cases, dividing the superior vein following the truncus anterior artery and then the upper bronchus is used. Sometimes divide the minor fissure help first staple the superior vein from anterior and superior to

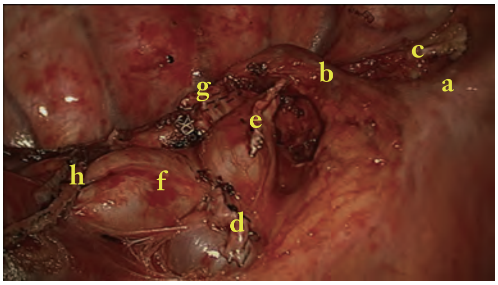

Figure 7 Surgical image after lobectomy and systematic lymphadectomy. a, superior vena cava; b, azygos vein; c, vagus nerve; d, stump of superior pulmonary vein; e, stump of truncus anterior; f, the pulmonary artery for middle and lower lobe; g, stump of right upper bronchus; h, the incisal margin of the fissure.

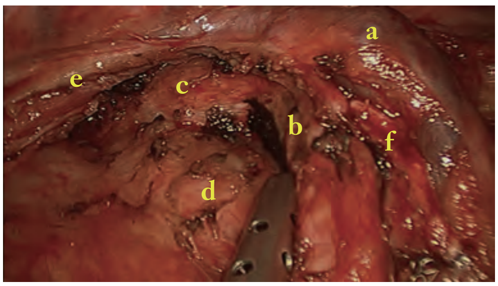

Figure 8 Surgical image after R7th lymph node dissection. a, azygos vein; b, right bronchus; c, left bronchus; d, left atrium; e, esophagus; f, stump of right upper bronchus.

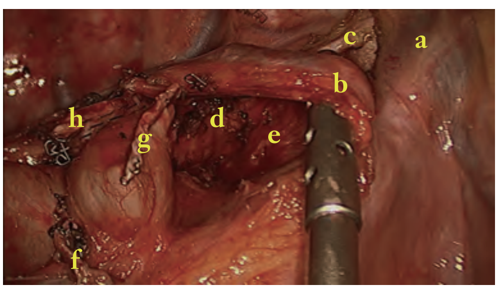

Figure 9 Surgical image after R2th and 4th lymph node dissection. a, superior vena cava; b, azygos vein; c, vagus nerve; d, trachea; e, aortic arch; f, stump of superior pulmonary vein; g, stump of truncus anterior; h, stump of right upper bronchus.

Figure 10 Single-chest tube placed in the posterior part of the incision up to the tip of the thoracic cavity.

the posterior and inferior direction.

Division and transection of right upper lobe bronchus

Identifying and clearing the lymph nodes between the upper and intermediate bronchus first. The bronchus can be transected via anterior or posterior approach by a stapler while the former is more convenient because of no need to expose the lung anteriorly.

Dissection of the horizontal fissure and the posterior halves of the oblique

The distal lymph nodes at the second carina should be dissociated to the distal end of the bronchus, and then removed *en bloc* with the right upper pulmonary lobe. The above fissures can be divided using stapler last. The lobe is extracted using a specimen retrieval bag.

Mediastinal lymph node (MLN) dissection

Move the operating table anteriorly. Systematic lymph node dissection using *en bloc* excision, instead of systematic sampling, is applied for the removal of 2, 4, 7, 8 and 9 MLNs. We use the same method as in the biportal approach (4). Cut open mediastinal pleura by a "∩" shaped incision for 7^{th}, a "⊿" above azygos vein and "–" beneath azygos vein for 2^{th} and 4^{th} which greatly simplify the *en bloc* MLNs dissection (*Figures 7-9*).

Leakage testing, intercostals nerve blockade, insert drainage tube and incision closure

The lung is re-expanded for air leakage testing for the bronchial stump and the pulmonary resection margin. Finally a single $24^{\#}$ chest tube with enough side holes is placed in the posterior part of the incision up to the tip of the thoracic cavity (*Figure 10*).

Comments

After sustaining and rapid evolution for more than two decades, VATS has permeated our thoracic surgical practice and now will develop in depth towards a next level of minimally invasive surgery (MIS) (5). Irrespective of generation gaps and diversified perception within thoracic community, more and more surgical teams are adapting to this new era. Since Diego from Spain optimize uniportal cVATS major pulmonary resections, uniportal approach development has become an increasingly popular approach to manage thoracic surgical diseases because of the reduced access trauma and better cosmesis, with several centres in Hong Kong, Taiwan, Singapore, Mainland China and Korea beginning to perform uniportal VATS major lung resections (5-9).

From June 2012, more than 160 cases of uniportal cVATS procedures have been accomplished in our center. On 16th August 2013, we performed the 1st uniportal left lower lobectomy for bronchiectasis; on 26th November 2013, the 1st bilateral same-stage single-port thoracoscopic right upper lobectomy for lung cancer and left lower lobectomy for destroyed lung caused by bronchiectasis; on 18th December 2013, the 1st uniportal right lower basilar segmentectomy; on 6th March 2014, the 1st combined uniportal right upper lobectomy and right lower superior segmentectomy for lung cancer. Until now, we have performed 33 cases of uniportal cVATS lobectomy and 16 cases of segmentectomy (unpublished).

After all, cVATS lobectomy through a single incision is a challenging technique for most thoracic surgeons especially those without experiences in biportal procedures. We surely believe Shenzhen People's Hospital experience partially combat the above obstacles and flatten the learning curve of uniportal approach.

(I) Interference of the thoracoscope, stapler and the instrumentation in and out of the thoracic cavity?

Initially, we use endoscopic and open-surgery instruments, 30° 5 mm thoracoscope and plastic wound protector. All the devices were crowded at the incision level and in and out of the thoracic cavity which require adequate patience and coordination between surgeon and camera person. Now, we abandon the use of plastic wound protector which leave much more space at the incision level. More importantly, certain modified tools are very helpful in the execution of uniportal procedures. The double-jointed and endoscopic instruments and articulating endostaplers contribute to avoid interference of the thoracoscope and the instrumentation. It is critical for adjust different stance for the operating personnel. The advantage of leaving the camera person in coordination with the surgeon anteriorly is that the vision is directed to the target tissue, bringing the instruments to address the target lesion from a straight perspective, thus we can obtain similar angle of view as for open surgery. Yet triportal VATS forces the surgeons to an unnatural eye to hand coordination compared to what they are used to in open surgery. The sagittal, caudo-cranial approach of uniportal cVATS amends this problem by letting the surgeon work along a plane he/she is mostly accustomed to in open (10). We have tried three cases of uniportal cVATS lobectomy via 3-dimension imaging system giving us the impression of raising one's head and operating "open" surgery.

(II) Whether the field of vision is enough or not without the other 1-3 ports to improve the exposure?

With experiences from biportal approach and uniportal approach for minor procedures, we learned that adequate exposure of the lung is mandatory in order to successfully access the interested lobe. The first assistant stands posteriorly responsible for the macro exposure. The surgeon always holds suction tube in the left hand for micro and dynamic exposure while in the right hand almost are the electrocautery or harmonic scalpel. The camera person leaves the scope displaying a close-up view of the target tissue. For all the team members and his devices, each does his part and work together and then contribute to good exposure.

(III) The optimal stapler introduction angle especially for upper and middle lobes resection?

Uniportal cVATS upper lobectomies are usually more difficult than lower obectomies in uniportal approach (11). The difficulty is mainly based on the sharp angles that are required to use instruments and staplers. Adjust the order for division of different hilar structures is conducive to access the target. For right upper lobectomy, the most common surgical steps are truncus anterior, upper vein, posterior ascending artery, upper bronchus and fissure which are similar to those of left upper lobectomy. The two strategies mentioned above for dividing superior pulmonary vein in unusual cases is helpful sometimes. But we strongly recommend placing hemoclips and ligation when there is no good angle for the stapler.

(IV) More importantly, the oncologic validity of uniportal procedures as well as the reduction of postoperative morbidity?

MLN dissection is the most critical point for lung cancer and is a prevalent concern relates to the ability of thoracoscopic operations to achieve adequate staging (12). To my knowledge, long-term oncologic outcomes including lymph node dissection efficacy, local recurrence, and survival after uniportal approach for lung cancer are lacking. Based on our own experience (4,8) and review from the literature (2,6,7), we surely believe MLN assessment in patients who underwent uniportal cVATS lobectomy was as effective as in those who underwent traditional cVATS lobectomy in experienced centers, with no difference in number of N2 LN stations or total number of LN stations resected.

In conclusion, uniportal cVATS lobectomy with systematic lymphadenectomy is technically safe and feasible and alternative approach to conventional thoracoscopic lobectomy in lung cancer treatment. The issues of patient acceptability, the cosmetic and oncologic results, and cost-effectiveness remain to be determined in the future through multi-institution randomized controlled trials and long-term follow-up.

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Preliminary results of single-port versus triple-port complete thoracoscopic lobectomy for non-small cell lung cancer

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Objective: To compare the feasibility and safety of single-port *vs.* triple-port complete thoracoscopic lobectomy for non-small cell lung cancer (NSCLC).

Methods: A retrospective study was conducted on 82 patients with NSCLC who underwent complete thoracoscopic lobectomy from August 2014 to October 2014 in Department of Thoracic Surgery, Fujian Medical University Union Hospital. There were 33 cases in single-port complete thoracoscopic lobectomy group (single-port group) and the other 49 ones in triple-port complete thoracoscopic lobectomy group (triple-port group). Total lymph node harvest, mediastinal lymph node harvest, dissection of mediastinal lymph node groups, operation time, intraoperative blood loss, chest drainage duration, postoperative hospital stay, postoperative one-day pain visual analogue scale (POP-VAS), and the complications were thoroughly compared between the two groups.

Results: There were no significant differences in total lymph node harvest, mediastinal lymph node harvest, dissection of mediastinal lymph node groups, intraoperative blood loss, chest drainage duration, postoperative hospital stay, and complications between the two groups ($P>0.05$). However, the operation time of single-port group was significantly longer than that of triple-port group (181.3±27.5 *vs.* 149.5±30.9 min, $P<0.05$). POP-VAS in single-port group was significantly lower than that in triple-port group (3.6±0.7 *vs.* 5.5±1.0, $P<0.05$).

Conclusions: For NSCLC, the feasibility and safety of single-port complete thoracoscopic lobectomy is similar to triple-port complete thoracoscopic lobectomy. Compared with triple-port complete thoracoscopic lobectomy, the operation time of single-port complete thoracoscopic lobectomy is longer, but its postoperative pain is gentler. As the experience accumulating, single-port complete thoracoscopic lobectomy should be popularized with its merits of minimal invasiveness.

Keywords: Single-port; triple-port; complete thoracoscopic lobectomy; non-small cell lung cancer (NSCLC)

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Introduction

Currently, lobectomy is the prior intervention to treat early-stage non-small cell lung cancer (NSCLC) (1). As a minimally invasive technique, thoracoscopic lobectomy has been widely used in thoracic surgery (2). Although single-port complete thoracoscopic lobectomy has been introduced to treat NSCLC, no literature was available as to compare its feasibility and safety with triple-port complete thoracoscopic lobectomy. Our operation team performed the first one of single-port complete thoracoscopic lobectomy in May 2014. After the preliminary exploration of 20 cases of surgery, we can coordinate by tacit agreement and the operation time tended stably. Then, we conducted a retrospective comparison study between single-port and triple-port complete thoracoscopic lobectomy for NSCLC enrolled from August 2014 to October 2014 to investigate the feasibility and safety of single-port complete thoracoscopic lobectomy.

Methods and materials

General information

A total of 82 patients with NSCLC who underwent complete thoracoscopic lobectomy from August 2014 to October 2014 in Department of Thoracic Surgery, Fujian Medical University Union Hospital were included in this retrospective study. There were 33 cases in single-port complete thoracoscopic lobectomy group (single-port group) and the other 49 ones in triple-port complete thoracoscopic lobectomy group (triple-port group). The selection criteria between single-port and triple-ports were not special or different. All patients underwent associated examinations such as thoracic computed tomography (CT), cerebral magnetic resonance imaging (MRI), skeletal emission computed tomography (ECT), and abdominal and cervical color Doppler ultrasound (CDU). Positron emission tomography-CT (PET-CT) might also need to be conducted when routine exam can't make sure to rule out the underlying metastasis. Electrocardiogram, cardiac CDU, and pulmonary function test were applied to assess cardiopulmonary function. The inclusion criteria include: (I) the patients with clinical TNM stage I-II NSCLC; (II) no thoracic surgery history; (III) the patients' cardiopulmonary function test reveal that the lobectomy is workable (The patient have the FEV_1 1.0 L and MVV 40% in the pulmonary function test as least, while the cardiac CDU show no structure deficiency. Exercise testing as well used in judging the cardiopulmonary function by more than two floors); (IV) preoperative comorbidities have been stably controlled.

Anesthesia and surgical procedure

All patients were given general anesthesia. Double-lumen endobronchial tubes (DLT) intubed in both groups, and the one lung ventilated. For single-port group, a 3.5-4.5 cm incision was made on the 4^{th} or 5^{th} intercostal space along the anterior axillary line. For triple-port group, a 1.5 cm observation port was on the 7^{th} intercostal space of midaxillary line, a 2.0-4.0 cm operation port was on the 4^{th} intercostal space of anterior axillary line and a 1.5-2.5 cm vice-operation port was on the 7^{th} intercostal space of scapular line. For peripheral lesions, pulmonary wedge resection was conducted to remove the focus. Once the resection samples were confirmed as malignant tumor by fast frozen pathology, the following standard lobectomy and mediastinal lymphadenectomy would be employed. For central lesions, lobectomy was conducted. After confirmed as malignant one, the following mediastinal lymphadenectomy would be employed. Electrocautery and ultrasonic scalpel were used to distract the vessels and bronchus. Linear stapler was used to deal with the great vessels such as pulmonary veins, pulmonary artery and so on. No definite order was made to conduct the lobectomy, which mostly depended on the development of interlobar fissure. Analgesia pumps were used for the two groups. There were no drug addiction patients. We have no previous medication. The patients' intra-operative and post-operative pain management was the same. And all the patients were given the same vein analgesic protocol, and the POP-VAS score was asked by the same anesthetist. The POP-VAS score '0' means no pain, and the '10' great pain. Indications for withdrawing the chest drainage (without vacuum) included: (I) 24 h drainage volume was less than 100 mL; (II) postoperative chest X-ray show that the left lung recruitment, and no effusion deposited. The discharge criteria in our study were that the patients recovered to normal mobility status, without obvious fever, after withdrawing the chest drainage.

Observation data

The observation data included: (I) perioperative parameters: operation time, estimated blood loss, chest drainage duration, POP-VAS, postoperative hospital stay and perioperative complications; (II) oncologic outcomes: total lymph node harvest, positive lymph node, total mediastinal lymph node harvest, and dissection of mediastinal lymph node groups .

Statistical analysis

Statistical software SPSS 16.0 was conducted to analyze the data. Quantitative data was showed as mean ± standard deviation, and independent *t*-test was used to test the group comparisons. Enumeration data was presented as rate, and chi-square test was compared. Statistical significance was set as $P<0.05$.

Results

Clinical characteristics

There were no significant differences in sex, age, tumor location, pathological type, tumor invasion, visceral pleura invasion, and tumor classification between the two groups ($P>0.05$, *Table 1*). In addition, there were no significant differences in total lymph node harvest, positive lymph

Table 1 Comparisons of clinical characteristics between single-port group and triple-port group

Items	Single-port group (n=33)	Triple-port group (n=49)	P value
Gender			0.616
Male	11	19	
Female	22	30	
Median age [range], years	62 [25-79]	59 [31-81]	0.683
Tumor location			0.854
Left upper lobe	8	9	
Left inferior lobe	6	11	
Right upper lobe	9	10	
Right middle lobe	3	5	
Right inferior lobe	7	14	
Tumor type			0.711
Adenocarcinoma	26	35	
Squamous carcinoma	5	11	
Others	2	3	
Tumor invasion			0.560
Carcinoma in situ	0	0	
Micro invasion	10	12	
Invasion	23	37	
Visceral pleura invasion			0.898
No	20	29	
Yes	13	20	
TNM classification			0.739
Stage 0	0	0	
Stage Ia	15	16	
Stage Ib	8	18	
Stage IIa	6	8	
Stage IIb	2	3	
Stage IIIa	2	4	

Table 2 Comparisons of oncologic outcome between single-port and triple-port group

Items	Single-port group (n=33)	Triple-port group (n=49)	P value
Total lymph node harvest	23.6±11.2	25.4±7.3	0.737
Positive lymph node	1.5±3.1	1.9±4.9	0.971
Total mediastinal lymph node harvest	16.2±9.2	17.2±6.5	0.731
Dissection of mediastinal lymph node groups	4.4±1.0	4.4±0.8	0.637

Table 3 Comparisons of perioperative parameters between single-port and triple-port group

Parameters	Single-port group (n=33)	Triple-port group (n=49)	P value
Operation time (min)*	181.3±27.5	149.5±30.9	0.007
Intraoperative blood loss (mL)	90.6±49.3	79.5±45.2	0.840
Chest drainage duration (d)	4.0±1.5	5.4±3.7	0.256
POP-VAS	3.6±0.7	5.5±1.0	0.000
Postoperative hospital stay (d)	6.9±4.0	7.2±3.5	0.631
Postoperative complications	3	5	0.554
Arrhythmia	1	2	
Systemic infection	1	0	
Air leakage	1	1	
Chylothorax	0	1	
Pneumonia	0	1	

*, operation time ranged from cutting till to suturing the skin, including the time of frozen section.

node, total mediastinal lymph node harvest, and dissection of mediastinal lymph node groups (P>0.05, *Table 2*).

Perioperative parameters

All patients underwent the complete video-assisted thoracoscopic lobectomy without conversion to open thoracotomy. No patient deaths occurred during perioperative period in either group. However, there were a total of eight cases with postoperative complications, three cases (one case of arrhythmia, one case of systemic infection and one case of air leakage) in single-port group (9.1%), and another five cases (two case of arrhythmia, one case of air leakage, one case of chylothorax and one case of pneumonia) in triple-port group (10.2%). There were no significant differences in complications between the two groups (P>0.05). Additionally, no significant differences in intraoperative blood loss, postoperative chest drainage duration and postoperative hospital stay were observed (P>0.05). However, operation time in single-port group was longer than that in triple-port group (181.3±27.5 *vs.* 149.5±30.9 min, P<0.05). In this study, all patients need frozen section and it occupied about 30 min. POP-VAS in single-port group was lower than that in triple-port group (3.6±0.7 *vs.* 5.5±1.0, P<0.05). The summary information was included in *Table 3*.

Discussion

Single-port thoracoscopic technique was first described to management non-complicated pleura-related disease in 2003 (3). In 2004, it was reported in pulmonary wedge resection by Rocco (4). Several years later, Gonzalez applied it in lobectomy and lymphadenectomy (5). Since then, it was applied gradually in pulmonary segmentectomy, pneumonectomy, bronchial sleeve resection and angioplasty of pulmonary arteries (6-9). However, most available literature focused on the feasibility and safety of single-port thoracoscopic lobectomy, and no studies compared those with triple-port one. The presented study retrospectively investigated the differences of clinical data between single-port thoracoscopic lobectomy and triple-port thoracoscopic lobectomy for NSCLC. Jiang compared 160 thoracoscopic lobectomies with 247 conventional open surgeries, they found no significant differences in perioperative mortality (0.6% *vs*. 2.8%) and complications (9.4% *vs*. 11.7%, P>0.05) (10). It indicated that thoracoscopic lobectomy was technically safe to treat NSCLC. Similarly in our study, the postoperative complications rates were 9.1% and 10.2% for single-port group and triple-port group respectively. However, it was no perioperative mortality in our study. Therefore, our study could conclude that single-port lobectomy was at least technically safe as well as the triple-port group.

The important focus of single-port thoracoscopic lobectomy used in treating NSCLC was on the dissection of lymph node. Jiang found no significant differences in dissection of mediastinal lymph node groups (2.4±1.5 *vs*. 2.6±1.6) and mediastinal lymph node harvest (9.8±6.2 *vs*. 9.9±5.9) between thoracoscopic lobectomy group and conventional open surgery group (P>0.05) (10). Similarly, Zhang *et al*. found no significant differences in total lymph node harvests (14.6±7.5 *vs*. 15.2±4.5) between video-assisted thoracoscopic surgery group and video-assisted thoracoscopy group (11). That was to say, the lymph node dissection by thoracoscopy was at least equivalent to that by open surgery. In the presented study, there were no significant differences in total lymph node harvest (23.6±11.2 *vs*. 25.4±7.3), mediastinal lymph node harvest (16.2±9.2 *vs*. 17.2±6.5), and dissection of mediastinal lymph node groups (4.4±1.0 *vs*. 4.4±0.8) between the single-port group and triple-port group. These results suggested that the lymph node harvest was not less than that reported in the previous studies. In other words, the dissection of lymph node by single-port thoracoscopic lobectomy met the oncologic require. However, the long-term outcomes need further studies to confirm.

The incision of single-port thoracoscopic lobectomy was located on 4^{th} or 5^{th} intercostal space along anterior axillary line, which, unlike triple-port one, canceled the observation port and vice-operation port. After comparing 20 cases of triple-port and 10 cases of single-port thoracoscopic surgery in treating interstitial lung disease, Chen *et al.* found that POP-VAS in single-port group was significantly lower than that in triple-port group (4.95±0.39 *vs*. 4.5±0.7, P=0.03) (12). Similarly in our study, POP-VAS in single-port group was significantly lower than that in triple-port group (3.6±0.7 *vs*. 5.5±1.0, P<0.05).

In the presented study, the operation time in single-port group was significantly longer than that in triple-port group (181.3±27.5 *vs*. 149.5±30.9 min, P<0.05). The reasons included: (I) all the operating instruments and thoracoscopy went through the single port, which might interfere each other, especially when the focus located near the dorsal cavity and diaphragm; (II) single-port thoracoscopic lobectomy had a strict skill requirement of qualified camera assistant to accommodate the geometrical changes of uniportal VATS (13). The camera assistant was supposed to know how to cooperate with the operator, how to allocate the space within the incision, and how to keep the camera stable. However, we believed that the operation time would be shortened with the improvement of operating instruments which can better suit single-port operation.

In summary, the feasibility and safety of single-port thoracoscopic lobectomy were similar to triple-port thoracoscopic lobectomy for NSCLC. With the development of instruments, the optimization of surgical procedure, and the accumulation of surgical experience, the operation time would likely be shortened gradually. At that time, single-port complete thoracoscopic lobectomy was supposed to be popularized with its merits of minimal invasiveness.

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Lobectomy

Thoracic surgery: single-port video-assisted thoracoscopic lobectomy

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Abstract: Single-port video-assisted thoracoscopic surgery (VATS) has been increasingly applied in clinical settings in the past two years along with the improvements in both endoscopic instruments and surgical skills. Our center began to perform single-port VATS lobectomy in May 2014 and had performed this procedure in 121 patients till January 2015. The surgical incision (3.5-4.5 cm in length) was created in the 4th or 5th intercostal space at the anterior axillary line at the diseased side. The operator standed at the abdominal side of the patient and operated using the endoscopic instruments only. The surgical steps of single-port VATS lobectomy were same as those of the triple-port VATS lobectomy. There was no fixed mode in handling the three major structures of the pulmonary lobes, and the resection sequence can be scheduled based on the development status of pulmonary fissures and on the difficulties in dissecting the relevant structures. We believe the single-port VATS lobectomy is a safe and feasible procedure and warrants further clinical applications after finishing these surgeries.

Keywords: Single-port; video-assisted thoracoscopic surgery (VATS); lobectomy

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Introduction

Single-port video-assisted thoracoscopic surgery (VATS) has been increasingly performed in clinical settings along with the wide acceptance of the concept of "minimally invasive" and the improvements in both endoscopic instruments and surgical skills. The single-port VATS was initially reported by Migliore, who applied this technique in the diagnosis and treatment of noncomplex pleural disease (1). Our center began to perform this procedure for pleural biopsy in diagnosis of pleural diseases. Subsequently, we also employed this technique for some relatively simple thoracic surgeries such as thoracic sympathectomy, pleurodesis, resection of pulmonary bullae, and resection of mediastinal tumors. In recent years, our staff received further training on more advanced VATS procedures in both domestic and foreign institutions. We began to perform single-port VATS lobectomy in May 2014 and had performed this procedure in 121 patients till January 2015. Among them 106 patients had lung cancer and received systematic mediastinal lymph node dissection.

Operation techniques

All surgical procedures were performed under general anesthesia with double-lumen endotracheal tube placement for one-lung ventilation at the healthy side. The patients were placed in a lateral decubitus position (healthy side). The surgical incision (3.5-4.5 cm in length) was created in the 4th or 5th intercostal space at the anterior axillary line at the diseased side. The incision protector was applied in the port, and no distraction device was employed to distract the ribs. The operator standed at the abdominal side of the patient, and operated using the endoscopic instruments only. The camera-holding assistant may stand at the ipsilateral or contralateral side of the operator. The surgical steps of single-port VATS lobectomy were same as those of the triple-port VATS lobectomy. There was no fixed mode in handling the three major structures of the pulmonary lobes, and the resection sequence can be scheduled based on the development status of pulmonary fissures and on the difficulties in dissecting the relevant structures. For patients with lung cancer, systematic mediastinal lymph node dissection was performed during the operation.

Single-port VATS right upper lobectomy

Before the surgery, the patient was pathologically confirmed to be with invasive adenocarcinoma at the right upper lobe. Right upper lobectomy and mediastinal lymph node dissection were then performed. After thoracic cavity exploration, the pleura facing the right superior pulmonary vein was opened in front of hilum. The station 10 lymph nodes were removed after the hilum being released. Dissociated the first branch of the pulmonary artery and then transected it using the linear stapler. Thoroughly dissociated the upper lobe branch of the pulmonary vein and then transected it with the linear stapler. The right upper lobe bronchus was then exposed. After a sufficiently long bronchus being dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected. Opened interlobular fissure to expose the posterior segmental branch of the right superior pulmonary artery, and then transected it with the linear stapler. Divided the hypoplastic lung fissures using the linear stapler, and then removed the lung specimen. Opened the upper mediastinal pleura, and then dissected the lymph node stations 2R and 4R with the electrocautery hook and ultrasonic scalpel, then removed the lymph node station 9. Finally, dissected the lymph node stations 7 and 8 using the electrocautery hook and ultrasonic scalpel (*Figure 1*).

Figure 1 Single-port VATS right upper lobectomy (2). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/508

Single-port VATS right middle lobectomy

The patient was found to be with non-peripheral hamartoma in the right middle lobe. Since it was difficult to perform wedge resection in this patient, right middle lobectomy was performed instead. After thoracic exploration, opened the anterior oblique fissure with the electrocautery hook and ultrasonic scalpel and then dissected the pleura surrounding the pulmonary vein to expose its middle lobe branch. Thoroughly dissected the three major structures in the right middle lobe, and then transected its vein, bronchus and artery one by one using the linear stapler. Finally, divided the hypoplastic horizontal fissure with the linear stapler (*Figure 2*).

Figure 2 Single-port VATS right middle lobectomy (3). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/509

Single-port VATS right lower lobectomy

The lesion was pathologically confirmed to be invasive adenocarcinoma in the right lower lobe after the pre-operative CT-guided lung puncture. Right lower lobectomy and mediastinal lymph node dissection were then performed. After thoracic exploration, released the inferior pulmonary ligament and removed the lymph node station 9 and dissociated the inferior pulmonary vein. Opened the mediastinal pleura upwards and then dissected the lymph node station 7. Dissected the oblique fissure using the electrocautery hook and ultrasonic scalpel to expose the pulmonary artery and then divided the posterior oblique fissure with the linear stapler. After the basal and dorsal segmental arteries being thoroughly dissected and exposed, transected them with the linear stapler. Transected the right

Figure 3 Single-port VATS right lower lobectomy (4). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/510

Figure 4 Single-port VATS left upper lobectomy (5). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/511

inferior pulmonary vein with the linear stapler. After the right lower lobe bronchus being dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected. Successively dissected the lymph node stations 10, 4R and 2R after removal of right lower lobe (*Figure 3*).

Single-port VATS left upper lobectomy

The lesion was pathologically confirmed to be an adenocarcinoma in the left upper lung. Left upper lobectomy and mediastinal lymph node dissection were then performed. After thoracic exploration, the inferior pulmonary ligament was dissociated till the inferior pulmonary vein level. Opened the mediastinal pleura in front of the hilum to expose the left superior pulmonary vein, followed by the removal of the lymph node station 5. Thoroughly dissociated the first branch of the pulmonary artery and then transected it using the linear stapler. Dissociated the left superior pulmonary vein and then transected it with the linear stapler. Dissected the interlobular fissure using the electrocautery hook and ultrasonic scalpel to expose the pulmonary artery and then transected two branches of the lingular segmental artery using the linear stapler. Ligatured the proximal end of the posterior segmental artery using the silk suture and then transected it with the ultrasonic scalpel. After the left upper lobe bronchus being dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected. After removal of the lung specimen, opened the mediastinal pleura in front of phrenic nerve and then dissected the lymph node station 6, followed by the dissection of the lymph node stations 7 and 8. Finally, removed the lymph node stations 10 and 4L (*Figure 4*).

Figure 5 Single-port VATS left lower lobectomy (6). VATS, video-assisted thoracoscopic surgery.
Available online: http://www.asvide.com/articles/512

Single-port VATS left lower lobectomy

In this patient with bronchiectasis in the left lower lobe, left lower lobectomy was performed. The inferior pulmonary ligament was dissociated till the inferior pulmonary vein level. Dissected the interlobular fissure using the electrocautery hook, ultrasonic scalpel were used to expose the inferior pulmonary artery. Transected the basal and dorsal segmental arteries with the linear stapler. Thoroughly dissociated the inferior pulmonary vein and then transected it with the linear stapler. After the left lower lobe bronchus being dissociated, it was clamped with the linear stapler; since the inspection showed that the residual lungs were well dilated, the bronchus was then transected (*Figure 5*).

Discussion

In recent years, the Spanish thoracic surgeon Diego Gonzalez-Rivas reported a series of lung surgeries (e.g., lobectomy, segmentectomy, pneumonectomy, sleeve lobectomy, and pulmonary artery plasty) using the single-port VATS technique in peer-reviewed journals (7-13). Also, he demonstrated these single-port VATS surgeries in many international and domestic conferences. His efforts have dramatically promoted the development of single-port VATS technique. In Asia, this technique was initially performed and reported by surgeons in China's Taiwan Province and Hong Kong SAR (14-16). In 2014, some authors in mainland China also began to report their experiences in this procedure (17-19).

The application of VATS technique marked a milestone innovation in thoracic surgery. However, there is often a long learning curve for the conversion from the conventional open surgeries to VATS surgeries. While the triple-port VATS has been widely recognized, the adoption of the single-port VATS is more challenging: during the single-port VATS, the thoracoscope and all the surgical instruments pass in and out from the same port and therefore may interfere each other. The beginners need to gradually reduce the number of incisions and thus lower the surgical risks. For instance, Gonzalez-Rivas *et al.* initially used three ports, then two ports, and finally one port when their experiences became rich enough. In contrast, Liu *et al.* directly converted from the triple-port surgeries to single-port surgeries (19). Our team has performed triple-port VATS lobectomy in over one thousand of patients, which lays a solid foundation for the conversion into the single-port surgeries. Thus, we also directly converted from the triple-port technique to the single-port technique, and it took a short time for us to be familiar with the single-port VATS lobectomy.

According to our experiences in single-port VATS lobectomy in over 100 patients: (I) incision. The incision is typically created in the 4th or 5th intercostal space at the anterior axillary line at the diseased side. We had tried to create the incision in the 4th intercostal space in our earlier cases; however, the 5th intercostal space was then found to be more feasible in most cases except in chunky individuals. The incision is 3.5-4.5 cm in length, and the incision at the muscular layer may be slightly longer than that the skin incision to facilitate the operation; (II) intra-operation cooperation. The surgery requires a close cooperation from an anesthesiologist to maintain the good collapse of the lung at the operated side. Furthermore, a close cooperation between the camera-holding assistant and the operator is particularly important. The camera-holding assistant may stand at the ipsilateral or contralateral side of the operator. According to our experiences, if the camera-holding assistant stands at the contralateral side of the operator, he/she will has less body contact with the operator and thus the operator could operate in a more comfortable way; (III) camera. The camera (30°, 10 mm in diameter) used in our surgery is same as that used in triple-port VATS. However, thinner and bendable cameras will be more feasible for the single-port VATS. The camera head is often located at one end of the incision, in particular the upper edge, so as to minimize its interference on the surgical instruments. The camera body should be vertical to the incision, so as to save the operation room. Towel clip can be used to fix the camera body, so as to increase the stability of the camera and reduce the camera-holding assistant's fatigue; (IV) surgical instruments. The surgical instruments during single-port and triple-port VATS are basically the same. However, bendable instruments such as double-joint vascular clamps can facilitate operations, reduce the interferences among instruments, and shorten the surgical duration; and (V) chest tube placement. In our earlier cases, the placement of chest tube was same as the open surgeries or triple-port lobectomy, two chest tubes were placed after upper lobe resection and one chest tube was placed after middle or lower lobe resection. They were all placed via the same incision. However, we then found such a placement method is not ideal for drainage. In two cases, pleural space drainage was performed again after the surgery. Furthermore, placement of two chest tubes in the same incision not only increases the pain but also affects incision healing. Later, we placed one chest tube (#28) in the incision. Based on the resection site, the chest tube can be placed beneath the ribs. In addition, a thin tube (Abel drainage tube) was placed in the 8th or 9th intercostal space at the posterior axillary line. The thick tube was withdrawn if there was no air leakage, and the thin tube can remained till the fluids became fewer. By doing so, the drainage effectiveness is satisfactory, and the patients feel more comfortable.

All the patients had been followed for more than one month, no perioperative major morbidity and mortality was noted. Thus, we believe the single-port VATS lobectomy is a safe and feasible procedure and warrants further clinical applications.

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History and indications of uniportal pulmonary wedge resections

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The occasion for writing this manuscript originates from the first world meeting on Uniportal VATS held in Naples on October 26, 2012. At that time, some of the world experts in the use of VATS and single-port VATS in the management of intrathoracic conditions convened to establish the status quo and the possible future perspectives of uniportal VATS as a possible adjunct to current minimally invasive techniques in the thoracic surgical armamentarium.

The concept of single port VATS dates back to 1924, when Singer presented his thoracoscope meant to help introducing more instruments through the same incision (1). Since early 2000, the current author devised a VATS technique for uniportal wedge pulmonary resection (2,3): (I) One small incision only; (II) Simultaneous introduction of instruments parallel to the videothoracoscope through an ideal cylinder wide as a surgeon's fingerbreadth (i.e., 2.5 cm) an no further dissection of the intercostal space; (III) Enhanced hand-eye coordination to visualize and operate the thoracoscope-instruments ensemble; In particular, handling the videothoracoscope is done so as to visualize the position of the instruments at any time during the procedure with simple zooming in or out of the operative field. Accordingly, in uniportal VATS pulmonary wedge resection, there is a more dynamic interpretation of the function of the thoracoscope-instruments ensemble later to be found in robotic surgery; (IV) A sagittal, caudo-cranial approach to the target lesion which allows for an increased depth of visualization. This geometric configuration renders uniportal VATS similar to the open approach and avoids the latero-lateral (i.e., baseball diamond) triangulation to address the target area in the lung. In fact, it is the creation of a dihedral or torsion angle that impedes in depth visualization by conventional, three port VATS and the uniportal approach enables the surgeon to overcome this issue (4); (V) The use of articulating instruments, both endograspers and endostaplers, described for the first time for thoracoscopic use together. In fact, cranial suspension of target parenchymal area and lateral as well as back-to-front displacement become of crucial importance to perform wedge resection.

Since its description in 2004 (2), uniportal VATS wedge resection has been used for several diagnostic or therapeutic pulmonary indications, including spontaneous pneumothorax, interstitial lung disease, and, peripheral (i.e., outer third) pulmonary nodules (5-7). Drs Brunelli and Salati will address the results of the former two indications in a separate contribution in this special issue (8). In a forthcoming publication, Rocco *et al.* will present the outcome of uniportal VATS wedge resections for pulmonary nodules in 162 patients over a 10-year period with excellent results in terms of duration of chest drain, hospital stay, and, postoperative pain (9). A no drain policy is being increasingly adopted in selected patients with the attendant repercussions on the duration of hospitalization (9). In this setting, uniportal VATS wedge resections are meant to facilitate fast tracking of patients by becoming an outpatient procedure (10). In this context, wedge resection through uniportal VATS for pulmonary nodules and pneumothorax has been recently described in the non intubated patient (11,12). Moreover, in the current biomolecular era, the availability of a procedure to obtain tissue diagnosis with the features provided by uniportal VATS wedge resection is likely to become an important adjunct both to on and off trial settings (13). To this purpose, a valuable addition to diagnostic protocols will be represented by the reliable identification of pulmonary nodules through an endoscopic ultrasound probe during uniportal VATS (14). In addition, the predominant views on lung cancer management emphasize the suitability of wedge resection for suspicious ground glass opacities, often preluding at the histological evidence of minimally invasive adenocarcinoma or adenocarcinoma in situ portending per se a favorable prognostic outlook (15). In this context, the impact of uniportal VATS in solving diagnostic dilemmas seems obvious.

In conclusion, uniportal VATS wedge resection of the lung is a versatile procedure which can be performed with very short hospitalizations and reduced postoperative morbidity and pain. From the very early days of thoracic surgery, the concept of single incision is evolving through uniportal VATS to be adapted to the new diagnostic and therapeutic challenges of the future.

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Uniportal video-assisted thoracoscopic anatomic segmentectomy

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Introduction

Anatomic segmentectomy was first described in 1939 for the treatment of benign lung conditions (1). The usual indications also include metastatic disease to the lung when ta parenchyma-sparing procedure is anticipated Nevertheless, anatomic pulmonary segmentectomy has been demonstrated to be effective in the resection of small primary lung cancers (2,3). Recently there has been a renewed interest in the use of anatomic segmentectomy, especially for patients unable to tolerate lobectomy because of poor cardiopulmonary function or severe comorbidities. Several recently published studies have shown that segmentectomy can be performed safely without compromising oncologic results (3-6).

Surgical technique

Single port VATS segmentectomy follows the principles of major pulmonary resections by VATS: individual dissection of segmental veins, segmental arteries and lobar segmental bronchus with a no rib spreading, video-assisted thoracoscopic approach. Radical mediastinal lymphadenectomy should complete the procedure (7).

The size of the utility incision is comparable to those commonly used for double-or triple-port approaches (8) and it is usually smaller than for a lobectomy, about 3-cm long. The incision is usually placed at the level of the 5th intercostal space (*Figure 1*) to get good access to upper hilar structures and lymph node stations. Adequate exposure of the lung is mandatory for successfully completion of the segmentectomy. The surgeon and the assistant must be positioned in front of the patient in order to have the some thoracoscopic vision during all these steps of the procedure and be more coordinated with the movements (*Figure 2*). Instruments must preferably be long and curved to allow the insertion of 3-4 instruments simultaneously (*Figure 3*). Optimal exposure of the lung is key to facilitate the dissection of the segmental structures and to avoid instrument interference. The HD 30° thoracoscope (the videolaparoscope with the distally mounted CCD design helps the instrumentation) is usually inserted in the posterior part of the incision and the instruments are placed below the camera. Bimanual instrumentation is crucial to achieve a successful segmental resection through a single incision VATS (*Figure 4*). A single chest tube is inserted through the same incision at the end of the procedure (*Figure 5*).

Different types of segmentectomies can be performed according the segment to be resected:

- ❖ RUL
  - Posterior segment
  - Apical segment
  - Anterior segment
  - Apico-posterior segmentectomy
- ❖ LUL
  - Lingulectomy
  - Apical trisegmentectomy (Lingula sparing)
- ❖ LLL/RLL
  - Superior segmentectomy
  - Composite basilar segmentectomy
  - Individual segments (7-8-9-10)
- ❖ RML
  - Medial
  - Lateral

The most frequent anatomic segmental resection is the

Figure 1 Incision for uniportal VATS segmentectomy.

Figure 2 Surgeons positioned in front of the patient watching the same monitor. The scrub nurse is located on the opposite side.

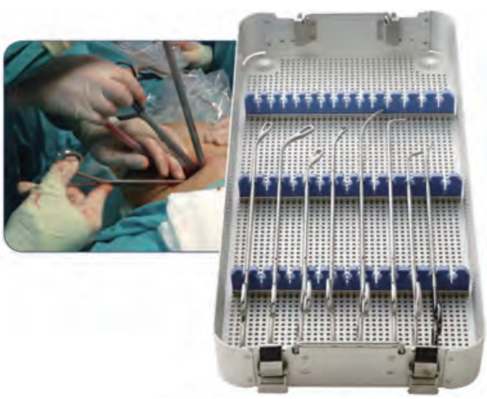

Figure 3 Uniportal of specific adapted instruments (proximal and distal articulation).

Figure 4 Bimanual Instrumentation during uniportal VATS segmentectomy (9).
Available online: http://www.asvide.com/articles/26

Figure 5 Single-chest tube placed in the posterior part of the incision.

superior lingulectomy and the superior segment of lower lobe (S6).

Left upper lobe (LUL)

A-lingulectomy (*Fgiure 6*-using staplers. *Fgiure 7*-using vascular clips)

The lingula is retracted laterally and posteriorly and the pleura overlying lingular vein (LV) is incised. The identification of LV and lower lobe vein (LLV) indicates the location to place the stapler to divide the anterior portion of major fissure (the anvil of the stapler is placed between the LLV and LV, and we pull the parenchyma into the jaws of the stapler). This maneuver facilitates the dissection and insertion of stapler to transect the vein (*Figure 6*). In some cases there is no angle for stapler insertion, then we use vascular clips, like click aV (Grena®) (*Figure 7*). Other option

Figure 6 Lingulectomy by using endostaplers (10).
Available online: http://www.asvide.com/articles/27

Figure 7 Lingulectomy by using vascular clips (Click aV) (11).
Available online: http://www.asvide.com/articles/28

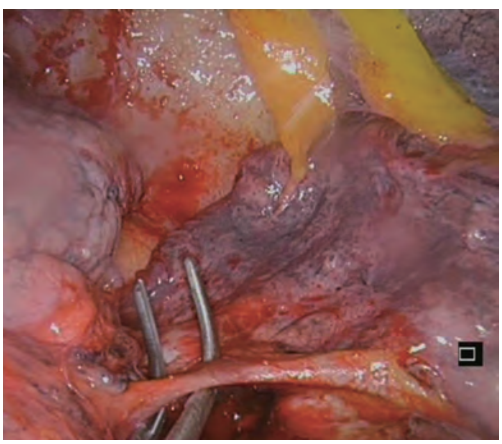

Figure 8 Dissection of lingular artery exposed in the fissure.

is to tie off the LV (the short distance from the incision facilitates this maneuver). Once the vein is divided, the lingular bronchus is exposed, dissected and stapled. When there is no angle for stapler we can transect bronchus by using scissors and close the stump at the end of the

Figure 9 Lef upper anatomic trisegmentectomy (12).
Available online: http://www.asvide.com/articles/29

Figure 10 Dissection of upper lobe vein for anterior, apical and posterior segment (13).
Available online: http://www.asvide.com/articles/30

procedure by using a stapler (*Figure 7*).

A ring forceps is then placed holding the lingula for traction, exposing the lingular artery which is then divided. Finally the intersegmental plane is divided (*Figures 6,7*). When the fissure is open, and the artery is visualized in the fissure, the dissection of the lingular artery can be performed from the fissure making easy the procedure (*Figure 8*).

B-apical trisegmentectomy (Lingula-sparing left upper lobectomy)-*Figure 9*

The anterior and apical arterial segmental branches are approached anteriorly, dissected and ligated by using stapler or vascular clips. The upper division of pulmonary vein is dissected and divided (anterior, apical and posterior veins) (*Figure 10*). The posterior artery is usually visualized after vein division and is divided by using vascular clips (we can use clips for proximal control and energy sealant devices for distal division)

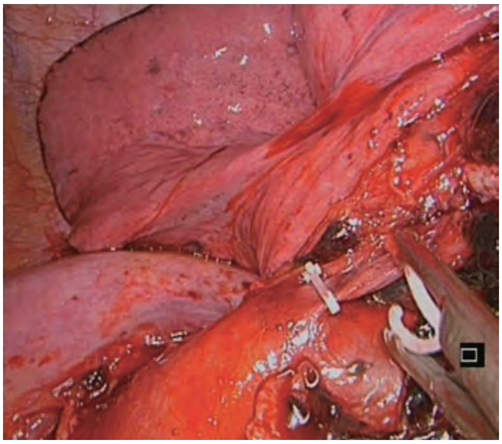

Figure 11 Division of posterior ascending artery during left upper lobe trisegmentectomy by using vascular clips.

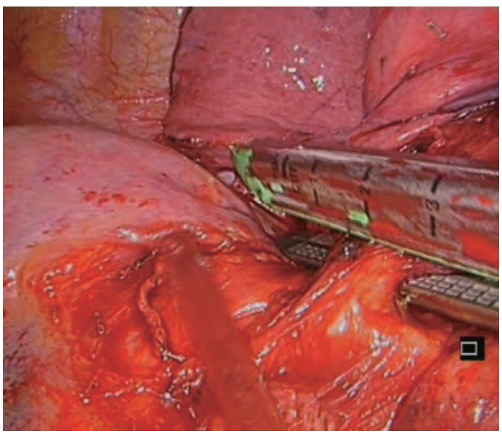

Figure 12 Division of segmental bronchus during left upper trisegmentectomy.

Figure 13 Superior segmentectomy left lower lobe (S6) (14). Available online: http://www.asvide.com/articles/31

Figure 14 Division of segmental artery during right lower lobe superior segmentectomy.

(*Figure 11*). The trisegmental bronchus is easily visualized after ligation of the segmental vein and arteries. Care must be taken during this dissection to avoid injury of lingular artery. After the bronchus is stapled (*Figure 12*) and divided the parenchymal resection is then completed through the segmental plane by using staplers (*Figure 9*).

Lower lobe (LLL-RLL)

A-superior segment lower lobe-*Figure 13*

The resection of the superior segment (S6) of lower lobe is easy because of the constant anatomical landmarks. The segmentectomy is done differently depending whether the fissure is complete or not. If fissure is complete we try to expose the superior segment artery in the fissure. To staple the artery we use a vascular clip (click aV, Grena®) or an endostapler (*Figure 14*) (7).

With a long ring forceps we retract the lower lobe and cut the pulmonary ligament to find the segmental vein (V6) for dissection and division by using a clip or a stapler. We dissect and expose the superior segmental bronchus and we staple it in the same way as mentioned for the vein (*Figure 15*). The last step is to divide the intersegmental plane (*Figure 16*) and remove the segment in to a protective bag (*Figure 13*).

Regarding segmentectomies with incomplete fissure or with no visible artery the procedure must be different. The preferred method does not involve dissection within the fissure in order to minimize postoperative air leaks. The resection must be performed from bottom to top, leaving the fissure stapling as the last step (fissureless technique). After cranial retraction of the lobe, the sequence of the dissection should be: inferior pulmonary ligament; segmental vein; segmental bronchus, segmental artery and intersegmental

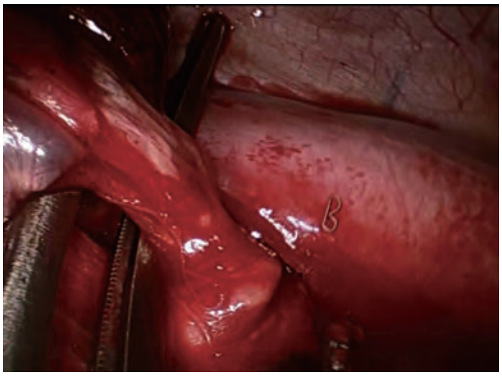

Figure 15 Division of segmental bronchus during left lower lobe superior segmentectomy.

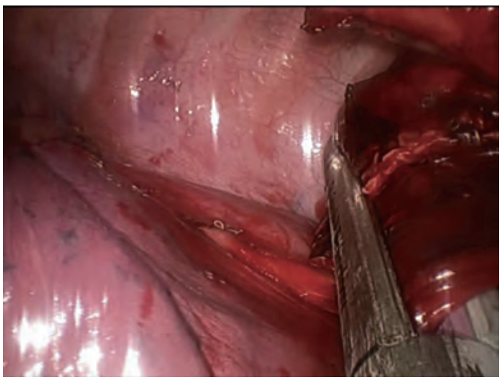

Figure 16 Intersegmental plane stapler division during left lower lobe superior segmentectomy.

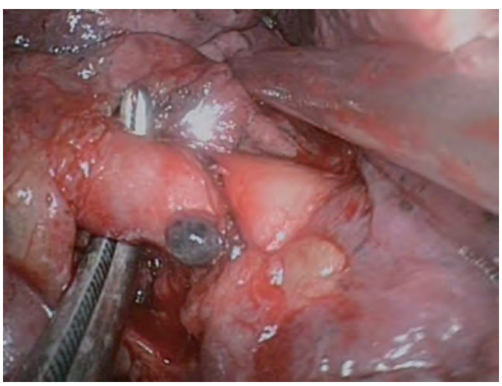

Figure 17 Division of basilar artery during right lower lobe basilar segmentectomy (artery exposed in the fissure).

plane. Once the segmental bronchus is stapled, the inflation of the lobe delimits the intersegmental plane.

B-basilar segmentectomy

Removal of 4 segments in the right lower lobe (S7-S8-S9-S10)

Figure 18 Division of segmental vein and basilar artery during right lower lobe basilar segmentectomy (15).
Available online: http://www.asvide.com/articles/32

or 3 segments in the left lower lobe (S7-S8-S9) sparing the apical segment (S6) is called basilar segmentectomy. These segments are usually removed together since they depend from a single bronchus.

When the fissure is open the procedure is easy, and the basilar artery can be easily dissected in the fissure (*Figure 17*), and divided. After division of the basilar segmental vein (*Figure 18*), the basilar segmental bronchus (the most difficult part of the operation) is dissected and stapled. The intersegmental plane is completed last.

When performed stepwise in a caudo-cranial fashion, extra care must be taken to correctly identify the segmental structures. Once the inferior segmental vein has been divided, the lower lobe basilar segmental bronchus is exposed, dissected and divided from its inferior aspect to its bifurcation with the middle lobe bronchus on the right side or the upper lobe bronchus on the left side. Dissection of the bronchus with development of the plane between the bronchus and artery is performed with visualization of the artery. We recommend the removal of the interbronchial lymph nodes to better define the landmarks. The basilar segmental arterial branch to the lower lobe is identified (*Figure 19*) and divided and the intersegmental plane is stapled (*Figure 20*).

Other more complex segmentectomies

The anatomic resection of a single segment like the anterior, posterior or apical segment of RUL (*Figure 21*) (*Figure 22*), medial or lateral segment of RML and 7, 8 or 9 segment of lower lobe (*Figure 23*) is a complex procedure. The difficulty of thoracoscopic anatomic resection of a single segment is mainly based on the division of the segmental plane and the

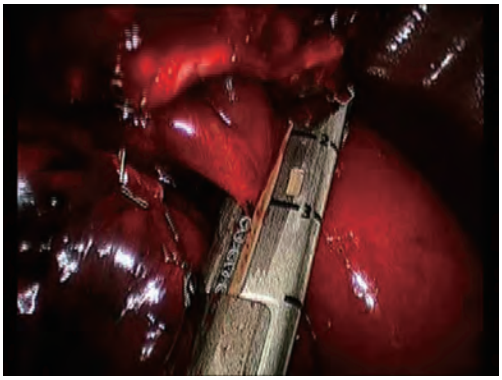

Figure 19 Division of basilar artery during left lower lobe basilar segmentectomy from down to up (fissureless technique).

Figure 21 Right upper lobe apical antomic segmentectomy (16). Available online: http://www.asvide.com/articles/33

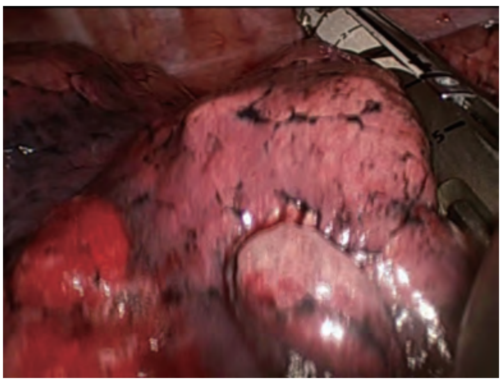

Figure 20 Division of intersegmental plane during left lower lobe basilar segmentectomy.

individual dissection of single segmental structures.

While the bronchial anatomy is very consistent, the arterial anatomy is variable. We always have to keep in mind that venous anatomy can drain multiple segments. It is very important to define the intersegmental plane. The ventilation of the lung delimitate the segmental plane once the segmental bronchus has been divided. To avoid collateral ventilation some authors have suggested following a reverse inflation-deflation technique, stapling the segmental bronchus once the whole lung is ventilated in order for the inflated segment to remain readily visible after deflation (6).

Discussion

Uniportal VATS segmentectomies are usually more difficult than lobectomies. Most of reported segmentectomies are related to segments that can be easily excised, such as the lingular, superior, and basilar segments (1-3). In these segments the parenchyma can be separated by using staplers. To remove other segments via uniportal VATS, the procedure is more difficult but feasible. The preoperative evaluation of branches of pulmonary veins (8) or trans-bronchial indocyanine green injection and the use of infrared thoracoscope helps the intersegmental plane identification of complex segmentectomies (7). Since June 2010 we have performed 17 uniportal VATS anatomic segmentectomies. Lingulectomy for lung metastasis was the most frequent operation. The mean surgical time was 94.5±35 minutes (40-150 minutes). The mean number of nodal stations explored was 4.1±1 (range, 0-5) with a mean of 9.6±1.8 (range, 7-12) lymph node resections. The median tumor size was 2.3±1 cm (range, 1-4 cm).The median chest tube duration was 1.5 days (range, 1-4 days) and the median length of stay was 2 days (range, 1-6 days).

In our experience, there was no conversion of uniportal segmentectomy to conventional VATS or open and this outcome is a direct consequence of greater skills acquired with experience (17).

Compared to segmentectomy by thoracotomy, uniportal thoracoscopic segmentectomy was associated with a shorter length of stay and with equivalent morbidity and mortality (18). The procedure has some difficulties: it is technically demanding and more challenging than lobectomy, requiring a perfect knowledge of the bronchial and arterial relationships and possible anomalies of arterial branches. Once bronchovascular structures have been divided, the division of the intersegmental plane is the most difficult step.

The advantage of using the camera in coordination with the instruments is that the vision is directed to the target tissue, bringing the instruments to address the target lesion

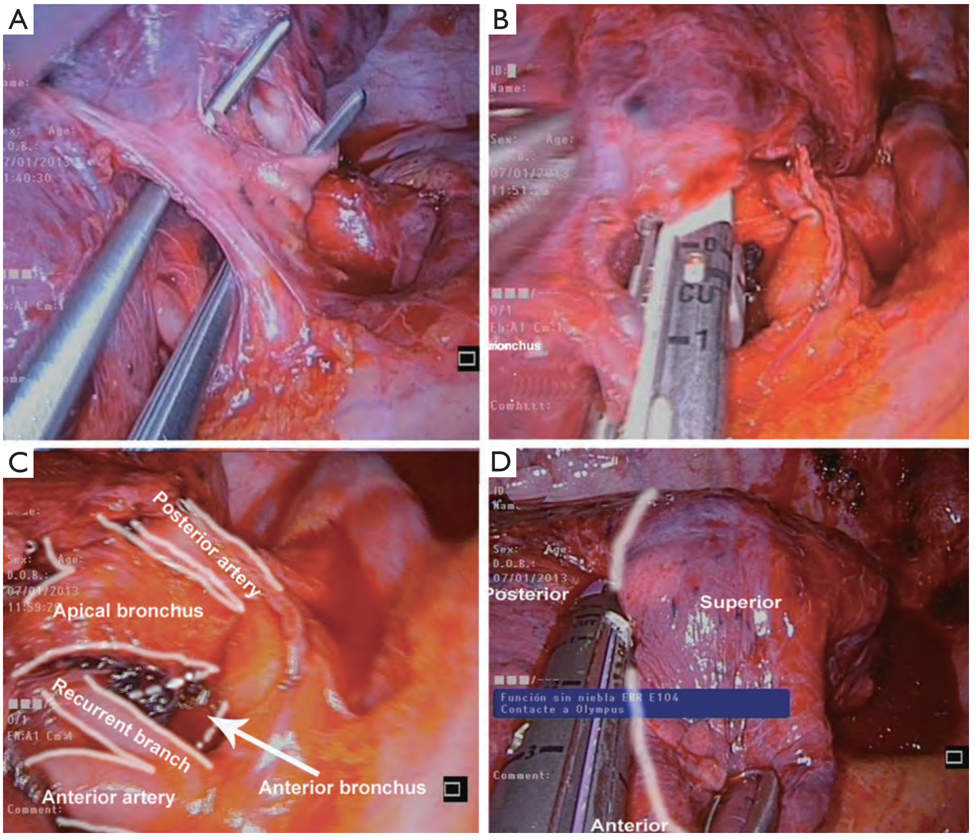

Figure 22 Right upper lobe apical segmentectomy. (A) Apical artery; (B) Apical vein; (C) Apical bronchus; (D) Intersegmental plane.

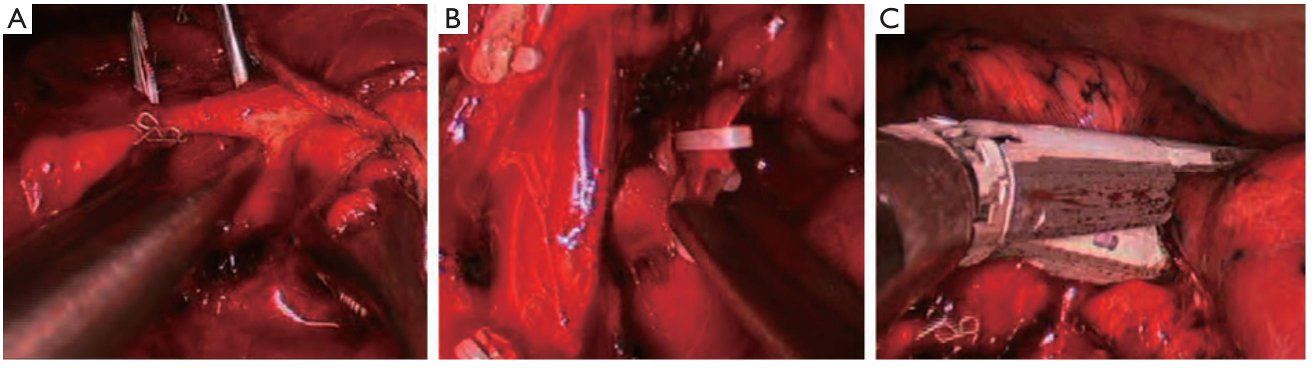

Figure 23 Segmentectomy of 7, 8 basal segments left lower lobe. (A) Segmental artery; (B) Segmental vein; (C) Intersegmental plane.

from a sagital perspective, thus we can obtain similar angle of view as for open surgery (19). Instruments inserted parallel to videothoracoscope mimic inside the chest maneuvers performed during open surgery.

Another potential advantage of this approach could be a reduction in post-operative pain. There could be several explanations for this issue: only one intercostal space is involved and avoiding the use of a trocar could minimize the risk of intercostal nerve injury (during instrumentation, we try to apply the force over the superior aspect of the inferior rib through the utility incision). We have observed that patients operated by conventional VATS sometimes refer their pain towards the posterior and inferior incision, and only a few times refer pain in the utility incision. We strongly believe that this pain could be explained by trocar compression over the intercostal nerve during camera movement. Some authors have reported less postoperative pain in patients operated on for pneumothorax through a single-incision, in comparison to the classical triple-port approach (20). Further studies will be required to demonstrate that there is less pain with single incision techniques, compared to conventional VATS for segmentectomy.

Conclusions

Single-port VATS segmentectomy is a feasible and safe procedure in experienced VATS centers. The uniportal thoracoscopic segmental resection should be performed by skilled VATS surgeons and is a good option for small primary tumors, metastasic lesions or benign conditions not suitable to be performed by wedge resection.

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Single incision video-assisted thoracoscopic anatomic segmentectomy

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Introduction

Anatomic segmentectomy was first described in 1939 by Churchill and Belsey (1). Although segmentectomy is usually indicated for benign lesions or for metastasis when the goal is resecting the lesion while sparing parenchyma, anatomic segmentectomy has also been demonstrated to be effective in the resection of small lung cancers (2). Recently, due to the increasing incidence of small lung tumors, there has been renewed interest in the use of anatomic segmentectomy, especially for patients unable to tolerate lobectomy. Several recently published studies have shown that segmentectomy can be performed safely without compromising oncologic results (3,4). Video-assisted thoracoscopic surgery (VATS) is currently a better choice than thoracotomy for segmentectomy. Although most surgeons use three to four incisions, the surgery can also be performed using only one (5).

Surgical technique

Single-incision VATS segmentectomy follows the principles of major pulmonary resections by VATS: individual dissection of segmental veins, segmental arteries and the segmental bronchus, as well as complete mediastinal lymphadenectomy with a video-assisted thoracoscopic approach and no rib spreading.

The size of the incision is comparable to the utility incision commonly used in a double- or triple-port approach and is usually smaller than that for a lobectomy, approximately 3 cm long (6). The incision is usually made at the level of the 5th intercostal space to provide access to upper hilar structures and lymph node stations. Both the surgeon and assistant are positioned anteriorly to the patient in order to have the same thoracoscopic vision during all the steps of the procedure and be more coordinated with the movements. Instruments with a proximal and distal articulation are preferable as they reproduce the same experience as a conventional instrument but also allow the insertion and manipulation of three to four instruments simultaneously (Scanlan International, Inc., MN, United States).

Optimal exposure of the lung is crucial for facilitating the dissection of the segmental structures and to avoid instrument malposition. The 30º high-definition thoracoscope is usually placed in the posterior part of the incision and the instruments are placed below the camera. Bimanual instrumentation is crucial to achieve a successful segmental resection through a single port VATS. A single chest tube is placed at the end of the procedure through the same working incision.

In this video we show seven different anatomic segmentectomies performed through a single incision thoracoscopic approach, including: (I) Right upper lobe apico-posterior segmentectomy (S1-S2); (II) Right upper lobe apical segmentectomy (S1); (III) Left upper lobe trisegmentectomy (S1-S2-S3); (IV) Left lower lobe superior segmentectomy (S6); (V) Right lower lobe basilar segmentectomy (S7-S8-S9-S10); (VI) Anatomic lingulectomy using vascular clips (S4-S5); and (VII) Anatomic lingulectomy using endostaplers (S4-S5).

Right upper lobe apico-posterior segmentectomy (S1-S2)

Exposure of the vein is achieved by retracting the upper lobe posteriorly. The common apico-posterior segmental vein is dissected as distal as possible and divided with an endostapler.

The upper lobe is then retracted upward and forward in order to expose the apical artery which is dissected and divided using a stapler.

When the fissure is complete, the posterior ascending artery can be easily dissected and divided from the fissure. When the fissure is incomplete, a fissureless technique is performed in order to expose the posterior artery. The anterior portion of the intersegmental plane is divided using a stapler to expose the posterior ascending artery and the bronchus. A posterior segmental artery is then discovered. A vascular clip for proximal transection and ultrasonic energy device to do the distal division. Now the trifurcation of the upper lobe bronchus is exposed. The apical and posterior lobar bronchus are dissected separately and freed from its attachments to the upper lobe. A loop is passed around the two segmental branches and both bronchus are cut with an endostapler.

Finally, the parenchyma is divided by placing the stapler in the border between the apico-posterior and the anterior segment plane. The specimen is inserted into a protective bag and retrieved through the single incision.

Right upper lobe apical segmentectomy (S1)

The second video shows an apical segmentectomy of a 2.5 hilar tumor not possible to remove with a wedge resection. The first step is to identify the mediastinal trunk of the artery. Once the segmental vein for segment 1 is dissected we use a vascular stapler to divide it. We usually insert the staplers through the inferior part of the incision and the camera is normally placed above.

By using scissors we release the adherences of the anterior branch of the artery from the inferior portion of the tumor.

We divide the apical artery using vascular clips. The anterior portion of the intersegmental plane is divided by a 60 mm stapler. After identification of the branches for the anterior and posterior segment, we continue with the division of the parenchyma by placing the staplers above the stumps. In this particular case, the apical bronchus is divided through the intersegmental plane due to the benign nature of the tumor.

Left upper lobe trisegmentectomy (S1-S2-S3)

The third case shows a trisegmental resection of left upper lobe (also known as lingular-sparing lobectomy). The view of the apico-anterior arterial trunk is direct, and this branch is approached anteriorly, dissected and ligated by a stapler. The upper division of the pulmonary vein is dissected and divided [anterior, apical and posterior veins, preserving the lingular vein (LV)]. The trisegmental bronchus is easily visualized after ligation of the segmental vein and arteries, with care taken during this dissection to avoid injury of the lingular artery. After the bronchus is stapled, the posterior artery is usually visualized and is then divided by using vascular clips. The last step is to divide the parenchyma through the segmental plane by using staplers.

Left lower lobe superior segmentectomy (S6)

The resection of the superior segment (S6) of the lower lobe is straightforward as there are consistent anatomical landmarks. The conduct of segmentectomy will vary slightly depending on whether the fissure is complete or not. In this case, the fissure is complete so the superior segment artery is exposed through the fissure. The artery is easily divided by using an endostapler.

With a long lung grasper, the lower lobe was held and the pulmonary ligament was cut to find the segmental vein for dissection, followed by division by using a vascular stapler. We dissect and expose the superior segmental bronchus and it was stapled in the same way as mentioned for the vein. The last step is to divide the intersegmental plane and remove the segment using a protective bag.

Right lower lobe basilar segmentectomy (S7-S8-S9-S10)

Removal of four segments in the right lower lobe (S7-S8-S9-S10) while sparing the apical segment (S6) is called basal segmentectomy. These segments are usually removed together since they are dependent on a single bronchus.

After identification of the artery in the fissure, a stapler was placed above to better expose the artery. The anterior portion of the fissure is stapled, which allowed division of the basilar artery using a stapler.

The next step is dissection of the basilar segmental vein. The direct view provided by the single incision approach allows excellent visualization of the plane between the superior segmental vein and basilar vein. The basal vein was divided with a stapler. Once the inferior segmental vein has been divided, the lower lobe basilar segmental bronchus is exposed, dissected and divided from its inferior aspect to its bifurcation with the middle lobe bronchus on the right side or the upper lobe bronchus on the left side. Dissection of the bronchus with development of the plane between the bronchus and artery is performed with visualization of the artery. We recommend the removal of the interbronchial lymph nodes to better define the anatomy. The intersegmental plane is completed last. The lung is inflated to confirm an adequate ventilation of the superior segment of the lower lobe.

Anatomic lingulectomy using vascular clips (S4-S5)

The next video shows two different ways to perform an anatomic lingulectomy. In the first video we used vascular clips for vessels. The lingula is retracted laterally and posteriorly and the pleura overlying the LV is incised. In this particular case, the tumor was involving part of the lower lobe in the fissure, so the first step was to divide the anterior portion of the fissure from an anterior view.

The identification of the LV, lower lobe vein (LLV) and the artery indicates the location to place the stapler to divide the anterior portion of major fissure. The anvil of the stapler is placed between the LLV and LV, and above the upper part of the artery, and the parenchyma is retracted into the jaws of the stapler.

This maneuver facilitates the dissection of the LV. A ring forceps is then placed while holding the lingula for traction, exposing the small recurrent lingular artery which is then divided with clips. Once this small vessel is divided, the lingular bronchus is exposed. In this particular case there was no angle for the stapler, so the bronchus was transected using scissors and the stump was closed using a stapler at the end of the procedure. Subsequently the main lingular artery is exposed and divided by using vascular clips.

Finally the intersegmental plane is divided and the stump of the bronchus with is closed with an endostapler at the end of the procedure.

Anatomic lingulectomy using staplers (S4-S5)

The last segment of this video shows a non-edited lingulectomy using endostaplers. The fissure is complete so the lingular artery is easily exposed, dissected and divided in the fissure by using a vascular stapler. The LV is dissected and divided by using a 30 mm vascular stapler. Once the vein is divided, the lingular bronchus is exposed and transected using endostaplers. The last step is to divide the intersegmental plane.

Comments

Uniportal VATS segmentectomies are usually more difficult than lobectomies. From June 2010 to February 2014, we have performed 28 uniportal VATS anatomic segmentectomies. The mean surgical time was 89.5±3 minutes (range, 40-150 minutes). The mean number of nodal stations explored was 4.1±1 (range, 0-5) with a mean of 11.5±1.8 (range, 7-25) lymph node resections. The mean tumor size was 2.24±1 cm (range, 1-4 cm). The median chest tube duration was 2 days (range, 1-6 days) and the median length of stay was 2 days (range, 1-6 days).

None of these segmentectomy cases required conversion, which may be attributed to experience in uniportal lobectomy, including vascular dissection, the management of fissures, as well as experience in more complex cases (lobectomy after induction therapy, hilar calcification, and pneumonectomy) (7).

Comparing segmentectomies by thoracotomy with uniportal thoracoscopic segmentectomies, the latter was associated with a shorter length of stay and with equivalent morbidity and mortality (8).

The advantage of using the camera in coordination with the instruments is that the vision is directed to the target tissue, addressing the target lesion from a straight perspective and thus obtaining a similar angle of view as with open surgery. In standard three-ports VATS, the geometric configuration of a parallelogram generates interference with the optical source, creating a plane with a torsion angle not favorable on the flat two-dimensional vision of currently available monitors (9).

Another potential advantage of this approach could be a reduction in postoperative pain, although this has not yet been demonstrated. There could be several explanations for this issue: only one intercostal space is involved and avoiding the use of a trocar could minimize the risk of intercostal nerve injury. During instrumentation, force is applied only over the superior aspect of the inferior rib through the utility incision.

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Benefits of awake uniportal pulmonary resection in a patient with a previous contralateral lobectomy

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Abstract: Surgical resection of a contralateral recurrence of non-small cell lung cancer (NSCLC) is indicated in patients without evidence of disseminated disease and considered functionally operable. General anesthesia and double-lumen intubation involves one lobe ventilation in a patient treated with a previous lobectomy, thus increasing the risks of ventilator-induced injuries and the morbidity. Awake procedures facilitate the surgery decreasing the anesthetic and surgical times, keeping the diaphragm motion and diminishing the ventilator-induced injuries into the remaining contralateral lobe. We present a 43-year-old woman with a previous left-lower lobectomy for a 3.1-cm mucinous adenocarcinoma 15 months before without nodal involvement, who presents a right-lower lobe 8-mm cavitated nodule, with evident radiological growth and fine-needle aspiration concordant with mucinous adenocarcinoma. We suggest an awake procedure with locoregional epidural anesthesia.

Keywords: Thoracoscopy/VATS; lung cancer surgery; anesthesia

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A 43-year-old woman with past history of left-lower lobectomy for a mucinous adenocarcinoma pathologic stage IB without nodal involvement, presents in a follow-up CT scan a 6-mm nodule in the upper segment of the right-lower lobe, growing to 8 mm in a later control. A fine needle aspiration is performed with diagnosis of mucinous adenocarcinoma concordant with a contralateral recurrence. Pulmonary function tests with 85% FEV1 and 73% DLCO enable surgery. We are developing two clinical trials comparing the standard general anesthesia with double-lumen orotracheal intubation and the awake nonintubated with locoregional epidural anesthesia, for both pulmonary metastasis and interstitial lung disease. In this specific case, we proposed an awake procedure in order to avoid double-lumen intubation and deleterious adverse effects of mechanical ventilation in the remaining left-upper lobe during the surgery, that we hypothesized could adversely affect the postoperative course of the patient in terms of pulmonary complications. After the proposal explaining the advantages and disadvantages of both ways of proceeding, the patient accepted the nonintubated one, so she signed a written informed consent.

A thoracic epidural catheter was inserted at the T4-T5 level with a single injection of 15 mL of bupivacaine 0.5% and left in place during the procedure, until 24 hours after the operation. Pressure of carbon dioxide ($PaCO_2$) and oxygen (PaO_2) were measured during the surgery. Midazolam and fentanyl were administered intravenously to keep the patient calm but under conscious sedation throughout the procedure, so she could communicate with the anesthetist and the surgeon. She was placed in left lateral decubitus position and continued breathing spontaneously. An intranasal multiperforated catheter was inserted with local anesthesia and left above the vocal cords to elevate the oxygen concentration in the inspired air. This device was used because it is very easy to put, well tolerated and it doesn't increase inspiratory flow. Before the incision, the O_2 pressure in arterial blood was 400 mmHg, and the CO_2 pressure was 44 mmHg.

Then we performed a 4-cm single incision in the 5th intercostal space (uniportal VATS) resulting in a surgical pneumothorax with excellent lung collapse owing to the

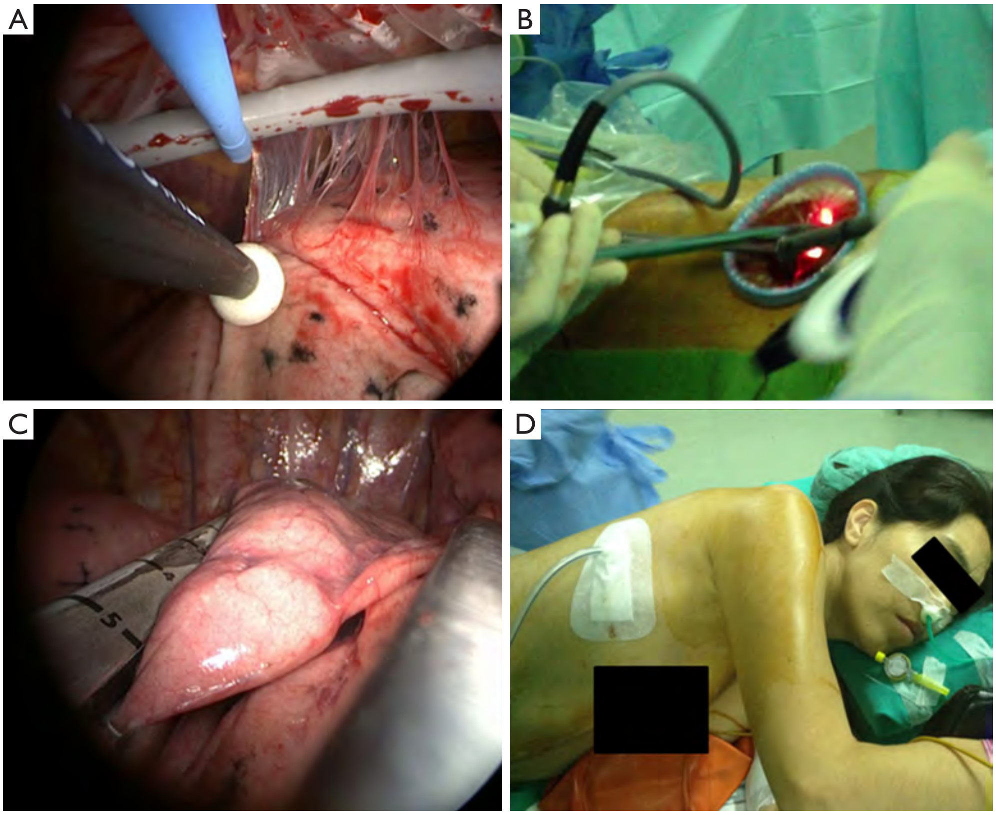

Figure 1 (A) Liberating adhesions through the incision with electrocautery; (B) working through the single incision of 4 cm with the camera, lung forceps and EndoGIA black load (Autosuture, Norwalk, CT); (C) performing the resection of the right-lower lobe nodule with oncologic margins after palpating the lesion; (D) the patient is mild-sedated with the intranasal multiperforated catheter breathing spontaneously.

absence of underlying pathology in her lungs. There were adhesions from the right upper and middle lobes to the chest wall. Some of the adhesions were liberated with monopolar electrocautery and the adhesions in the most-upper part were left in place to keep the apex without complete collapse (*Figure 1A*). After the surgical pneumothorax the O_2 pressure in arterial blood kept in 446 mmHg, and the CO_2 pressure elevated to a moderate hypercapnia degree (56 mmHg) without clinical repercussion. There were no changes in the heart rate, blood pressure and respiratory rate (*Table 1*).

After visualization and palpation of the nodule in the right-lower lobe, we performed a wide wedge resection of the lesion (EndoGIA black load, Autosuture, Norwalk, CT) and the specimen was removed with a specimen bag (*Figure 1B,C*). Intraoperative analysis showed an adenocarcinoma with more than 1-cm free margin. There were no other lesions and no lymph nodes enlarged. A 24 Fr chest drain was inserted through the single-port and connected to suction under 10 cm H_2O while the patient was asked to breathe deeply and cough to completely reexpand the lung. Operative time was 30 minutes, and total anesthesia time was 40 minutes, with a global in-operation time of 70 minutes. Intranasal catheter was well tolerated (*Figure 1D*) and kept the oxygenation high, while hypercapnia was completely asymptomatic.

The patient stayed in an intermediate care unit for 24 hours, without evidence of air leak, and the chest X-ray showed complete lung reexpansion since 2 hours after the operation. In the 6 hours control heart rate, blood pressure and respiratory rate were kept in normal values. O_2 pressure in arterial blood was kept in 87 mmHg with nasal cannula at 3 lpm, and CO_2 pressure decreased to normal values immediately after the surgery (38 mmHg). There was no pain with the epidural catheter (visual analogue scale), and the patient resumed oral intake in the evening. A total of 24 hours after the procedure, she was moved into the hospitalization unit, the drainage was removed without air leak and epidural catheter was changed by oral analgesia,

Table 1 Operative and postoperative parameters

Parameters	Supine decubitus	Lateral decubitus	Surgical pneumothorax	Chest wall closed	24 hours	Discharge
Heart rate (bpm)	86	68	83	70	73	80
Blood pressure (mmHg)	96/72	112/74	120/80	110/82	116/75	120/70
Respiratory rate (/min)	12	12	12	13	15	16
% O_2	60	60	80	80	21	21
PaO_2 (mmHg)	227	253	87	345	82	78
$PaCO_2$ (mmHg)	53	53	60	60	42	44
pH	7.32	7.32	7.28	7.26	7.39	7.40
PAS	–	–	–	–	3	2
Pain location	–	–	–	–	Drainage	Drainage

bpm, beats per minute; % O_2, oxygen inspired fraction; PaO_2, oxygen blood partial pressure; $PaCO_2$, carbon dioxide blood partial pressure; pain analogue scale [0-10].

and with a chest X-ray showing complete lung reexpansion she was discharged 1 day after the surgery. In the late control she had O_2 pressure in arterial blood of 94 mmHg without any device, and no changes in CO_2 pressure (38 mmHg). We systematically quantify the satisfaction level according to a subjective four degree scale (excellent, good, tolerable, bad), and this patient expressed excellent tolerance without any complaint.

Final pathologic exam confirmed the recurrence nature of the lesion, with an 8-mm mucinous adenocarcinoma concordant to the former one, free margins of 1.3 cm.

In the postoperative visit to the clinic three weeks later she had no pain, and she expressed high level of satisfaction with the procedure, with radiological and clinical excellent parameters.

Discussion

Awake thoracic procedures have gained approval in the last years as an alternative to the standard procedures performed under general anesthesia and double-lumen intubation (1). Pioneers surgical teams as E. Pompeo and colleagues have shown feasible and safe to perform pulmonary biopsies, lung-volume reduction surgery of the emphysematous patient, sympathectomies for hyperhidrosis and pulmonary resections, as many other groups do. Even some groups have proved feasible to perform major pulmonary resections like lobectomies and also thymectomies in the awake patient (2).

Indications for awake procedures are getting elucidated after accumulating experience, but it is essential that the surgical and anesthetic team understand the physiologic changes occurring during the awake procedure in a spontaneously breathing patient, the changes in the operating maneuvers, and the potential complications of the procedure, and working with a skilled nursing team used to awake operations (3). An emergency protocol has to be well designed before venturing (*Table 2*). One of the main aspects of suggesting these procedures consists on strictly selecting the patient, because not all the patients are psychologically prepared and if the patient gets nervous and anxious the operation can be difficult (4).

The potential advantages of these procedures include minimizing the ventilator-induced injuries (barotraumas, atelectrauma, volutrauma) thus decreasing the risks of respiratory postoperative infections, special in patients with pulmonary underlying disease. Avoiding the effects of general anesthesia on the cellular and humoral immune response, can potentially diminish the incidence of postoperative infections and even it has been suggested the possibility of decreasing the chance of tumor progression (5). Uniportal VATS approach, in experienced hands, allows to perform the procedure without extending the operative time, and seems to reduce postoperative pain unless there is still a lack of clinical trials comparing with normal VATS approaches.

In this patient we suggested an awake surgery because she had been previously performed a contralateral lobectomy. We hypothesized that avoiding mechanical ventilation in the remaining lobe could prevent potential damages, so the remaining lobe was spontaneously ventilated with high oxygen concentration, keeping the diaphragm motion. It only appeared what has been called “permissive hypercapnia”, but the patient didn’t experience dyspnea. She could also resume normal activities like walking and oral

Table 2 Emergency protocol

Criteria for a conversion to thoracotomy or general anesthesia
Respiratory acidosis with pH <7.1, with taquipnea (higher than 30 rpm)
Hypoxemia (pO2 <60 mmHg) with no improvement despite high flow oxygenation nor non invasive-ventilation
Continuous cough with no improvement despite aerosolized lidocaine nor vagal blockade
Anxiety attack with no improvement with sedation
Moderate to major bleeding, uncontrollable with the single incision/awake procedure, which requires more important maneuvers (pulmonary artery clamp, primary suture, reconstruction)
Non adequate lung collapse which make lung mobilization and resection difficult
Adhesions in more than 50% of the lung surface which lengthens the procedure or makes the procedure difficult
Impossibility of nodule palpation through the single-incision or the awake fashion (small nodules, central location, excessive cough reflex without improvement with vagal blockade)
Pulmonary lesions requiring major lung resection (lobectomy, pneumonectomy) through the single-incision/awake procedure (relative criteria)
Patient voluntary desire of conversion
Conversion to general anesthesia/thoracotomy
Introduce thoracic drainage through the incision, connect it to water seal system and close the wound with a sterile transparent dressing around the drainage, to let the lung reexpand again and improve oxygen saturation or dyspnea
General anesthesia and orotracheal lateral decubitus intubation
Perform the thoracotomy or the additional ports and proceed

intake the same day of the surgery, and the reexpansion was complete without air leak so she was discharged 24 hours after a lung resection without pain, so recovery of normal life can be fastened. Cardiovascular parameters remained without changes throughout all the process and CO_2 pressure in arterial blood decreased to normal values immediately after the surgery ($PaCO_2$ 42 mmHg).

Intranasal multiperforated catheter has proved to be a very useful device and well tolerated with mild sedation, increasing the oxygen concentration just above the airway without elevating the flow neither the pressure in the airway, keeping the O_2 pressure in arterial blood in excellent values.

Decreasing the need of general anesthesia and mechanical ventilation, the operative and anesthetic times, and the length of stay, also decreases the economical costs of the procedure (6).

We hypothesized that decreasing the interference with immune response with an awake procedure can potentially be beneficial in recurrent neoplastic disease in order to decrease the chance of reappearance of the tumor, but more evidence is needed showing that this benefit could potentially counteract the hypothetic stress related to surgical pneumothorax in an awake patient.

We conclude that awake uniportal limited pulmonary resections in recurrent non-small cell lung cancer (NSCLC), in the absence of high comorbidity and satisfactory functional tests, are feasible and have a safe pattern avoiding complications related to mechanical ventilation and general anesthesia, letting the patient resume his normal life sooner. Multiperforated intranasal catheter is a useful device in this purpose. Prospective randomized clinical trials are needed to confirm this hypothesis.

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Uniportal video-assisted thoracoscopic pneumonectomy

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Abstract: Video-assisted thoracoscopic surgery (VATS) was introduced nearly 2 decades ago and has experienced an exponential increase for lung cancer treatment. A pneumonectomy can be performed by video-assisted thoracoscopic surgery and the lung usually fits through the incision as usually used for VATS lobectomy. The most common approach for pneumonectomy is undertaken with 3 or 4 incisions, including a utility incision of about 3-6 cm. However, this resection is amenable by using only a single utility-incision. This chapter describes the technique for pneumonectomies by single-incision thoracoscopic approach with no rib spreading.

Keywords: Video-assisted thoracoscopic surgery (VATS); right pneumonectomy; left pneumonectomy; intrapericardial pneumonectomy; completion pneumonectomy

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Introduction

During the past two decades, thoracoscopic procedures have increasingly gained acceptance specially with the introduction of video-assisted thoracoscopic surgery (VATS) major pulmonary resections. Since introducing the VATS programme at our hospital in July 2007, we have evolved from 3 ports to single-port technique (introduced in June 2010) for lobectomy and pneumonectomy (1). Recent studies have reported on the feasibility and safety of thoracoscopic pneumonectomy compared with conventional thoracotomy for lung cancer (2).

Surgical technique

The uniportal thoracoscopic resection of the whole lung is technically easier to perform than a lobectomy because the fissure do not need to be managed. However, extra care must to be taken during dissection and division of the main artery and transection of the main bronchus.

Once the lung is removed a radical mediastinal lymph node dissection is performed.

Right pneumonectomy

Initially, a 4-5 cm incision is made in the 5th intercostal space in the antero-lateral position (*Figure 1*). We introduce a 30 degree, high-definition, 10-mm thoracoscope in the posterior part of the incision and explore the chest cavity. Digital palpation confirms the need for a pneumonectomy. We only perform pneumonectomy when sleeve resection is not a feasible option. Optimal exposure of the lung is key to facilitate the dissection of the structures and to avoid instrument malposition (*Figure 2*).

On the right side the procedure is similar to that of the left, except for differences especially concerning the anatomy of the right pulmonary artery and its relationship to the main bronchus and superior vena cava.

The transection of azygos vein is not necessary but in some cases could help the mobilization of main pulmonary artery and paratracheal lymph node dissection. The lung is retracted posteriorly and the upper and inferior pulmonary vein are dissected and encircled. To dissect the main pulmonary artery we recommend to first divide the boyden trunk with vascular endostapler or vascular clips (click aV,

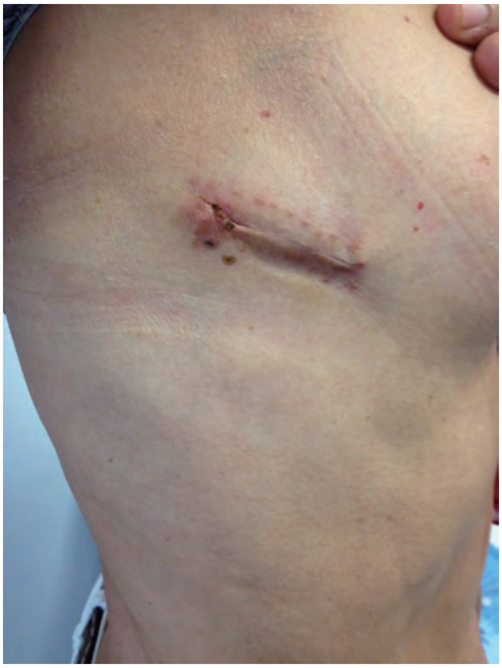

Figure 1 Incision on the right side.

Figure 2 Instrumentation during right pneumonectomy.

Figure 3 Right pneumonectomy (part 1) (3).
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Figure 4 Right pneumonectomy (part 2) (4).
Available online: http://www.asvide.com/articles/51

Grena). The uniportal approach provides a direct view to the artery. Once this branch is stapled, the lung is retracted caudally so as to havea good angle to staple the superior vein (*Figure 3*). The next step is the dissection and division of inferior vein. We retract the lung cranially, towards the apex of the chest, divide the pulmonary ligament and use an endostapler to divide the inferior vein (*Figure 4*).

Another option is to divide first the superior pulmonary vein by using 2 loads of (linear vascular stapler. and we could easily dissect the main pulmonary artery (therefore, the division of the boyden trunk is not necessary as the first step).

We dissect the main pulmonary artery with blunt dissection and the use of right angle clamp or thoracoscopic dissector. The removal of level 10 nodes and the previous posterior dissection of superior aspect of main bronchus help the dissection of the main artery. The pulmonary artery is encircled and divided by using a vascular endostapler.

Finally the main bronchus is divided by using a bronchial endostapler (a linear stapler is not usually needed on the right side) (*Figure 4*). Bronchial stump coverage with a vascularized flap is not usually performed. The lung is extracted in a protective bag. A systematic complete lymph node dissection is done upon completion of the procedure. A single chest tube is placed in the posterior part of the incision (*Figure 5*). If the tumor is too big to be removed by VATS, we enlarge de incision at the end of the surgery. In case of huge tumors we use a rib retractor to take out the specimen. In this unusual cases we recommend to perform another incision at the end of the surgery only to insert the chest tube (*Figure 6*).

Figure 5 Postoperative result of right pneumonectomy with chest tube placed in the posterior part of the incision.

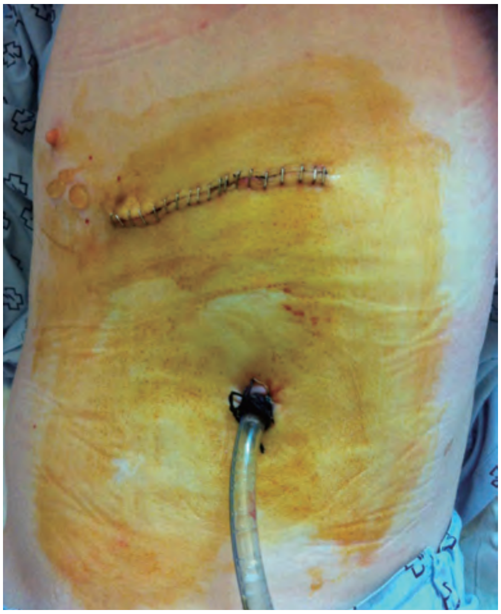

Figure 6 Chest tube placed through additional incision in case of big tumors removed by using rib spreader (left pneumonectomy, 12 cm tumor).

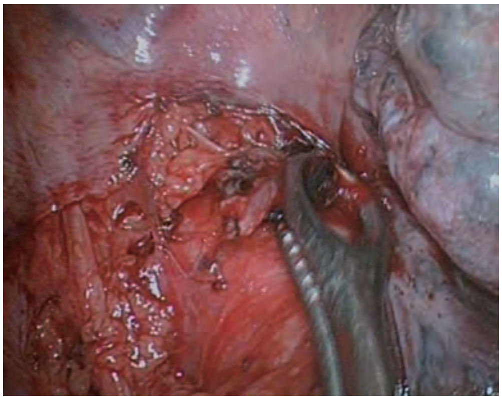

Figure 7 Aortopulmonary lymph node removal.

Left pneumonectomy

The incision is perfomed in the fifth intercostal space and is about 4-6 cm length. The thoracoscope is usually placed in the posterior part of the incision and the instrumentation is normally perfomed in the anterior portion of the incision. The staplers are also inserted through the anterior part of the incision.

The lateral aspect of the mediastinum is approached. The sequence for pneumonectomy on the left side could be different to the right side and includes the main pulmonary artery, superior pulmonary vein, inferior pulmonary vein, subcarinal lymph node dissection, and left mainstem bronchus.

We retract the lung posteriorly and inferiorly and we start the dissection by opening the mediastinal pleura to expose the pulmonary artery and the upper vein. It is important to remove the lymph nodes from the aortopulmonary window and divide the posterior pleura to better expose the artery (*Figure 7*). On the left side, the uniportal approach provides with an excellent and direct view to dissect and divide the main artery as the first step (*Figure 8*). The dissection and retraction of the upper pulmonary vein helps the exposure of the main artery. The dissection on the right side of the main pulmonary artery is very complex before the upper vein is transected). We divide the pulmonary artery by using a vascular endostapler (*Figure 9*). The superior pulmonary vein can then be divided with an endostapler. This is the most frequent sequence to divide the artery on the left side.

If the main pulmonary artery is not immediately accessible, our advice is to divide the superior pulmonary

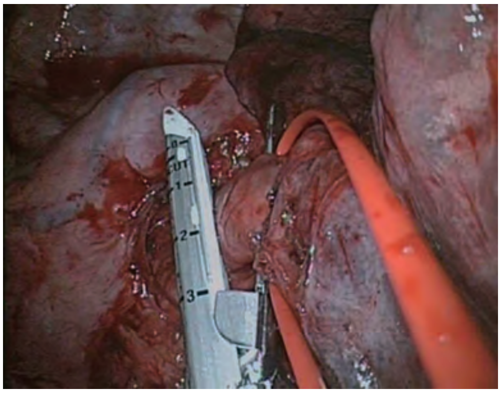

Figure 8 Division of left main pulmonary artery.

Figure 9 Division of left main pulmonary artery by using an endostapler (5). Available online: http://www.asvide.com/articles/52

Figure 10 Division of left inferior pulmonary vein (6). Available online: http://www.asvide.com/articles/53

vein first. This is done either by ligating or stapling the anterior branches of the pulmonary artery to the upper lobe first to improve access to the superior vein or by using a TA 30 vascular stapler (2 loads) to divide the vein to expose the main pulmonary artery.

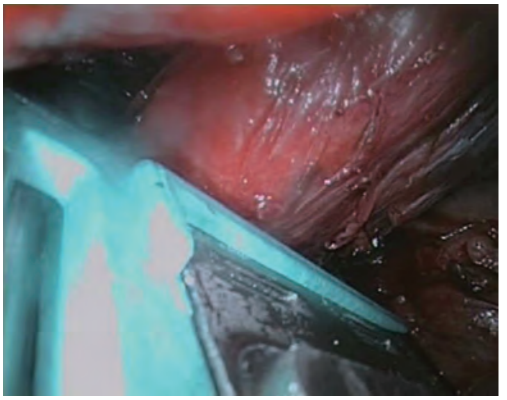

Figure 11 Use of TA 30 linear stapler to transect the left main bronchus.

Access to the inferior pulmonary vein is granted by taking down the pulmonary ligament. The inferior vein can then be easily divided with an endostapler after retracting the lung cranially (*Figure 10*). Subsequently, the lung is retracted anteriorly to perform a subcarinal lymph node dissection and to better expose the main bronchus. The lymph node dissection of level 5 mobilizes the superior aspect of the mainstem bronchus and level 7 lymphadenectomy mobilizes the posterior aspect of main bronchus.

When the angle for artery is not adequate for endostaplers we recommend to use a linear stapler for the main artery. We put the pin down and pull the lung through the stapler and we place an additional stapler, distally to the artery to avoid back bleeding when artery is cut with scissors or long knife.

The bronchus is dissected as proximal as possible after all the vascular elements have been divided (*Figure 11*). The bronchus is elevated by retracting the whole lung and we recomend to use a linear stapler used in open surgery, either a TA 30 (Covidien Inc, Mansfield, MA) or TX 30 (Ethicon Endosurgery, Cincinnati, OH). The pin is put down and we pull the lung through the stapler to achieve a short bronchial stump (*Figure 12*). Bronchial stump coverage with a vascularized flap is not usually performed. A single chest tube is placed in the posterior portion of the incision at the end of the surgery (*Figure 13*)

Intrapericardial pneumonectomy

The performance of intrapericardial pneumonectomy is more complex but the steps are similar to standard

Figure 12 Transection of lef main bronchus by using a TA 30 linear stapler (7). Available online: http://www.asvide.com/articles/54

Figure 13 Single chest tube placed in the posterior portion of the left incision.

Figure 14 Left intrapericardic pneumonectomy after induction treatment (8). Available online: http://www.asvide.com/articles/55

pneumonectomy (*Figure 14*). The pericardium is opened with scissors or cautery between the phrenic nerve at the anterior portion of the superior pulmonary vein. The incision is continued upward toward the pulmonary artery and downward toward the inferior pulmonary vein. Extra care must be taken in case of adhesions or fibrotic tissue. The intrapericardial proximal division of vessels facilitates the insertion of staplers to divide the main artery as the first step.

The main pulmonary artery and both pulmonary veins are encircled. The aortopulmonary window is dissected taking care to identify and divide the ligamentum arteriosum and to identify and protect the left recurrent laryngeal nerve which lies in the operative field. The main artery is divided by using an endostapler after caudal retraction of lung. Once the artery is divided the upper vein is stapled holding the lung in the same position. To divide the inferior pulmonary vein the lung is retracted cranially. The use of TA linear stapler for vessels is not usually needed but is an option in case of no good angles for endostaplers. The bronchus is mobilized from the pericardium and a TA stapler is used to transect the bronchus as deep as posible, closest to the carina.

Figure 15 Left pneumonectomy in two steps: lower and upper lobectomy (9). Available online: http://www.asvide.com/articles/56

Completion pneumonectomy

The pneumonectomy can also be performed removing both lobes separately (lower and upper lobectomy). We have performed this procedure in case of N1 persistent interlobar lymph node affection discovered after lobe removal or positive margins (when sleeve reconstruction is not possible). It is an option to accomplish the pneumonectomy performing upper and lower lobectomy separately. If the lower lobectomy is performed first we need to assure that the main artery and bronchus is stapled as proximal as posible in order to minimize the risk of fistula (*Figure 15*).

Uniportal Re-VATS for completion pneumonectomy refers to surgery intended to remove remaining lobe not

Figure 16 Completion pneumonectomy: right lower lobectomy after induction chemotherapy (previous bilobectomy) (10). Available online: http://www.asvide.com/articles/57

Figure 17 Instrumentation for completion pneumonectomy.

resected during a previous operation. The procedure carries a higher risk of operative mortality and morbidity than does standard pneumonectomy, specially when chemo or radiotherapy has been previously administered (*Figure 16*).

The use of induction chemotherapy or radiotherapy may increase the fibrotic tissue surrounding the hilum. This makes thoracoscopic surgery harder but does not necessarily contraindicate the procedure. A careful vascular dissection is mandatory and a sponge stick should always be available for compression in case of major bleeding. An energy device facilitates the dissection of hilar structures (*Figure 17*). Intrapericardial resection is usually frequent for completion pneumonectomy cases, especially after induction treatment.

Discussion

Recent advances in surgical and video-assisted techniques have allowed minimally invasive pneumonectomy to be safely performed. VATS pneumonectomy is not a new procedure. In fact, it was initially reported 15 years ago and associated with less postoperative pain and a faster return to normal activities (11). Despite this, there have been only a few series published (2,12).

Most of the authors describe the VATS approach to pneumonectomy using 3 to 4 incisions (13). The surgery can also be performed with 2 incisions with similar outcomes (14) and even by a single-incision (15).

Single-incision pneumonectomy is a feasible and safe procedure from a center with consistent experience with VATS lobectomy (15). Since June 2010, we started performing VATS major pulmonary resections by a single-incision and non rib-spreading (16). Individual division of all hilar structures and mediastinal lymph node dissection was performed in all patients. To date, we have performed 10 uniportal VATS pneumonectomies (80% intrapericardic; 4 right, 6 left). The mean surgical time was 201±40 minutes (range, 130-250 minutes).The mean number of nodal stations explored was 5.4±1 (range, 4-7) with a mean of 17.1±7 (range, 9-29) lymph node resections. The mean tumor size was 4.8±2.1 cm (range, 3-12 cm).The median length of stay was 4 days (range, 3-12 days). One patient needed a reoperation by VATS due to bleeding on the fifth postoperative day.

The size of the utility incision is comparable to the ones commonly used for double or triple-port approach. The incision is made at the level of the 5th intercostal space in a more lateral position as usually reported with VATS. The proper placement of this incision and an adequate exposure of the lung is crucial in order to get good access to the hilar structures. The parallel instrumentation achieved during the single port approach mimics inside the maneuvers performed during open surgery. The direct view to the target tissue facilitates the hilar dissection and the bleeding control in case of vascular injury. In our experience, resulting from the evolution from multiple port to single port VATS, the bleeding can be better controlled through a single incision approach when performed by experienced uniportal VATS surgeons.

Sequential extraction of the upper and lower lobe in a protective bag facilitated the entire lung removal through the 4-5 cm utility incision. We recommend to open the external bag neck to allow for air release and subsequently pull and slide the lobes. Decompression of blood and air from the surrounding pulmonary parenchyma facilitates the entire lung extraction.

VATS pneumonectomy should be only performed in centers with experience in minimally invasive VATS lobectomy. We believe that the decision to proceed with an uniportal thoracoscopic pneumonectomy requires thoracoscopic assessment at the time of operation. We consider pneumonectomy in cases where it is not feasible to perform a sleeve resection. As has been shown in many minimally invasive procedures, there is a learning curve with thoracoscopic pneumonectomy as with the lobectomy (17). The completion of pneumonectomy is a difficult procedure but is feasible by VATS in experienced centers (18). There are several studies reporting that pneumonectomy performed either by means of thoracoscopy or thoracotomy resulted in equivalent survival rates. Further studies and follow-up are needed to verify the benefits of VATS pneumonectomy for lung cancer (19).

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Uniportal video-assisted thoracoscopic sleeve lobectomy and other complex resections

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Abstract: Thanks to the recent improvements in thoracoscopy, a great deal of complex lung resections can be performed without performing thoracotomies. During the last years, experience gained through video-assisted thoracoscopic techniques ,enhancement of the surgical instruments and improvement of high definition cameras have been the greatest advances. The huge number of surgical videos posting on specialized websites, live surgery events and experimental courses has contributed to the rapid learning of minimally invasive surgery during the last years. Nowadays, complex resections, such as post chemo-radiotherapy resections, lobectomies with chest wall resection, bronchial and vascular sleeves are being performed by thoracoscopic approach in experienced centers. Additionally, surgery has evolved regarding the thoracoscopic surgical approach, allowing us to perform these difficult procedures by means of a small single incision, with excellent postoperative results.

Keywords: Sleeve lobectomy; bronchoplasty; bronchial anastomosis; uniportal VATS; single-port lobectomy

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Although the first thoracoscopic lung resection was performed in 1991 (1), the development and expansion of video surgery has been greater in the last 10 years. Internet and specialized web pages have been critical in this expansion, for they have given access to a great number of videos showing surgical techniques. Nowadays, more complex resections, such as post chemo-radiotherapy resections, lobectomies with chest wall resection, bronchial sleeves or vascular reconstructions are being performed and published. The experience acquired in the last years, as well as the development of thoracoscopic equipment (especially the introduction of the high definition) and the improvements of the surgical instruments have contributed to this.

The bronchial or vascular reconstruction procedures are usually planned to preserve the lung parenchyma, avoiding pneumonectomies. Generally, these are complex procedures even with open surgery, but they can be performed thoracoscopically obtaining similar postoperative results in expert hands. During the last years, many groups have published their experience with sleeve procedures by conventional VATS (2,3). Most surgeons use a 3-4 incision VATS technique for sleeve anastomosis but the surgery can be performed by using only one incision (4,5). When performing bronchial suturing using single port VATS, it's very important to maintain the camera on the posterior part of the incision, operating with both hands below the camera. Here we apply the same principle as when performing an anterior thoracotomy in open surgery: to have a direct view with the surgeon's eyes above his/her hands. Using a plastic wound protector is helpful when dealing with obese patients because fatty tissue could interfere with the suture threads.

The use of material with proximal and distal articulation (Scanlan International Inc.) is crucial (*Figure 1*). The surgeon ties the knot outside of the chest with the right hand, holding both ends of the thread with the left hand's index and little fingers and pushing down the knots using a thoracoscopic knot pusher (*Figure 2*). We usually don't buttress the suture except in cases of preoperative

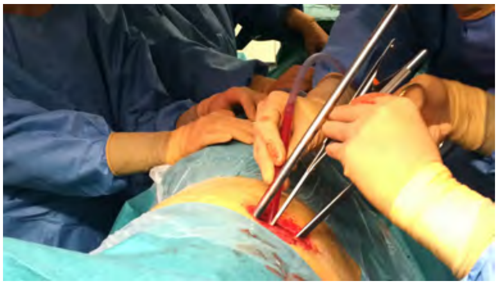

Figure 1 Surgical image of instrumentation during sleeve procedures.

Figure 2 Technique for knot pushing through a single port (6).
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Figure 3 Simple bronchoplasty (7).
Available online: http://www.asvide.com/articles/353

radiotherapy. In these cases we use an intercostal muscle flap or a pedicle pericardial or mediastinal fat pad.

The operating table's position makes the lung exposure easier to perform the anastomosis (the anterior rotation of the table 45° to the surgeon places the lung on an anterior position and makes easier the posterior bronchial suture, especially the membranous portion).

Suture may be performed with single stitches or

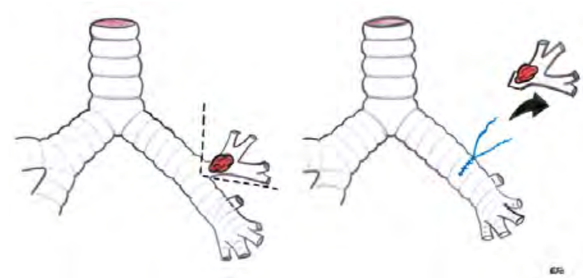

Figure 4 Drawing showing wedge bronchoplasty.

continuous suture. The usage of monofilament suture makes the thread movement easier, as well as the tying. The bronchial edge must be assessed during the operation, the suture is checked at the end of the surgery using insufflation under water and bronchoscopic control to check integrity and secretion aspiration.

We can classify three types of bronchoplastic procedures according to the resection type:

(I) Simple bronchoplasty. The bronchus is cut in its origin using a scalpel, when the tumor is located to the bronchial base (due to this the use of an endostapler is not possible). For the closure, we use single double PDS 3/0 stitches (flushed shape) (*Figure 3*). Flap protection is not usually needed. When doing a simple bronchoplasty on the inferior right lobe, the suture must be carefully handled to avoid stenosis of the middle lobe bronchus.

(II) Wedge bronchoplasty. In this case the bronchial cut is made deeper in wedge shape to the main bronchus (*Figure 4*). This kind of suture may call for a transverse closure, but if the wedge is large and doesn't allow the approximation, it may be reconstructed using a lateral closure (*Figure 5*). We recommend the subcarinal lymph node dissection (lymphadenectomy) before the bronchoplasty in order to free the main bronchus and avoid an excessive traction once the suture is done.

The suture is made without tension, with approximation to the mucosa using monofilament absorbable interrupted or continuous suture (PDS 3/0), with all knots preferably placed externally. The monofilament suture facilitates the movement through the bronchus and the tying of the knots.

(III) Sleeve bronchoplasty. The bronchial sleeve resections with end to end anastomosis are the most complex bronchoplastic procedures (*Figure 6*). The right upper lobe bronchoplasty is normally the less difficult procedure, due to the alignment of

Figure 5 Wedge bronchoplasty (8).
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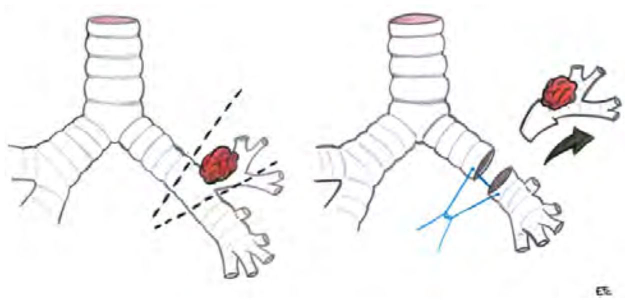

Figure 6 Drawing showing sleeve bronchoplasty.

Figure 7 Sleeve bronchoplasty (9).
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the main and the intermediate bronchi (4). This location makes operating with both hands easier. The liberation of the pulmonary ligament, as well as the subcarinal lymph node dissection facilitate the lung mobility and avoid tension during the anastomosis.

The bronchus may be cut initially using a long scalpel,

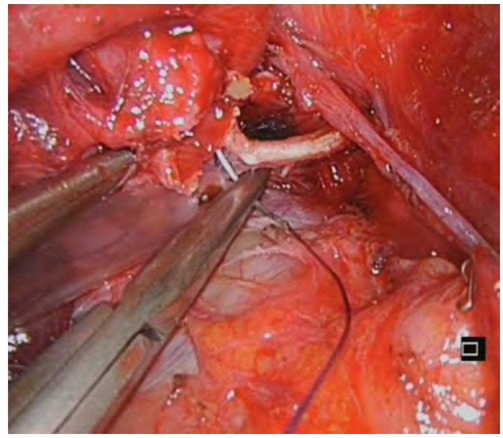

Figure 8 Surgical image of left lower sleeve anastomosis (main bronchus to left upper bronchus).

the bronchial circumference section may be completed using scissors.

We can use single stitches for the cartilage part and continuous suture for the membranous portion. It's best to tie the single suture one by one, to avoid that the threads touch each other, and it's preferable to tie the knot outwards (*Figure 7*). Another, more simple option (and with identical results) is to make the whole anastomosis using continuous PDS 3/0 suture. Usually, the posterior bronchus wall is stitched first and the anterior wall, from behind so that both edges are tied at the anterior level.

The most complex sleeve procedures are usually those of the left side, due to the presence of the aortic arch and the bigger size of the pulmonary artery (*Figure 8*) (5). For left-sided bronchial resections, it's best to use a right-sided double-lumen tube, in order to make suture easier and reduce the bronchus tension.

Segmental bronchial sleeve reconstruction (*Figure 9*)

In this particular case, In order to avoid a full sleeve, we perform a resection of the right main bronchus and right upper bronchus after a lower bilobectomy. The reconstruction is more complex in these cases, with anastomosis of the main bronchus to the right upper individual segmental bronchi. A careful reconstruction of the main bronchus' suture is especially important, in order to avoid that the small segmental bronchi be closed after the anastomosis. In this scenario is better to perform interrupted sutures to adjust the segmental bronchi

Figure 9 Sleeve segmental bronchoplasty (10).
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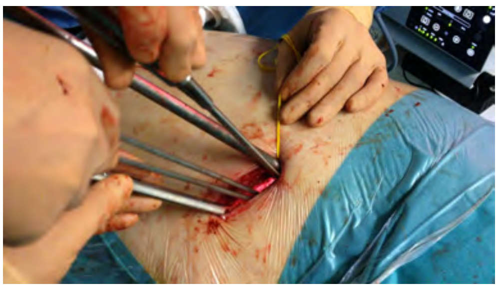

Figure 10 Surgical image of instrumentation during right vascular reconstruction.

Figure 11 Vascular reconstruction (12).
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Vascular resections

These procedures are complex and usually performed by open surgery or by conventional VATS by experienced and skilled thoracoscopic surgeons. However the same operation can be accomplished by using only a single incision VATS approach.

When the tumour invades the pulmonary artery, the artery as well as the basal trunk must first be controlled and dissected. Sometimes it's necessary to perform an intrapericardial control. Before the pulmonary artery clamping, 5,000 UI heparine iv must be administered to prevent thrombosis. We prefer the pulmonary artery clamping with a large thoracoscopic clamp (D'Amico Clamp, Scanlan International, Inc.), which is placed on the inferior part of the wound. For distal clamping it's better to use bulldog clamps on the most distal part of the basal trunk, or clamping the inferior pulmonary vein to interfere as less as possible with the instruments. Sometimes, a double vessel loop is enough for distal clamp, especially in the less complex reconstructions (*Figure 10*).

There are three types of vascular reconstructions:

Partial resection of the pulmonary artery

It's a less complicated vascular reconstruction and it's performed especially when the tumor invades the base of one of the mediastinal branches but without a large involvement into the main pulmonary artery (11).

After heparinization and clamping of the main artery and basal trunk we perform a tangential incision on the pulmonary artery and a direct closure by means of a running suture with prolene 5/0 or with several interrupted double sutures (*Figure 10*).

Once the suture is completed we release the most distal clamp to release any air thanks to the return flow and we tie once the artery is full. Then we do a progressive release of the proximal clamp. The clamp will not be entirely removed until we confirm that there is no bleeding (*Figure 11*).

Patch reconstruction

It's a complicated procedure with VATS. Bovine pericardium may be used as well as a patch from the patient's pericardium. The use of patches should be avoided as it could increase the risk of thrombosis. In the case of an extensive end-to-end resection, a tube may be created out of the pericardium in order to do an end-to-end anastomosis at each end of the resection. To our knowledge, these procedures have not been reported yet by VATS.

End-to-end anastomosis

Is probably the most complex procedure that can be done through VATS and it requires special skills and an extensive

Figure 12 Sleeve end to end vascular anastomosis (13). Available online: http://www.asvide.com/articles/358

Figure 13 Surgical image of double bronchovascular procedure.

experience with video-assisted thoracoscopic surgery. In these cases of vascular reconstruction, it is advisable that this be the last step of the lobectomy (first divide the veins, bronchus and fissure) in order to have a larger surgical field and more control of the section of the pulmonary artery. Once the arterial trunk is clamped we cut the proximal and distal side using scissors and we position the lobe in the costodiaphragmatic angle, over the diaphragm in order to be extracted once the suturing is complete.

Vascular sleeve is more frequent on the left side, with tumors that invade the main pulmonary artery or the mediastinal branches that lead to the upper lobe.

For the end-to-end anastomosis it is important to free up the pulmonary ligament and sometimes open up the pericardium to free up tension. Due to the fragility of the pulmonary artery and in order to avoid ruptures during the anastomosis, special care must be given to the manipulation of sutures as well as a correct traction of the pulmonary artery.

It's very important to adjust the diameters of the main artery to the lobar branches during anastomosis, in order to avoid kinking or stenosis. We start anastomosis with an anterior and posterior traction suture to adjust the diameters by using prolene 4/0 or 5/0. For the posterior suture, both needles are kept and once the knot is tied one of them is kept separately in the interior of the chest cavity (it will be used for suturing the superior face). A running suture is done on the inferior side of the artery from a posterior to anterior direction and we tie it to the anterior traction end. Then we use the other needle from the posterior traction end to complete the suture of the superior side and it is then tied to the anterior suture. Before tying we must release air and check the flow after opening the distal clamp (*Figure 12*).

In case of the double sleeve, it is better to do the bronchial suturing first and after that the arterial reconstruction in order to avoid traction on the arterial suture (14) (*Figure 13*).

Other complex resections

The single port technique allows us to make other complex procedures, such as Pancoast tumors (hybrid approach is necessary), superior sulcus tumors, and tumors with chest wall invasion or contralateral nodule resections on patients with previous pneumonectomy.

Sulcus tumors

The approach for Pancoast tumors approach is hybrid. We make the incision at the fifth intercostal space for the lobectomy and a high posterior incision or anterior superior Dartevelle or Grünenwald incision for the resection at apical level and vascular control. We can perform the superior approach first in order to free the lobe to the superior level or we can begin with the lobectomy and then perform the superior approach for resection, once the lobe has been freed.

For sulcus tumors without bone or vascular involvement, sometimes it's enough to perform a deep extrapleural resection. We present the following case: a 50-year-old man with a sulcus tumor, treated with chemotherapy and concomitant radiotherapy, having good response. A right upper lobectomy was done, from anterior to posterior using the fissureless technique with the lung fixed to the apex. Once the lobectomy was done, a partial resection of the healthy lobe zone was performed in order to obtain more space to accomplish the resection of the tumor. It's important to use energy devices to perform a more secure apical and extrapleural liberation. Surprisingly, the final pathological examination of this case confirmed a complete tumoral Junker regression. After 3 years there hasn't been

Figure 14 Superior sulcus tumor (15).
Available online: http://www.asvide.com/articles/359

Figure 15 Lower lobectomy with chest wall resection (17).
Available online: http://www.asvide.com/articles/360

Figure 16 Nodule resection in a patient with contralateral pneumonectomy (18).
Available online: http://www.asvide.com/articles/361

any sign of the tumor growing again (*Figure 14*).

Tumors with chest wall involvement

When dealing with tumors that invade the chest wall we use a combined approach: single port for the lobectomy (fifth intercostal space) and a small lateral or posterior incision for the costal resection, according to the location of involvement (16). After evaluation of costal invasion and the tumor's size (better or worse lobe mobility), we will perform either the lobectomy or the costal resection first. On this video we performed the right inferior lobectomy first using single port, once the lobe was freed the chest wall was resected and a mesh was placed thanks to the thoracoscopic vision (*Figure 15*).

Tumors on patients with previous pneumonectomy

Surgery on these patients must be extremely careful. Therefore, the resection must be as limited as possible. It's important that the lobe to be operated is collapsed. A good option is the endotracheal intubation with a single tube and fogarty catheter directed with bronchoscopy to collapse the selected lobe. In this case we present a video of a patient with previous pneumonectomy (10 years before) and a new primary tumor. The patient presented costal fractures and hemothorax (which needed chest tube) in the past, as well as a previous intervention of pericardiectomy caused by a chronic constrictive pericarditis. These findings increased the difficulty and risk of the case. However the patient was proposed for a uniportal VATS resection. After a difficult extrapleural liberation of the lung (maintaining the superior lobe ventilation), we palpated the tumor into the left lower lobe and we resected it with endostaplers (*Figure 16*).

Discussion

Uniportal VATS is not only indicated to initial stages or easy cases. With gained experience the most complex cases can be performed in the same manner as with double or triple port approach (19,20). Previous experience in VATS is necessary to perform these advanced cases with success (21). We have performed lobectomies with strong adherences after TB, redo-VATS, tumors with chest wall involvement, cases after high doses of chemo-radiotherapy, anatomic complex segmentectomies, vascular reconstruction, sleeve lobectomies, double sleeve, pneumonectomies and huge tumors by single incision VATS.

Despite the multiple advantages of conventional or uniportal VATS compared with thoracotomy as decreased postoperative pain, decreased hospitalization, diminished inflammatory response or faster access to chemotherapy, the uniportal VATS approach for advanced stages of lung cancer is still infrequent. The concern about an intraoperative thoracoscopic major bleeding or the technical complication of performing a radical oncologic resection by single port VATS in advanced cases are the main reasons for the low adoption. We recently assessed and published the feasibility of uniportal VATS approach in the treatment of advanced NSCLC and compared the perioperative outcomes with early-stage tumors with excellent postoperative results (21).

Since we developed our uniportal technique for VATS lobectomies in 2010 we have increased the application of this technique to more than 90% of cases in our routine surgical practice. The experience we acquired with the uniportal technique during the last years, as well as technological improvements in high definition cameras, development of new instruments, vascular clips and more angulated staplers have made this approach safer, incrementing the indications for single-port thoracoscopic resections. We believe it is important to minimize the surgical aggressiveness especially in advanced stage lung cancer patients where the immune system is weakened by the disease or by induction treatments (22). The minimally invasive surgery represents the least aggressive form to operate lung cancer and the single-port or uniportal technique is the final evolution in these minimally invasive surgical techniques.

The most complex resections are the thoracoscopic sleeve procedures. There are few articles published in the literature describing bronchial sleeve, vascular sleeve or combined bronchovascular sleeve by VATS, and all of these resections are reported by using conventional thoracoscopic techniques (23,24). As our experience has grown with the single-port VATS approach (4,20) we have increased the rate of thoracoscopic sleeve procedures and decreased the incidence of pneumonectomy, and even we have performed bronchovascular sleeve procedures by uniportal VATS (14,25). We found several advantages of the single incision thoracoscopic technique especially for sleeve procedures. The geometrical explanation of the approach, the direct view and bimanual instrumentation could explain the excellent results we have obtained with this technique (26).

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Bronchovascular right upper lobe reconstruction by uniportal video-assisted thoracoscopic surgery

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Abstract: Lung cancer requiring double bronchial and vascular reconstruction of the pulmonary artery is a challenging procedure usually performed by thoracotomy. However, recent development of video-assisted thoracoscopic techniques allows experienced and skilled surgeons to perform these cases through a minimally invasive approach. Most of these complex thoracoscopic resections are performed by using 3 to 4 incisions. We present the first report of a right side combined vascular reconstruction and bronchoplasty performed through a single-incision video-assisted thoracoscopic surgery (VATS) technique.

Keywords: Thoracoscopy/video-assisted thoracoscopic surgery (VATS); minimally invasive surgery; pulmonary artery reconstruction; vasculoplasty; vascular reconstruction; bronchoplasty; surgery/incisions/technique

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Introduction

In the past two decades with increasing frequency video-assisted thoracoscopic surgery (VATS) has been performed for lung cancer treatment. However, complex cases are only performed in a few centers. Most surgeons use a 3-4 port VATS approach for difficult resections such as bronchial or vascular sleeves. This report describes the technique for a right upper lobectomy with bronchoplasty and vascular reconstruction by using a uniportal VATS technique.

Clinical summary

A 73-year-old male, smoker, with severe comorbidities (COPD, obesity, hypertension and cardiomiopathy) was diagnosed with a right upper lobe (RUL) tumor. The CT scan showed the tumor located on the posterior segment of the RUL with bronchial and vascular invasion by lymph nodes (*Figure 1*). The pulmonary function test was normal (FEV1 70%). The patient was proposed for single incision VATS approach.

Surgical technique

Under general anesthesia, a VATS approach using a 4 cm single-incision was made in the 5th intercostal space with no rib spreading (no soft tissue retractor and no direct vision).

A tumor was detected in the RUL and lymph nodes were involving the bronchus and apical-anterior branch of the pulmonary artery (PA) and interlobar artery. The incomplete fissure was divided from anterior to posterior from the hilum to expose and control the artery. The RUL bronchus was not possible to be dissected so it was transected by using a long knife. The main pulmonary artery and the basal trunk were dissected to have adequate proximal and distal vascular control. Before clamping the PA, 5,000 units of heparin were injected intravenously to prevent clotting. The interlobar artery was occluded by using a double vascular sling vessel loop and the main PA was closed using a thoracoscopic clamp (Scanlan International, Inc, Saint Paul, MN, USA). The clamp was placed towards the anterior portion of the incision and the vessel loop was placed in the posterior part. The camera

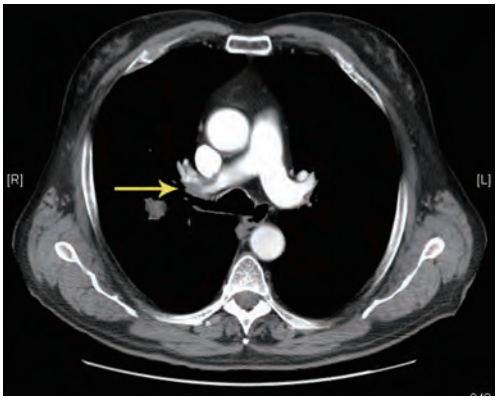

Figure 1 Computed tomography scan showing right upper lobe (RUL) bronchial and vascular lymph node invasion.

Figure 2 Bronchovascular resection and reconstruction (1). Available online: http://www.asvide.com/articles/515

Figure 3 Surgical image of instrumentation during bronchoplasty.

was located in the posterior part of the incision, and the instrumentation was placed and used below the camera.

The PA was transected laterally and the specimen was temporarily placed in the costo-diaphragmatic space. The defects in the interlobar artery and base of apico-anterior branch were repaired by using interrupted double lateral 4-0 monofilament non-absorbable sutures. The sutures were tied and the air was released through one of the posterior branches which was cut and then closed by using a vascular clip (Click aV, Grena^{R}) (*Figure 2*). The specimen was then removed in a protective bag (2).

Figure 4 Postoperative result with chest tube placed in the posterior part of the incision.

The bronchus was reconstructed and closed by using interrupted double sutures of 3-0 PDS (*Figure 3*). The lung was inflated and no air leak was observed. Systematic lymph node dissection was then performed to complete the procedure and a single chest tube was placed (*Figure 4*). Total surgery time was 310 min and estimated blood loss was 180 cc. The chest tube was removed on the sixth postoperative day and the patient was discharged on the same day with no complications and excellent recovery.

Discussion

Bronchovascular reconstructive surgery is a technically feasible alternative to pneumonectomy and has the advantage of sparing the functioning of the lung parenchyma. These procedures are very complex and usually performed by open surgery (3). However, with the recent developments in VATS technology and acquired experience, this surgery can be performed thoracoscopically by experienced and skilled VATS surgeons. There are very few articles published in the literature describing a combined bronchial and vascular reconstruction by VATS, and these resections are reported on the left side by using conventional multiport thoracoscopic technique (4,5). We have recently published the first case of double sleeve VATS resection by a single incision approach (6).

As our experience has grown with the single-port VATS approach (7) we have increased the rate of thoracoscopic sleeve procedures and decreased the incidence of pneumonectomy and today our list of contraindications is very limited (8). Advanced uniportal thoracoscopic procedures as bronchial sleeve lobectomy (9), lobectomy with chest wall resection, vascular reconstruction (10) and double sleeve (6) have already been performed with good postoperative outcomes. To April 2014 we have performed 11 uniportal VATS lobectomies with reconstruction: wedge bronchoplasty (3 cases), bronchial sleeve (5 cases), pulmonary arterioplasty 3 (1 vascular reconstruction, 1 vascular reconstruction combined with bronchoplasty and one double bronchovascular sleeve). The postoperative course of these patients was uneventful. Mean operative time was 215±54 minutes (range, 120-310 minutes) and median hospital stay was 6 days (range, 2-21 days).

The success in performing complex lobectomies by uniportal approach is a result of skills and experience accumulated over time by performing many uniportal VATS surgeries (7). The advantage of uniportal VATS surgery is the vision is direct to the target tissue providing a similar angle of view as for open surgery. Conventional multi-port VATS triangulation creates a new optical plane with genesis of torsional angle that is not favorable with standard two-dimension monitors. Another advantage of the uniportal VATS technique is that instruments inserted parallel to the camera mimic inside the chest maneuvers performed during open surgery. This geometric uniportal VATS concept facilitates the bronchovascular reconstruction in complex resections such as the one described in this article (11).

Most of the published cases requiring sleeve or vascular reconstruction are located on the left side. Infiltration of the PA on the right side requiring arterial reconstruction is less frequent. Reconstruction of the PA enables complete cancer resection while preserving functioning pulmonary tissue, and has a definitive role in the surgical management of lung cancer. In this particular case there was a partial infiltration of the surface of the artery (base of apical-anterior and posterior branch) by lymph nodes needing tangential resection with direct repair, and a total sleeve was not necessary. In this case partial resection of the PA was performed in conjunction with bronchoplasty of the RUL. The use of thoracoscopic instruments with proximal and distal articulation (Scanlan International, Inc, Saint Paul, MN, USA) facilitate the instrumentation through a single-incision, especially for clamping the main pulmonary artery with no interference to the broncho-vascular reconstruction. For clamping the basal trunk we usually prefer to use a double vessel loop or a bulldog-clamp (placed inside the cavity) to facilitate the instrumentation.

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Non-intubated single port thoracoscopic procedure under local anesthesia with sedation for a 5-year-old girl

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Abstract: Medical thoracoscopy is a feasible procedure for the diagnosis or treatment of thoracic diseases, and it can be performed under local anesthesia without tracheal intubation in cooperative adult patients. However, for younger than school aged patients, even simple procedures require general anesthesia with tracheal intubation. In this case report, we demonstrated the safe performance of a single port thoracoscopic procedure without tracheal intubation in a 5-year-old girl under local anesthesia and sedation. Local anesthesia around the site of a previous chest tube and sedation with intravenous (IV) dexmedetomidine and ketamine were applied. In the aspect of not only minimal injection of local anesthetics but also enhanced visualization of the thoracic structures, the non-intubated single port thoracoscopic surgery under local anesthesia with sedation was a good option for performing a simple thoracoscopic procedure in this 5-year-old patient.

Keywords: Thoracoscopy; non-intubated; single port; local anesthesia; sedation; bispectral index (BIS)

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Introduction

Medical thoracoscopy is a short and simple procedure for the diagnosis or biopsy of thoracic disease (1). In adult patients, it can be easily performed using local anesthetics with or without sedation under the cooperation of the patient (2). However, this is not feasible in pediatric thoracoscopy, which often requires general anesthesia (3). In pediatric patients less than 30 kg, carbon dioxide gas insufflation into the chest cavity through an air-tight port is needed to collapse the lung for operation (4).

In our case, we demonstrated the use of a non-intubated single port thoracoscopic procedure in a 5-year-old girl under local anesthesia with sedation for the management of a chest tube which was inadvertently sutured in the thoracic cavity.

Case report

A girl aged 5 years and 2 months (height 109 cm, weight 18.6 kg) experienced recurrent pneumonia over a 2-year period. Chest radiographs and computed tomographic (CT) scan showed extra lobar pulmonary sequestration in the left lower lung. Her vital signs were stable, and no other anomalies were detected during preoperative evaluation. We resected the lesion through an incision in the left lateral thoracotomy (length, 3 cm) along the fifth intercostal space, under general anesthesia with a single lumen tracheal tube (*Figure 1*). After resection of the sequestrated lung, a 16-Fr chest tube was inserted into the seventh intercostal space. The intercostal space was repaired using a 4-0 absorbable suture. After two days, the chest tube could not be withdrawn. It seemed to have been inadvertently sutured beneath the thoracotomy incision inside the thoracic cavity. At this point, we decided to perform the thoracoscopic procedure through the chest tube insertion site under sedation without tracheal intubation.

Sedation was achieved using Intravenous (IV) dexmedetomidine (1.0 μg/kg) for over 15 min before the injection of local anesthetics, followed by 1 mg/kg of IV ketamine and dexmedetomidine 0.2-1.0 μg/kg/h IV (5). Oxygen at 6 L/min was administered via a pediatric face mask. The patient was monitored during sedation, and the bispectral index (BIS) was maintained between 45 and 65 during the procedure. The thoracoscopic procedure was performed in the right lateral decubitus position (*Figure 2A*). Local anesthesia was achieved around the hole where the chest tube was inserted, using a 2% lidocaine solution.

After the chest tube was pulled and shortened, a 2-mm thoracoscope was inserted through the chest tube site (5.5 mm incision) (*Figure* 2B). The ipsilateral lung was collapsed, during which the patient kept breathing with the contralateral lung. The intercostal suture material penetrating the middle part of the chest tube was found underneath the thoracotomy wound (*Figure 2B*). The suture was intrathoracically cut using 2-mm endoscopic scissor and grasper (*Figure 2C*), and the chest tube was removed. The new 16-Fr chest tube was inserted through the same hole, and anchored outside of the hole.

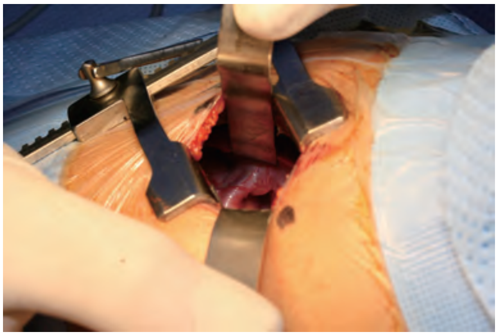

Figure 1 The extralobar type pulmonary sequestration with aberrant arterial pedicle from descending aorta was resected through a 3 cm thoracotomy incision.

The patient's vital signs were stable during the entire operation (intraoperative mean arterial pressure, 85-90 mmHg; intraoperative heart rate, 90-92 beats/min; and intraoperative SPO_2, 99-100%). Ketamine 0.5 mg/kg (IV) was added as a bolus when involuntary movements or cough reflex occurred. The total operation time was 35 min, and the sedation time was 55 min. The IV dexmedetomidine infusion was discontinued at the end of surgery. After returning to the supine position, she was transferred to the recovery room.

The second chest tube was withdrawn immediately after checking the chest radiography. She was allowed to drink water one hour later, and was discharged after two days. No delayed complications were observed during the follow-up.

Discussion

In thoracoscopic procedures for pediatric patients less than 30 kg, comprehensive visualization of the surgical field is

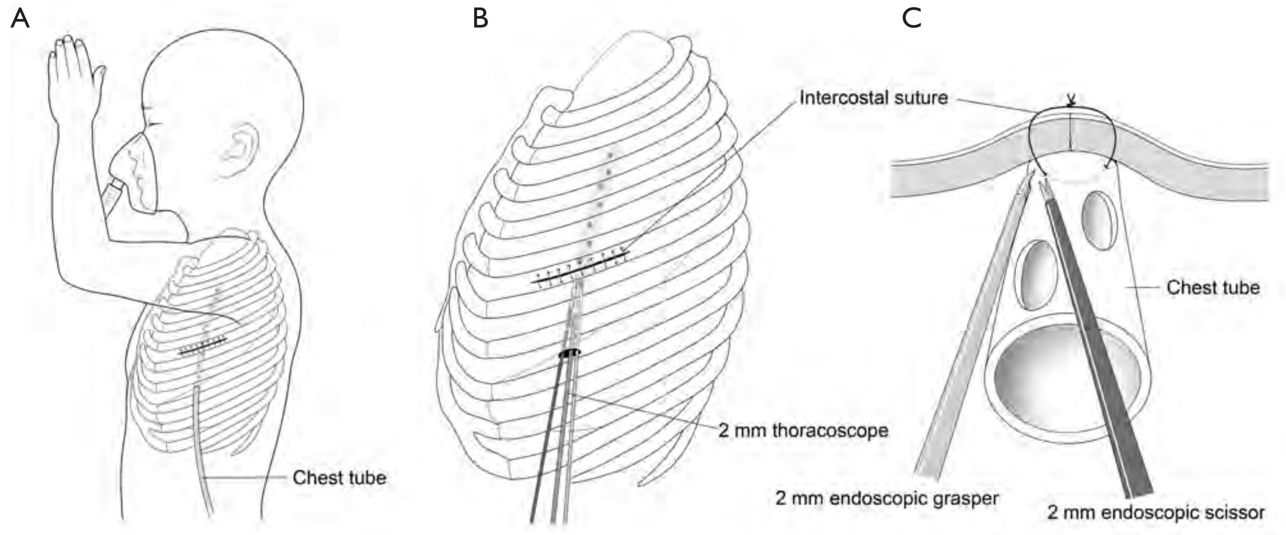

Figure 2 (A) The patient posed in the lateral decubitus position with oxygen supplied by facial mask, in deep sedation status; (B) the chest tube was shortened outside the thoracic cavity, and local anesthetic solution was injected around the chest tube site. A 2-mm-thoracoscope and other instruments were introduced through the chest tube site; (C) intercostal suture penetrated the chest tube underneath the thoracotomy incision. The suture material was cut using 2-mm endoscopic scissor and grasper under thoracoscopy.

quite difficult, even under general anesthesia (3,4). A collapse of the ipsilateral lung is essential for the surgeon to be able to perform a thoracoscopic procedure in thoracic cavities which have limited space. Because there are no appropriate double lumen tracheal tubes, which are used for selective one lung ventilation in adult patients, generally, single lumen tracheal intubation is generally applied in small pediatric patients, with carbon dioxide gas insufflations through air-tight ports into the thoracic cavity to collapse a lung (3,4).

In the present case, a self-ventilating thoracoscopic procedure under local anesthesia with sedation was planned. We considered that the repeat of general anesthesia in a patient who had undergone general anesthesia for the surgery just three days before may be harmful, especially for performing a short and simple procedure, such as cutting a suture material in the thoracic cavity. In addition, the ventilation of two lungs using a single lumen tracheal tube has no benefit in thoracoscopic surgery.

Active negative ventilation and opened thoracic cavity can collapse the ipsilateral lung, maintaining the ventilation of the contralateral lung under local anesthesia with sedation. Previous studies reported non-intubated thoracosopic bleb resections and lobectomies under sedation combined with various local anesthetic methods (1,6-9).

Sedation with IV ketamine and dexmedetomidine was available, and could provide a stable condition for uncooperative pediatric patients during the procedure. Even a simple procedure cannot be performed under local anesthesia without sedation in younger than school-aged patients because of their uncontrollable movement (4). This creates the necessity of deep sedation, which can often cause respiratory depression (3). We chose to combine IV ketamine with IV dexmedetomidine for our patient. Dexmedetomidine has been shown to produce stable sedation without respiratory depression (10), and provides analgesia and hemodynamic stabilization. In addition, it may prevent tachycardia, hypertension, and emergence phenomena associated with ketamine, while ketamine prevents bradycardia and hypotension, which have been reported with dexmedetomidine (11).

The procedure through the single hole from the previous chest tube, that is, the single port procedure was adjustable for an unconscious sedated patient. If possible, less irritation of the wound during the operation is better to maintain sedation. Compared with multiple port surgery, the stimulation of the port site can be reduced in single port surgery.

To the authors' knowledge, this report is the first report of a non-intubated single port thoracoscopic procedure under local anesthesia with sedation in a patient younger than school age. In the present case, non-intubated surgery improved the surgical view in pediatric thoracoscopic surgery, and single port surgery was effective under local anesthesia with sedation. However, our case was of a very short and simple procedure. Prospective randomized trials are required to determine the efficacy of non-intubated single port thoracoscopic surgery under local anesthesia and sedation in cases of complicated and long thoracoscopic procedures for pediatric patients.

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Future

Single-staged uniportal VATS major pulmonary resection for bilateral synchronous multiple primary lung cancers

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Abstract: It is difficult to make diagnosis and treatment decision for patient with bilateral multiple pulmonary foci. Surgical resection can offer sufficient specimens for diagnostic differentiation and the greatest chance for long-term survival in patient with presumptive synchronous multiple primary lung cancers (SMPLC). Since uniportal video-assisted thoracoscopic surgery (VATS) is a less invasive technique and has been attempted in lung cancer surgery, we transferred it into the management of SMPLC. In this paper, we report two cases of bilateral SMPLC managed through single-staged uniportal VATS with major pulmonary resection. This successful attempt provides an optimized idea to accomplish simplified mini-invasive diagnosis and synchronous treatment using the less invasive uniportal VATS technique for the management of SMPLC, especially for those with multiple bilateral lesions.

Keywords: Synchronous multiple primary lung cancers (SMPLC); video-assisted thoracoscopic surgery (VATS); single-port; ground glass opacity (GGO); diagnosis; treatment

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Introduction

Difficulty in diagnosis and treatment decision making for patient with bilateral multiple pulmonary foci usually raises a clinical dilemma for clinicians. An aggressive surgical approach can offer sufficient specimens for diagnostic differentiation and the greatest chance for long-term survival in patient with presumptive synchronous multiple primary lung cancers (SMPLC) (1,2). In such situation, mini-invasive technique of video-assisted thoracoscopic surgery (VATS) has been reported to be effective (1,3,4). Since uniportal VATS has been attempted as a less invasive technique (5), we transferred it into the management of presumptive SMPLC. Here, we present two cases of bilateral SMPLC managed through single-staged uniportal VATS with major pulmonary resection, which provides simplified mini-invasive diagnosis and synchronous treatment.

Cases report

Patient 1 was a 67-year-old female, who was presented with chest pain for about 2 months. Preoperative high-resolution computed tomography revealed four ground glass opacity (GGO) lesions (two in the right upper lobe, each in the left upper and lower lobe, respectively, *Figure 1A-D*). Patient 2 was a 53-year-old female, who was admitted with a mass in the right upper lobe (*Figure 1E*) and a GGO lesion in the superior segment of the left lower lobe (*Figure 1F*). Both of them were presumptively diagnosed with bilateral SMPLC. The preoperative staging work-up indicated no sign of lymphadenopathy or distal metastasis. Given no surgical contraindication, single-staged uniportal VATS for bilateral pulmonary foci was planned for each of them with written informed consent.

General anesthesia with double-lumen endotracheal intubation was administered to each of them. A 5 mm 30° thoracoscope was used for inspection. Patient 1 was firstly placed in a right lateral decubitus position. On the left, a 3.5 cm incision was made in the fourth intercostal space at the anterior axillary line. Each of the two lesions was identified through digital palpation and the surface of the lung right on the top of each lesion was marked

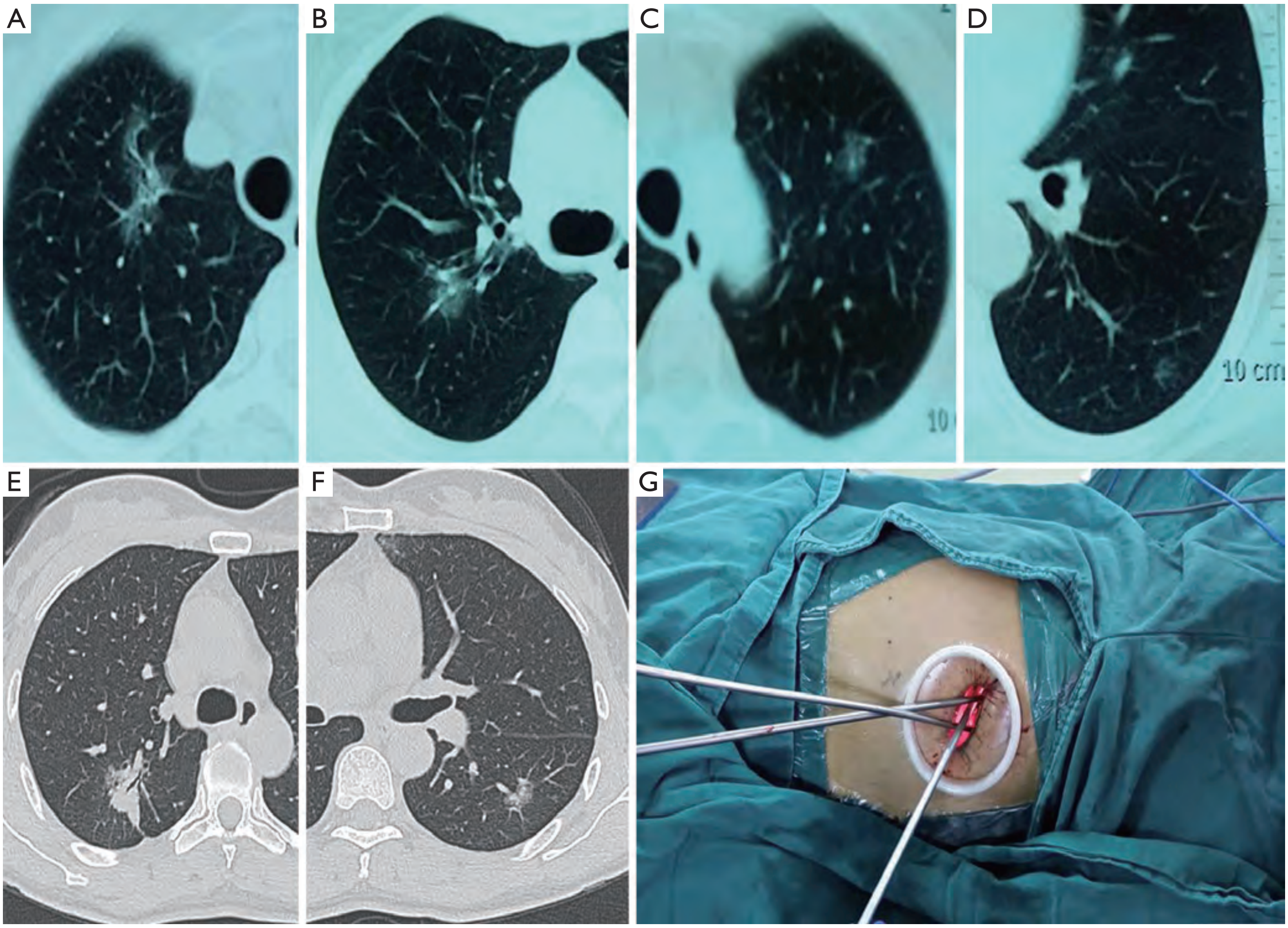

Figure 1 (A-D) High-resolution computed tomography (HRCT) reveals four ground glass opacity (GGO) lesions of patient 1 (a 3.2×1.5 cm lesion located at the apical segment of the right upper lobe, a 1.3×1.0 cm lesion located at the posterior segment of the right upper lobe, a 1.0×0.8 cm lesion located at the apical segment of the left upper lobe, and a 0.8×0.8 cm lesion located at the posterior basal segment of the left lower lobe); (E,F) HRCT reveals two tumor-like lesions of patient 2 (a 3.0×2.5 cm mass located at the posterior segment of the right upper lobe and a 1.6×0.9 cm GGO lesion located at the superior segment of the left lower lobe); (G) surgical image of instrumentation during right upper lobectomy.

using a suture, which was also used for retraction during resection. Then wedge resections were performed using curved endostaplers with margins ≥2 cm. Frozen-section examination confirmed an adenocarcinoma in the upper lobe and a carcinoma *in situ* in the lower lobe. One chest tube was placed at the posterior part of the incision. After the left-side operation, the patient was rotated to the opposite side for right upper lobectomy. Cushions were used to lift the patient to avoid kicking or compression to the contralateral chest tube during positioning. On the right, a 4.5 cm incision was made in the fifth intercostal space at the anterior axillary line (*Figure 1G*). Right upper lobectomy (*Figure 2*) was performed with the right upper pulmonary vein, arterial branches, bronchus and pulmonary fissures dissected and divided sequentially. Then frozen-section examination confirmed two adenocarcinomas and systematic lymph node (LN) dissection was performed (a total of 7 stations and 15 LNs were harvested). One chest tube was placed at the posterior part of the incision. Patient 2 was also firstly placed in a right lateral decubitus position to undergo left lower lobe superior segmentectomy (*Figure 3*) via a 4.5 cm incision made in the fifth intercostal space at the anterior axillary line. The superior segmental artery, bronchus, drainage vein, and the intersegmental plane were dissected and divided sequentially. Frozen-section examination confirmed an adenocarcinoma followed by

Figure 2 Right upper lobectomy (6). Single port was made in the 5th intercostal space about 4 cm. Wedge resection was first performed, which confirmed the malignant lesion; the right upper lobe was gripped and tucked dorsally; the front of the right hilus was exposed, and the pleura were peeled with the electrocoagulation hook; the right superior pulmonary vein was dissected and transected by a stapler; the apico-anterior arterial trunk was dissected and transected by a stapler; after that, the posterior ascending artery was ligated with silk thread and transected by harmonic scalpel; the next step was to dissect and transect the right upper bronchus; at last, the pulmonary fissures were completed by stapler; the specimen was then retrieved via a self-made protective bag using a rubber gloves; systemic mediastinal lymph node dissection was following. We stuck to the non-grasping and en bloc strategies. Firstly, stations 2 and 4 LNs were dissected; station 3 LNs were dissected; the inferior pulmonary ligament was transected and the station 9 LNs were simultaneously harvested if there was any; the last step was to dissect the subcarinal station 7 LNs; bronchial arteries across the subcarinal area were clipped by hem-o-lock and cut by the harmonic scalpel.
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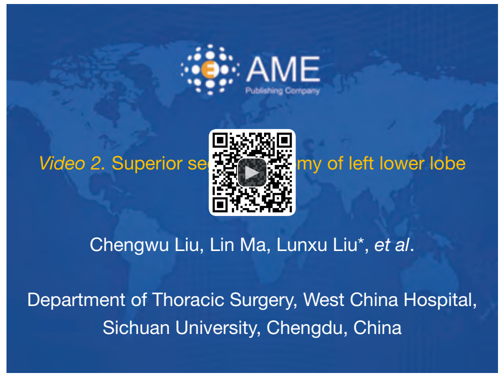

Figure 3 Superior segmentectomy of left lower lobe (7). The target nodule in superior segment of left lower lobe was firstly located by digital palpation and marked via a stitch; the posterior part of the major pulmonary fissure was incompletely developed, and was opened with electric hook and harmonic scalpel to facilitate the exposure of the interlobar artery; the superior segmental artery had two branches, which were dissected and transected by stapler one by one; subsequently, the underlying superior segmental bronchus was dissected and transected by a gold color stapler; the posteroinferior drainage vein was isolated, and clipped by a hem-o-lock, cut by harmonic scalpel; the last step was to identify the intersegmental plane and cut it; the intersegmental plane was identified by inflation of left lung and cut along the remnant basilar artery and bronchus; the specimen was then retrieved via a self-made protective bag using a rubber gloves.
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systemic LN dissection (a total of four stations and seven LNs were harvested). After the left-side procedure, she was rotated to the opposite side for right upper lobectomy followed by systemic LN dissection (a total of five stations and seven LNs were harvested) after confirmation of adenocarcinoma by frozen-section examination. Chest tube strategy was the same as did for patient 1. The operation time for patient 1 and 2 were 260 and 285 min, respectively. The intraoperative blood loss of patient 1 and 2 were 30 and 60 mL, respectively. The postoperative courses were both uneventful. Pathological examination documented four primary lung cancers of patient 1 (right upper lobe, two minimally invasive adenocarcinomas, T2aN0M0 and T1aN0M0, respectively; left upper lobe, minimally invasive adenocarcinoma, T1aN0M0; left lower lobe, adenocarcinoma *in situ*, TisN0M0) and two primary lung cancers of patient 2 (right upper lobe, acinar predominant adenocarcinoma, T1bN0M0; left lower lobe, lepidic predominant adenocarcinoma, T1aN0M0).

Discussion

The common criteria used for differentiating between SMPLC and intrapulmonary metastases depend on the results of pathologic examination and even molecular and genomic analysis (8). However, preoperative diagnosis is often difficult due to difficulty in obtaining sufficient specimens for histological examination whether through bronchoscopy or percutaneous puncture, especially for those small peripheral lesions. Single-staged procedures executed via traditional multiportal VATS have been demonstrated to be feasible and safe for selected patients with bilateral SMPLC (3). Although it may be also reasonable to perform delayed resections for some small GGO lesions with no negative effect on outcomes (9), we prefer to perform single-staged surgery when the lesions are highly suspected of malignancy. Since introduced by Rocco *et al.* in 2004 (10), sporadic reports on uniportal VATS for lung cancer have been published (5,11,12). Uniportal VATS causes less postoperative pain and fewer paresthesia owing to less intercostal space involved (13). For our patients, it's hard to procure thorough diagnoses for all lesions through neither bronchoscopy nor percutaneous puncture due to their disperse locations, small sizes, and manifestations of GGO. To simplify the diagnosis and treatment course, we transferred the less invasive technique of uniportal VATS into the management of SMPLC to achieve mini-invasive diagnosis and synchronous treatment. Systemic LN dissection is routinely performed when anatomic pulmonary resection (lobectomy or segmentectomy) is planned in our daily work. But for pure GGO lesions, especially those ≤1 cm, wide wedge resection with adequate free margin seems to be oncologically enough because there is seldom invasiveness or LN involvement (14). Therefore, we didn't perform LN dissection for the left side of patient 1 while station seven would be dissected from the right side.

This successful attempt first demonstrates the feasibility of simplified mini-invasive diagnosis and synchronous treatment using bilateral uniportal VATS major pulmonary resection for the management of SMPLC with multiple bilateral lesions.

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Future

Is uniportal thoracoscopic surgery a feasible approach for advanced stages of non-small cell lung cancer?

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Objectives: Conventional video-assisted thoracoscopic (VATS) lobectomy for advanced lung cancer is a feasible and safe surgery in experienced centers. The aim of this study is to assess the feasibility of uniportal VATS approach in the treatment of advanced non-small cell lung cancer (NSCLC) and compare the perioperative outcomes and survival with those in early-stage tumors operated through the uniportal approach.

Methods: From June 2010 to December 2012, we performed 163 uniportal VATS major pulmonary resections. Only NSCLC cases were included in this study (130 cases). Patients were divided into two groups: (A) early stage and (B) advanced cases (>5 cm, T3 or T4, or tumors requiring neoadjuvant treatment). A descriptive and retrospective study was performed, comparing perioperative outcomes and survival obtained in both groups. A survival analysis was performed with Kaplan-Meier curves and the log-rank test was used to compare survival between patients with early and advanced stages.

Results: A total of 130 cases were included in the study: 87 (A) *vs.* 43 (B) patients (conversion rate 1.1 *vs.* 6.5%, P=0.119). Mean global age was 64.9 years and 73.8% were men. The patient demographic data was similar in both groups. Upper lobectomies (A, 52 *vs.* B, 21 patients) and anatomic segmentectomies (A, 4 *vs.* B, 0) were more frequent in group A while pneumonectomy was more frequent in B (A, 1 *vs.* B, 6 patients). Surgical time was longer (144.9±41.3 *vs.* 183.2±48.9, P<0.001), and median number of lymph nodes (14 *vs.* 16, P=0.004) were statistically higher in advanced cases. Median number of nodal stations (5 *vs.* 5, P=0.165), days of chest tube (2 *vs.* 2, P=0.098), HOS (3 *vs.* 3, P=0.072), and rate of complications (17.2% *vs.* 14%, P=0.075) were similar in both groups. One patient died on the 58th postoperative day. The 30-month survival rate was 90% for the early stage group and 74% for advanced cases

Conclusions: Uniportal VATS lobectomy for advanced cases of NSCLC is a safe and reliable procedure that provides perioperative outcomes similar to those obtained in early stage tumours operated through this same technique. Further long term survival analyses are ongoing on a large number of patients.

Keywords: Advanced lung cancer; uniportal; thoracoscopy; video-assisted thoracoscopic(VATS) lobectomy; minimally invasive surgery; non-small cell lung cancer (NSCLC)

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Introduction

Despite the multiple advantages of video-assisted thoracoscopic (VATS) compared with thoracotomy (1) as decreased postoperative pain, decreased hospitalization, diminished inflammatory response or faster access to chemotherapy, the thoracoscopic approach for advanced stages of lung cancer is still infrequent. The concern about an intraoperative thoracoscopic major bleeding or the technical complication of performing a radical oncologic resection by VATS in advanced cases are the main reasons for the low adoption.

There are few studies reporting perioperative results and survival of patients with advanced disease operated by thoracoscopic approach (2,3). These cases are operated by using conventional VATS. However the same procedure can be performed by using a single incision approach. Since we developed our uniportal technique for VATS lobectomies in 2010 (4) we have increased the application of this technique to more than 90% of cases in our routine surgical practice. The experience we acquired with the uniportal technique during the last years (5), as well as technological improvements in high definition cameras, development of new instruments, vascular clips and more angulated staplers have made this approach safer, incrementing the indications for single-port thoracoscopic resections. We believe it is important to minimize the surgical aggressiveness especially in advanced stage lung cancer patients where the immune system is weakened by the disease or by neoadjuvant treatments. The minimally invasive surgery represents the least aggressive form to operate lung cancer and the single-port or uniportal technique is the final evolution in these minimally invasive surgical techniques.

The objective of this study is to assess the feasibility of uniportal VATS approach in the treatment of advanced non-small cell lung cancer (NSCLC) and to compare the perioperative outcomes and overall survival with early-stage tumors.

Methods

A retrospective descriptive prevalence study was performed on patients undergoing single-port approach for major pulmonary resections at Coruña University Hospital and Minimally Invasive Thoracic Surgery Unit (UCTMI) between June 2010 and December 2012. This study was approved by the review board at Coruña University Hospital and UCTMI. All patients were informed and had a written consent before surgery. A total of 163 surgical interventions (major pulmonary resections) were performed using this technique during the study period. Most were conducted by surgeons experienced with the uniportal approach for minor and major resections.

Only NSCLC were included in the study. Advanced clinical stage NSCLC were considered as tumors bigger than 5 cm, T3 or T4 and/or tumors that received neoadjuvant chemotherapy or radiotherapy. Most of the patients underwent routine preoperative pulmonary function testing, bronchoscopy, computed tomography, and fused positron emisión tomography-computed tomography.

Patients were divided into two groups: (A) early stage (T1 and T2) and (B) advanced clinical stages. A descriptive and retrospective study was performed, comparing perioperative outcomes and survival obtained in both groups.

Thanks to our previous VATS experience with conventional and double-port VATS (6), the indications and contraindications have changed overtime. The only absolute contraindication considered was surgeon discomfort and huge tumors impossible to remove without rib spreading.

Variables studied in each patient were age, sex, smoking habits, COPD, pulmonary function (FEV1 and FVC), presence of associated comorbidities, how the lesion is presented, tumor type and location, type and duration of surgical intervention, surgery-associated adhesions, stage, histology, tumor size, lymph nodes affected (number of lymph nodes retrieved and number of nodal stations explored), duration of chest tube, length of hospital stay, postoperative complications, 60-day mortality and survival.

Statistical analysis

A descriptive analysis of the variables studied was carried out. The quantitative variables are expressed as mean ± standard deviation, median and range. Qualitative variables are expressed by means of frequencies and the corresponding percentages. SPSS 17 for Windows for statistical analysis.

To compare the postoperative course according to perioperative characteristics, the Mann Whitney test was used for quantitative variables and Chi square test or Fisher exact test was used for qualitative variables.

A survival analysis was performed with Kaplan-Meier curves and the log-rank test was used to compare survival between patients with early and advanced stages.

Surgical technique

All patients in both groups were operated by using a single-incision VATS approach with no rib spreading and no wound protector (7). No epidural catheter was used. The 4-5 cm incision was placed in the fifth intercostal space. Anatomic major pulmonary resections were performed in all patients. Following anatomical resection, a complete mediastinal lymphadenectomy was performed in the patients with a diagnosis of malignancy. Instruments used were long and curved with proximal and distal articulation to allow the insertion of 3 or 4 instruments simultaneously and the camera used was 10 mm HD scope 30 degree. Intercostal infiltration was performed at the end of the

Table 1 Patient characteristics

	Mean ± SD [range] or No. (%)	
	A	B
Age	64.87±10.41 [38-84]	65.05±8.99 [47-81]
Sex		
Male	61 (70.1)	35 (81.4)
Female	26 (29.9)	8 (18.6)
Smoking history		
Yes	68 (78.2)	68 (78.2)
No	19 (21.8)	19 (21.8)
Comorbidity		
COPD	34 (39.1)	34 (39.1)
Cardiovascular risk factor	73 (83.9)	73 (83.9)
Cardiac disease	21 (24.1)	21 (24.1)
Previous cancer	22 (25.3)	22 (25.3)
Symptoms		
Casual finding	58 (66.7)	58 (66.7)
Hemoptysis	8 (9.2)	8 (9.2)
General syndrome	7 (8.0)	7 (8.0)
Cough	5 (5.7)	5 (5.7)
Pneumonia	6 (6.9)	6 (6.9)
Chest pain	1 (1.1)	1 (1.1)
Endobronchial tumor	6 (6.9)	6 (6.9)
Preoperative histology	13 (13.8)	13 (13.8)
Neoadyuvant treatment	0	29 (67.4)
Chemotherapy alone		24 (55.8)
Chemo-radiotherapy		5 (11.6)
Pulmonary function		
FEV1	89.06±25.35 [27-134]	79.56±19.87 [45-126]
FVC	94.24±21.04 [57-139]	90.62±14.75 [67-121]

Table 2 Anatomic pulmonary resections (n=130)

	No. (%)	
	A	B
Right upper lobectomy	26 (29.9)	17 (39.5)
Right middle lobectomy	5 (5.7)	3 (7.0)
Right lower lobectomy	11 (12.6)	7 (16.3)
Left upper lobectomy	26 (29.9)	4 (9.3)
Left lower lobectomy	13 (14.9)	5 (11.6)
Typical segmentectomy	4 (4.6)	0
Right pneumonectomy	0	1 (2.3)
Left pneumonectomy	1 (1.1)	5 (11.6)
Bilobectomy	1 (1.1)	1 (2.3)

surgery under thoracoscopic view and only one chest tube was placed in all patients.

We always start all lung operations with uniportal VATS to assess the extent of the disease and to rule out any pleuro-pulmonary metastasis. Conversions were defined as operations that began with a thoracoscopic dissection-division of hilar structures and were concluded as ribspreading thoracotomies. The cases that required conversion to open surgery were performed by extending the existing incision and continuing surgery through an anterior minithoracotomy with rib spreading and support of optics (like hybrid VATS).

Results

Since the start of the Uniportal VATS program in June 2010 until December 2012, we have performed 163 major lung resections using this technique (That is now, December 2013, a total of 323 major resections). Only NSCLC cases were included in this study so a total of 130 cases were studied: 87 (group A) *vs.* 43 patients (group B). The demographic characteristics of the patients in both groups are described in *Table 1*. There were no significant differences in terms of patient age, sex, smoking status, past medical history or associated comorbidity between the two groups. The lesions were most often casual findings (66.7% in group A and 37.2% in B). From the patients in group B, 67.4% of them received chemo or chemo-radiotherapy induction treatment before surgery.

The types of resection performed and their frequency are shown in *Table 2*. Upper lobectomies (A, 52 *vs.* B, 21 patients) and anatomic segmentectomies (A, 4 *vs.* B, 0) were more frequent in group A while pneumonectomy was more frequent in B (A, 1 *vs.* B, 6 patients).

In group A, 68.3% of the patients and 40% of those in group B showed no adherences following lung collapse. In contrast, significant adherences complicating surgery were recorded in 15.4% of the cases in group A and 28.9% in group B.

The advanced group included very complex cases like bronchial sleeve resections, lobectomies with vascular reconstruction, chest wall resection, lobectomies after high

Table 3 Intraoperative data

	Mean ± SD; median [range]		P
	A	B	
Surgical time (minutes)	144.94±41.34; 140.0 [60-300]	183.26±48.97; 180.0 [100-310]	<0.001
Number of lymph nodes	14.36±6.71; 14.0 [5-38]	16.52±6.16; 16.0 [7-29]	<0.001
Number of explored nodal stations	4.76±1.11; 5.0 [3-7]	4.97±1.31; 5.0 [1-8]	NS
Tumor size (cm)	2.55±1.02; 2.5 [0.5-4.8]	3.92±2.38; 4.0 [0-9]	NS

Table 4 Postoperative results

	Mean ± SD; Median [range] or No. [%]		P
	A	B	
Days of chest tube	2.92±2.4	3.42±2.66	
	2.0 [1-16]	2.0 [1-14]	NS
ICU	2.0±6.54	1.15±0.36	
	1.0 [0-54]	1.0 [1-2]	NS
HOS	4.45±7.27	4.26±2.87	
	3.0 [1-58]	3.0 [2-14]	NS
Rate of complications	15 [17.2]	6 [14.0]	NS
Prolonged air leak (>5 days)	3	2	
Atelectasis	1	0	
Wound problems	3	0	
Atrial fibrillation	3	2	
Respiratory failure/SIRS	1/1	0	
Postoperative bleeding requiring reoperation	2	2	
Reinsertion of chest tube	1	2	

Table 5 Concordance between clinical and pathological staging (NSCLC)

	Preoperative No. (%)			
	A		B	
Stage				
IA	59 (67.8)	50 (57.5)	1 (2.3)	6 (14.0)
IB	15 (17.2)	16 (18.4)	4 (9.3)	5 (11.6)
IIA	6 (6.9)	7 (8.0)	7 (16.3)	9 (20.9)
IIB	1 (1.1)	2 (2.3)	1 (2.3)	4 (9.3)
IIIA	3 (3.4)	9 (10.3)	26 (60.5)	9 (20.9)
IIIB	0	0	0	0
IV	0	0	2 (4.7)	2 (4.7)
pT0N0M0				6 (14.0)
Concordance N (%)	74 (85.1)		20 (46.5)	
Downstaging chemo N (%)			16 (55.2)	

NSCLC, non-small cell lung cancer.

doses of chemo-radiotherapy, redo-VATS, completion pneumonectomy or sulcus tumor after induction treatment.

The intraoperative results are described in *Table 3*. Conversion rate was higher in group B (1.1% *vs.* 6.5%, P=0.119). Also in group B, surgical time was longer (144.9±41.3 *vs.* 183.2±48.9, P<0.001) and median number of lymph nodes (14 *vs.* 16, P=0.004) was statistically higher in advanced cases.

The postoperative results are described in *Table 4*. There were no significant differences in terms of days of stay in the intensive care unit, days of chest tube, HOS and rate of complications. One patient died on the 58th postoperative day due to a respiratory failure (group A).

In both groups the majority of the patients (A, 82.8% and B, 86%) suffered no postoperative complications. From the patients in group A, 65.5% of them were discharged in the first 72 hours versus 51.2% of patients in group B. All patients (100%) were discharged without any nursing assistance at home.

The most common histological type in group A (48, 55.1%) was adenocarcinoma while in group B (24, 55.8%) it was squamous cell carcinoma. The concordance between clinical and pathological stages is described in *Table 5*. A total of 85.1% of patients (A) and 46.5% (B) presented concordance between preoperative and postoperative staging. From the patients receiving chemotherapy 55.2% (16 patients) were pathologically downstaged (six of them were down-staged to pT0N0M0, total tumoral regression).

The survival rates are described in *Table 6*. The 30-month survival was 90.4% for early stages (group A) and 73.7% for advanced cases (group B). The 30-month overall survival of the 130 pacients was 85% (Kaplan-Meier).

Discussion

Since the first lobectomies using VATS were reported 20 years ago (8), the thoracoscopic approach has experienced an exponential increase for lung cancer treatment, especially for early stages. The majority of publications on VATS

Table 6 Survival data (n=130)

	Mean ± SD (range) or No. (%)	
	A	B
Postoperative mortality	1 (1.1)	0
Actual survival		
Alive	82 (94.3)	33 (76.7)
Deceased during following	5 (5.7)	10 (23.3)
Estimated survival (months)	39.02±1.02 (37.02-41.01)	25.25±1.48 (22.34-28.16), P<0.002
30 months-estimated survival (Kaplan-Meier)	90.4%	73.7%

lobectomy focus on patients with early stages of NSCLC, showing less postoperative pain, lower stress responses and improved outcomes, when compared with thoracotomy (9). However the role of VATS for treatment of advanced stages of lung cancer is not clear and has been questioned.

Thanks to the advances in the field of thoracoscopic surgery the indications and contraindications for lung cancer treatment have been changed overtime. Initially only early stages were considered for VATS approach and advanced NSCLC tumors were considered a contraindication for thoracoscopic surgery (10). Several concerns regarding the radicality of oncologic resection, technical challenges, and safety has reduced the incorporation of VATS for more advanced stages of lung cancer. In cases of extended resections such as vascular or bronchial sleeve, chest wall resection or tumors after high doses of induction chemo-radiotherapy; the VATS approach is even less frequent. However, thoracoscopic major lung resection for advanced stage lung cancer is now gaining wide acceptance in experienced VATS departments (11). Skilled VATS surgeons can perform 90% or more of their lobectomies thoracoscopically, reserving thoracotomy only for huge tumors or complex broncho-vascular reconstructions.

Despite the increasing implementation of the techinque by experienced surgeons to deal with advanced tumors, the number of publications showing results is still insignificant. Hennon and colleagues, showed similar outcomes of advanced cases performed by VATS when compared with open surgery (2). In this study the perioperative complications were equal in patients undergoing thoracoscopic resection when compared to those having a thoracotomy. No difference was observed for disease-free and overall survival.

In another multi-institutional experience, more than 400 patients with stage III or IV disease were treated with a VATS approach over a period of 8 years. The preliminary analysis indicate no significant difference in overall survival between VATS and open thoracotomy groups, with a conversion rate of approximately 5% in the cohort of patients with advanced stage NSCLC (12).

The incidence of surgical complications after neoadjuvant therapy has been reported in the literature to be high (13). VATS lobectomy has been usually avoided in patients undergoing preoperative chemotherapy or radiotherapy due to concerns regarding the propensity of induction therapy to increase the difficulty of hilar and mediastinal dissection, especially around vessels. In our series of patients the induction treatment increased the complexity of hilar and lymph node dissection but these were performed successfully, most likely due to our previous thoracoscopic experience (5,6). There are publications reporting that pulmonary resection may be performed safely after induction chemo or high doses of radiotherapy (14,15). However, recent publications showed prior chemotherapy as one of the significant predictors of morbidity in a multivariable analysis (16). The rate of complications in our study in patients receiving induction treatment had not increased, being similar to perioperative results in early stage tumors.

Recently, Huang J and colleagues published a study of 43 locally advanced NSCLC patients (including nine sleeves and four pneumonectomies) undergoing VATS following neoadjuvant therapy with good posotperative results (3). Lee and colleagues report that thoracoscopic pulmonary resection for NSCLC showed better compliance with adjuvant chemotherapy, allowing to apply the thoracoscopic procedure not only to patients with early stage NSCLC but also to patients who need adjuvant chemotherapy (17).

Uniportal VATS has become an increasingly popular and effective approach in our unit to manage early and advanced stages of NSCLC, because of the reduced access trauma, advantages in view and more anatomic instrumentation and good perioperative results. The success in performing uniportal complex VATS lobectomies is a result of skills and experience accumulated over time from performing uniportal VATS surgery (5). With gained experience with the uniportal VATS technique the most complex cases can be performed in the same manner as with double or triple port approach. We have performed advanced NSCLC cases via single-port VATS including lobectomies with chest wall resection (18), redo-VATS and completion pneumonectomies, cases after high doses of chemo-radiotherapy, vascular reconstruction (19), bronchial sleeve lobectomies (20) and complex pneumonectomies (21).

Mean operation time for advanced uniportal VATS resections was higher than for early stage tumors (188 *vs.* 141 m), as expected. However our surgical time is less than other authors by using more number of thoracoscopic incisions (11). We found several advantages of the single incision technique especially for advanced cases. The geometrical explanation of the approach could explain our results (22). The advantage of using the camera in coordination with the instruments is that the vision is directed to the target tissue, bringing the instruments to address the target lesion from a straight perspective, thus we can obtain similar angle of view as in open surgery. Bimanual instrumentation also facilitates the surgery for complex cases. Conventional three port triangulation makes a forward motion of VATS camera to the vanishing point. This triangulation creates a new optical plane with genesis of dihedral or torsional angle that is not favorable with standard two-dimension monitors. Instruments inserted parallel to the videothoracoscope also mimic inside the chest maneuvers performed during open surgery. There is a physical and mathematical demonstration about better geometry obtained for instrumentation and view in the uniportal VATS over conventional approach (22). This fact in combination with the expierence obtained so far as well as recent improvements in surgical instruments, new energy devices and modern high definition cameras enable us to be very confident with the instrumentation and the manipulation of tissue even in very complex and advanced procedures.

The rate of pneumonectomies was logically higher in patients with advanced stages.

Pneumonectomy is only considered in cases where it is not possible to perform a sleeve resection. In our unit it is mandatory to do a careful assessment of the location of the tumor in order to proceed with a uniportal VATS pneumonectomy. Sleeve resections are also performed via single-incision VATS with no need to convert to thoracotomy allowing patients a better postoperative recovery (23). This is especially important in patients receiving induction chemo-radiotherapy as performing a pneumonectomy would increase the rate of postoperative complications. The uniportal thoracoscopic resection of the whole lung is technically easier to perform than a lobectomy because the fissure doesn't need to be managed. However extra care must to be taken during dissection and division of the main artery and transection of the main bronchus (21). There are several studies reporting that pneumonectomies performed thoracoscopically or via thoracotomy resulted in equivalent survival rates (24). Further studies and follow-up is needed to verify the benefits of VATS pneumonectomy for lung cancer.

From the literature, conversion rates from VATS lobectomy to open surgery have been reported to be from 2% to 23%, with these higher rates coming from patients with more advanced tumors (2). Most frequently the conversion to thoracotomy was considered necessary because of bleeding during dissection or oncological reasons, such as centrally located tumors requiring sleeve resection, or unexpected tumors that infiltrate the mediastinum or chest wall. In our series, the rate of conversion for advanced cases is low (only 6.5%) compared with other series (2,3). Furthermore, no patient was converted to conventional thoracotomy in our study (enlarged incision to antherior thoracotomy and Hybrid VATS).

Also in our study, the incidence of postoperative complications in early stages and advanced stages were similar. The uniportal technique was developed in 2010 by one of the surgeons of the department and sequentially taught to a total of four consultant surgeons and two trainees. Most of the advanced cases were performed by the surgeon who developed the technique, and with more thoracoscopic experience. This surgeon's experience in managing complex and highly difficult procedures under uniportal VATS and the advantages of the minimally invasive approach (small incision, no rib retractor and only one intercostal space opened) is also important to reduce the prevalence of postoperative complications, especially in the advanced group.

We believe that minimize the surgical aggression is particularly important given the large number of frail patients with advanced stage disease who require multimodality therapy, sometimes being difficult to tolerate in older patients or patients with severe comorbidity. Several articles in the literature suggest that the immune response is better preserved after VATS surgery than thoracotomy (1). Given that immune function is an important factor in controlling tumor growth and recurrence, we have hypothesized that the reduced inflammatory response associated with thoracoscopy, especially with uniportal VATS (which represents the minimal invasive approach) may be associated with improved long-term survival. Further studies to analyze inflamatory response and long term survival on uniportal VATS are ongoing.

This study is limited by its retrospective design and absence of comparative subjects with open approach. Most of the data except on present survival were collected from chart review, with the limitations accompanying a retrospective study. Also, the follow-up duration was relatively short, and the free-disease period was not studied making it difficult to conclude whether survival rates were favorable for patients undergoing uniportal VATS lobectomy.

Another limitation of the study is the absence of an analysis of the results based on the cases performed by surgeons with a greater experience in the technique (those who have performed most operations), compared to those surgeons who started the technique later.

There are few reports regarding perioperative results and survival of advanced cases of NSCLC operated by thoracoscopic approach. According to the VATS Consensus Statement (agreement among 50 international experts to establish a standardized practice of VATS lobectomy after 20 years of clinical experience), eligibility for VATS lobectomy should include tumour size ≤7 cm and N0 or N1 status. Chest wall involvement was considered a contraindication for VATS lobectomy, while centrality of tumour was considered a relative contraindication when invading hilar structure (25). The Consensus Group acknowledged the limitations of VATS lobectomy based on their individual experiences with a recommendation to convert to open thoracotomy in cases of major bleeding, significant tumour chest wall involvement and the need for bronchial and/or vascular sleeve procedures. However, these recommendations are directed at the general thoracic surgical community, and indications for VATS lobectomy and conversion to thoracotomy should depend on each surgeons experience.

In conclusion, Uniportal VATS lobectomy for advanced cases of NSCLC is a safe and reliable procedure that provides perioperative outcomes similar to those obtained in early stage tumours operated through this same technique. Our 30-month survival rate is acceptable and similar to survival rates reported in other studies performed by conventional VATS. Further analyses of long term survival for advanced cases operated by uniportal VATS needs to be performed with a large number of patients to validate the oncologic outcomes of the technique.

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Future

Double sleeve uniportal video-assisted thoracoscopic lobectomy for non-small cell lung cancer

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Double sleeve (vascular and bronchial) lobectomy is a reasonable alternative to pneumonectomy in patients with centrally located tumors involving the pulmonary artery and bronchus. However, it is a challenging and complex procedure even when performed through thoracotomy.

Despite the advances in thoracoscopic surgery, double sleeve lobectomy by conventional thoracotomy is still the preferred approach because of the technical difficulties of thoracoscopic surgery and the potentially increased operative risks even when performed by experienced video-assisted thoracoscopic surgery (VATS) surgeons. There are very few reported cases of double sleeve lobectomy by VATS using 3-4 incisions (1,2). We present the first report of double VATS sleeve resection by a single incision approach.

Clinical tummary

A 65 year-old male, smoker, was diagnosed with a 7.2 cm left upper lobe adenocarcinoma with vascular and bronchial involvement. The patient received neoadjuvant Platinum based chemotherapy (six sessions) with poor response. A chest computed tomography (CT) scan performed before surgery (*Figures 1* and *2*) showed progression of the tumor (9 cm mass with left upper lobe atelectasis) despite neoadjuvant chemotherapy. The patient was offered left upper lobe resection with uniportal VATS.

Surgical technique

Under general anesthesia, we performed flexible video bronchoscopy. The right-sided airways had normal anatomy with no endobronchial lesions and no significant amount of secretions or pus. In the left-sided airways, there was an obvious tumor mass that had completely occluded the entire orifice of the left upper lobe of the lung and was entering the distal left main bronchus.

The patient was positioned into right lateral decubitus position with the left side up, and a VATS approach using a 5 cm single-incision was made in the 5th intercostal space with no rib spreading (no soft tissue retractor and no direct vision).

The upper lobe was adherent to the chest wall, the mediastinum, and the aorta without signs of invasion, and was detached and freed of its adhesions using cautery. Digital palpation confirmed the presence of a 9 cm mass occupying most of the upper lobe and involving all arterial branches of the upper lobe. There was no other evidence of pleural disease in the chest.

The first step was to expose and control the main pulmonary artery (PA), which was dissected and encircled with a double vessel loop, while the superior pulmonary vein was also dissected free and transected using endostaplers. We then opened the fissure between the upper and lower lobe. The tumor did not involve the fissure or the lower lobe and the artery was dissected and mobilized.

The left main bronchus and the lower lobe bronchus were dissected and cleared, with dissection of the subcarinal lymph node and subsequently the interlobar and peribronchial lymph nodes up towards the specimen. The main bronchus and left lower lobe bronchus were transected with a long handle No. 10 blade (sleeve resection). The inferior pulmonary ligament was released to allow greater mobilization of the lower lobe. Before clamping of the PA, 5,000 units of heparin were given intravenously to prevent clotting. The main PA was occluded using a thoracoscopic D'Amico clamp (Scanlan International, MN, USA) and

Figure 1 Computed tomography scan after chemotherapy showing arterial involvement.

Figure 2 Computed tomography scan after chemotherapy showing bronchial involvement.

the interlobar artery was occluded with a bulldog clamp (Aesculap, Inc., Center Valley, PA, USA). The main PA and the basal artery were transected with scissors (vascular sleeve) to remove the left upper lobe en-block. The specimen was temporarily placed in the lower chest cavity above the diaphragm. We started the double sleeve reconstruction by the bronchial anastomosis using a running, non-absorbable suture (PDS 3/0) for cartilaginous and membranous portions. The posterior wall of the bronchus was sutured first, the anterior wall was sewn up last, and then both sutures were tied together. The lower lobe was inflated and no air leakage was detected underwater. The arterial sleeve anastomosis was performed thereafter by using a monofilament non-absorbable continuous suture (prolene 4/0) in two different rows, with a similar method as for the bronchus (the medial arterial wall was sutured first, followed by the lateral wall). Both suture lines were tied together at the anterior part of the anastomosis using a thoracoscopic knot pusher.

The edges of the anastomosis were everted to enhance arterial intimal interface and maximize the opening of the anastomosis. The bulldog clamp was opened for back bleed to remove the air, and the inflow and outflow were flushed and checked prior to the anastomosis. The clamp from the main PA was slowly opened and no bleeding from the vascular anastomosis was found.

The bronchial anastomosis was then wrapped with a piece of oxidized regenerated cellulose (Surgicel®), to be isolated from the vascular suture. The specimen was inserted into a protective plastic bag and removed by enlarging the incision. A single chest tube was placed at the end of the operation. Frozen section confirmed that all surgical margins were clear, including our bronchial and left main stem bronchus margin. The total surgical time was 260 min and estimated blood loss was 170 cc.

Patient recovery was satisfactory, and the chest tube was removed on the 5th postoperative day. Pathological examination revealed a 7.5 cm adenocarcinoma with bronchial and vascular involvement (free tumoral margins) and no lymph node malignancy (pT3N0M0).

Discussion

The thoracoscopic approach for major lung resection for advanced lung cancer is now gaining wide acceptance worldwide (3). However, lobectomies requiring double sleeve are challenging procedures, even when performed by thoracotomy. As such, it still remains a contraindication for VATS approach, even for experienced thoracoscopic surgeons, primarily due to concerns of vascular injury during thoracoscopy as well as the technical complexity of the procedure for an optimal bronchovascular reconstruction. There are few articles published in the literature describing a double bronchial and vascular sleeve reconstruction by VATS, and all of these cases are reported by using 3-4 incisions (2,3). VATS sleeve lobectomies are still being refined.

Through recent technical advances in VATS lobectomy (instruments and HD cameras) and the skills and experience gained from treating large numbers of patients, these complex procedures can be performed by using only a single incision approach. As a result, advanced procedures such as uniportal sleeve lobectomy (4,5) or uniportal vascular reconstruction (6) have already been published with good postoperative outcomes (7). The advantage of uniportal VATS surgery is that it allows the target tissue to be directly visualised at a similar angle of view as for open surgery (8). Conventional multi-port VATS triangulation creates a new optical plane for the genesis of a dihedral or torsion angle not favorable with 2D monitors. Another advantage of the uniportal VATS technique is that instruments are inserted parallel to the video-thoracoscope, therefore mimicking the maneuvers performed inside the chest during open surgery. This geometric uniportal VATS concept facilitates the double bronchial and vascular anastomosis in complex resections such as the one described in this article.

The use of thoracoscopic instruments with proximal and distal articulation is very useful for sleeve procedures through a single incision approach, especially for clamping the pulmonary artery and for suturing the artery and bronchus. The use of a bulldog clamp placed inside the chest cavity for clamping the basal artery allows surgeons to have more space for instrumentation through a single incision approach. The clamp for the main artery is placed in the anterior portion of the incision and the camera in the posterior portion, making the instrumentation similar as for an open approach for bronchial and vascular anastomosis.

With the single incision thoracoscopic view, the bronchus is located behind the artery, making it easier to perform bronchial anastomosis first, followed by arterial, in order to avoid excessive manipulation and traction to the arterial suture.

Several reports confirm the safety of bronchovascular reconstructions after chemotherapy (9). Video-assisted thoracoscopic sleeve procedures enable faster patient recovery and preserve pulmonary function (10,11). This is especially important in patients receiving induction treatment, as the implementation of a pneumonectomy would increase the rate of postoperative complications (12). In the current literature, there is also evidence supporting the use of neoadjuvant treatment and minimally invasive techniques.

In conclusion, single incision thoracoscopic bronchovascular double sleeve lobectomy is technically difficult, but feasible, when performed by skilled surgeons experienced with the uniportal approach.

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Future

Uniportal video-assisted thoracoscopic left upper lobectomy under spontaneous ventilation

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Abstract: Intubated general anesthesia with one-lung ventilation was traditionally considered necessary for thoracoscopic major pulmonary resections. However, non-intubated thoracoscopic lobectomy can be performed by using conventional and uniportal video-assisted thoracoscopic surgery (VATS). These non-intubated procedures try to minimize the adverse effects of tracheal intubation and general anesthesia but these procedures must only be performed by experienced anesthesiologists and skilled thoracoscopic surgeons. Here we present a video of a uniportal VATS left upper lobectomy in a non-intubated patient, maintaining the spontaneous ventilation.

Keywords: Non-intubated patient; single-port video-assisted thoracoscopic surgery (VATS); awake surgery; lobectomy; uniportal; spontaneous ventilation

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Intubated general anesthesia with one-lung ventilation was traditionally considered necessary for thoracoscopic major pulmonary resections. However, non-intubated thoracoscopic lobectomy can be performed by using conventional and uniportal video-assisted thoracoscopic surgery (VATS). Here we present a video of a uniportal VATS left upper lobectomy in a non-intubated patient.

A 73-year-old female, non-smoker, was admitted to our department for surgery. A control CT scan revealed a mass in the left upper lobe. The patient was proposed for non-intubated VATS surgery. A facial mask was used to have control of the airway. Propofol and continued perfusion of remifentanil were administered for sedation. No epidural catheter was placed. The skin and the intercostal space were infiltrated with levobupivacaine. A 3-cm incision was made in the 5th intercostal space. A 3-cm adenocarcinoma was detected in the left upper lobe so a left upper lobectomy and lymph node dissection was performed. The total surgical time was 90 minutes (*Figure 1*).

The patient was sent to a recovery room for 1 hour and then to the ward. The patient was discharged home on the second postoperative day with excellent recovery. The final pathological result revealed a 3.5-cm adenocarcinoma with no lymph node involvement.

Discussion

The first non-intubated VATS for lobectomy was initially described in 2007 (2). Since then, only three groups have published major pulmonary resections by VATS in non-intubated patients (3-5).

The non-intubated procedures try to minimize the adverse effects of tracheal intubation and general anesthesia such as intubation-related airway trauma (6), ventilation-induced lung injury, residual neuromuscular blockade (7) and postoperative nausea and vomiting. Avoidance of general anesthesia also results in a faster recovery with immediate return to daily life activities.

We consider this procedure feasible for selected patients with no difficulties for intubation, with no obesity and good cardiopulmonary function. In addition, this surgery should only be performed by experienced anesthesiologists and

Figure 1 Uniportal VATS left upper lobectomy under spontaneous ventilation (1).
Available online: http://www.asvide.com/articles/468

thoracoscopic surgeons (preferably skilled and experienced with complex or advanced cases and bleeding control through VATS).

In this video we show the technique for lobectomy by using a 3 cm single incision approach with no intubation, no vagus blockade, no central vein, no epidural and no urinary catheter. The future of the thoracic surgery is to reduce the surgical and anesthetic trauma. The combination of nonintubated or awake thoracoscopic surgery and the single-port VATS probably represents the least invasive procedure for pulmonary resections. Thanks to avoidance of intubation, mechanical ventilation and muscle relaxants, the anesthetic side effects are minimal allowing to most of the patients to be included in a fast protocol avoiding the stay in an intensive care unit.

The success in performing lobectomies by a single incision approach in non-intubated patients is a result of skills and experience accumulated over time by performing many uniportal VATS surgeries (8,9).

In conclusion, uniportal video-assisted thoracoscopic lobectomy in patients under spontaneous ventilation is a feasible and a safe procedure in expert hands. It represents a good option for high risk patients for intubated general anesthesia such as elderly patients. This procedure should only be performed by experienced anesthesiologists and skilled single-port thoracoscopic surgeons.

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Future

Uniportal VATS for pneumothorax and interstitial lung disease

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Abstract: The algorithms for the management of primary spontaneous pneumothorax (PSP) consider the surgical approach as the recommended treatment after the first recurrent episode. Surgical lung biopsy should be performed in order to reach the specific diagnostic definition in case of interstitial lung disease (ILD). The uniportal video-assisted thoracic surgery (VATS) has been proposed as an innovative minimally invasive approach for performing the optimal surgical management in both PSP and ILD. The aim of the present review is to describe and discuss this operative technique, as a valuable option for treating the above-mentioned thoracic diseases. To this purpose, we herein describe the theoretical and practical aspects of the uniportal VATS technique (with the support of two specific videos) and review the literature inherent to the use of this approach for managing PSP and ILD, demonstrating that this is a well defined and standardized surgical technique for performing several intra-thoracic operation and, particularly, an effective approach for treating PSP and for managing patients affected by ILD.

Keywords: Minimally invasive surgical procedure; video-assisted thoracic surgery (VATS); pneumothorax; interstitial lung disease (ILD)

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Introduction

The American College of Chest physicians and the British Society of Thoracic Surgeons have published guidelines for the management of primary spontaneous pneumothorax (PSP) (1,2). Both reports stated that, after the first recurrence, PSP should be treated surgically, performing a thoracoscopic bullectomy associated with a procedure for inducing pleural adhesions.

A joint document from the American Thoracic Society and European Respiratory Society (3) recommends the use of surgical lung biopsy for obtaining an accurate diagnosis in patients affected by interstitial lung disease (ILD). The choice of performing this procedure, however, should take in to consideration a considered judgment of the surgical risk and general anesthesia. In this perspective, the minimally invasive approach should be preferred.

In 2004, Rocco and Colleagues published their first paper about the use of the uniportal video-assisted thoracic surgery (VATS) (4) as a novel mini-invasive surgical technique designed to perform pulmonary resections in patients affected by PSP or ILD. The authors described the theoretic aspects of this surgical approach and their results on an initial cohort of 15 patients. Since then, the uniportal VATS has been applied for treating several intra-thoracic diseases and its short and long term results have been reported, confirming the advantages in comparison with traditional techniques (5).

This paper presents the principal steps to follow in order to perform a uniportal VATS pulmonary resection, and reviews its role in managing PSP or ILD patients.

The uniportal VATS: technical hints

The uniportal VATS approach is a minimally invasive technique, which allows to perform intrathoracic surgical procedures through a single incision (2-2.5 cm long). The patient is usually positioned in lateral decubitus and the

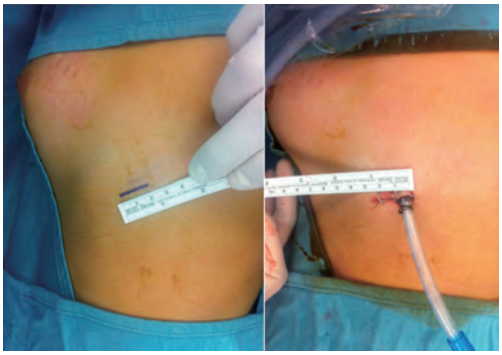

Figure 1 Uniportal access before the skin incision and at the end of the surgical procedure.

Figure 2 Uniportal VATS for PSP (8).
Available online: http://www.asvide.com/articles/139

unique port represents the inlet for the optical source as well as for all the other operative instruments (4,6) (*Figure 1* freezed image of the patient in OR). Usually no devices are used to dress the incision and generally the trocar used to insert the videocamera is retracted along the stem, in order to maximize the movement of the instruments.

The position of the incision could vary depending upon the procedure and the site of the target lesion, even though most of the operations can be performed using an access lying at the level of the fifth intercostal space on the mid axillary line (5).

Differently from the standard three-port VATS approach, where the lesion represents the apex of an ideal pyramid and the camera and instruments are positioned in correspondence of the other three vertexes, the uniportal VATS technique implies that the lesion, the camera and the instruments all lie in the same sagittal plane. The single incision is the fulcrum from which the parallel instruments reach the target, arranging themselves in a cranio-caudal direction (4,6).

The use of 5-mm articulating instruments and a 5-mm 30-degree optical source allows to increasing their mutual mobility, facilitating the execution of the planned procedure.

Uniportal VATS for PSP

The surgical approach is considered the best treatment to minimize the risk of recurrence in patients, who experienced a PSP (1,2). There is a solid evidence in the literature demonstrating that the minimally invasive approach should be preferred to the open procedure since it is able to reduce the postoperative pain and it is associated with a faster recover of the physical and working activity (2). The uniportal VATS technique allows to performing all the main surgical steps recommended for treating patients affected by PSP, amplifying the clinical advantages of the traditional three-port VATS (7).

In fact, as shown in the *Figure 2*, using this surgical technique it is possible:

(I) to explore the entire chest cavity and pulmonary parenchyma;
(II) to identify blebs or bullae;
(III) to suspend and resect the affected areas of the lung;
(IV) to perform adequate pleurodesis procedures (i.e., mechanical parietal pleural abrasion, talc poudrage, pleurectomy).

At the end of the procedure a chest tube can be positioned using the single thoracic access.

Compared to the traditional three-port technique, the uniportal VATS offers clinical and management advantages. Rocco and colleagues (7) retrospectively compared a group of 16 patients submitted to uniportal VATS with 19 patients treated by three-port VATS. They found that the use of a single access resulted in a lower early postoperative pain score measured by a visual analogic score ranging from 0 to 4 (mean postop pain: uniportal 0.4±0.5 *vs.* three-portal 0.8±0.7 P=0.06, maximum postop pain: uniportal 1.4±0.9 *vs.* three-portal 2.6±0.9 P<0.001). Moreover, at the telephonic interview follow-up (mean follow-up time: uniport 9.4±6.6 months, three-port 32.1±9.9 months), they found a reduction of long term neurologic symptoms (uniport 14% of pts, three-port 58% of pts).

Chen and Colleagues (9) recently corroborated these results presenting the comparison between 20 PSP

Figure 3 Uniportal VATS for ILD (14).
Available online: http://www.asvide.com/articles/140

patients submitted to three-port VATS and 10 treated by uniportal VATS. The uniportal group experienced a lower postoperative pain in the first 24 hours measured by the visual analogic scale ranging 0 to 10 (three-port 4.95±0.39 *vs.* single port 4.5±0.7, P=0.03) and reported an higher patient satisfaction scale (graded from grade1: excellent satisfaction to grade 4: poor satisfaction) in the first and second postoperative days (1st day: three-port 2.55±0.82 *vs.* single port 1.9±0.74, P=0.045; 2nd day: three-port 2.9±0.64 *vs.* single port 2.4±0.52, P=0.041).

In 2008 Salati and Colleagues (10) restrospectively compared 28 patients submitted to uniportal VATS with 23 patients submitted to standard three-portal VATS for PSP. They showed that the uniportal approach reduced the postoperative hospital stay (three-port 4.9±2.4 *vs.* uniport 3.8±1.8, P=0.03), concurring to a reduction of the global hospital costs (postoperative hospital cost three-port 1,793 Euros ±893 *vs.* single port 1,407±649, P=0.03). Similarly to Rocco, they registered at the telephonic interview (mean follow-up time: three-port 39 months, uniport 13 months, P<0.001) a lesser paresthesia complain rate for patients treated by the single port technique (three-port 94% *vs.* uniport 35%, P<0.001).

All these three papers found that the uniportal VATS did not increase the operation time nor the incidence of PSP recurrences compared to three-port VATS.

Uniportal VATS for ILD

The correct diagnostic definition represents the starting point to set an effective therapeutic protocol for patients affected by ILD. Even if, in some cases, the specific diagnosis can be established on the basis of clinical, laboratory, radiological and cytological examinations, it is often necessary to perform a surgical biopsy in order to obtain an adequate sample of lung tissue for the histopathological analysis. This surgical procedure should be proposed, taking into account the associated risks in a kind of patients already suffering for compromised respiratory function.

The most recent guidelines (3,11) recommend to taking at least two samples of lung tissue from two different lobes in order to optimize the diagnostic accuracy. At the same time it is suggested to perform the procedure using a minimally invasive approach in order to minimize the surgical risks.

In this respect, Fibla and Colleagues (12) developed a risk score to predict the risk of mortality after surgical biopsy for interstitial lung disease. They reviewed 311 consecutive patients submitted to lung biopsy for suspected ILD and found an increased risk of 90 days mortality for those patients having an age older than 67 years (dead group mean age: 68.8 years *vs.* alive group: 59.9 years, P<0.001), an history of preoperative intensive care unit admission (dead group: 27% *vs.* alive group: 3.6%, P<0.001), an immunosuppressive treatment (dead group: 27% *vs.* alive group: 6.1%, P<0.001) and an open surgery approach (dead group: 36% *vs.* alive group: 7.2%, P<0.001). The Authors assigned to each of these factors a specific risk score (open surgery =1, immuno-suppressive treatment =1.5, age >67=1.5, pre-ICU =2). So they were able to define 4 classes of incremental risk of death that could be used in the clinical practice to define the cost-effectiveness of the possible surgical biopsy (score 0: mortality risk 2%, score 1-2: mortality risk 12%, score 2-3: mortality risk 40%, score >3: mortality risk 86%).

As also emphasized by this article, it is evident that the uniportal approach is a viable option to reduce even more the impact of the surgical procedure compared with the traditional three-portal VATS, maintaining the required characteristics for an effective lung biopsy procedure.

In fact, in 2005 Rocco and Colleagues reported their experience about 20 patients submitted between January 2000 and April 2004 to uniportal VATS wedge resection of the lung for diagnosis of ILD (13). They demonstrated that using this technique was possible to obtain a median of two specimens for each patient without mortality nor major morbidity. All patients received a correct diagnosis, which altered the treatment protocols in 70% of them.

The following video (*Figure 3*) shows how the use of the uniportal approach makes possible:

(I) to explore the entire chest cavity and pulmonary

parenchyma;
(II) to identify the target areas of each lobe;
(III) to suspend and resect parts of the affected areas of the lung.

Conclusions

We have described the theoretical and practical aspects of the uniportal VATS technique for managing PSP and ILD. Our experience and the available data from the literature demonstrates that uniportal VATS is a well defined and standardized surgical technique which may be used to perform several intra-thoracic operation and, in particular, an effective approach for treating PSP and for achieving diagnosis in patients affected by ILD.

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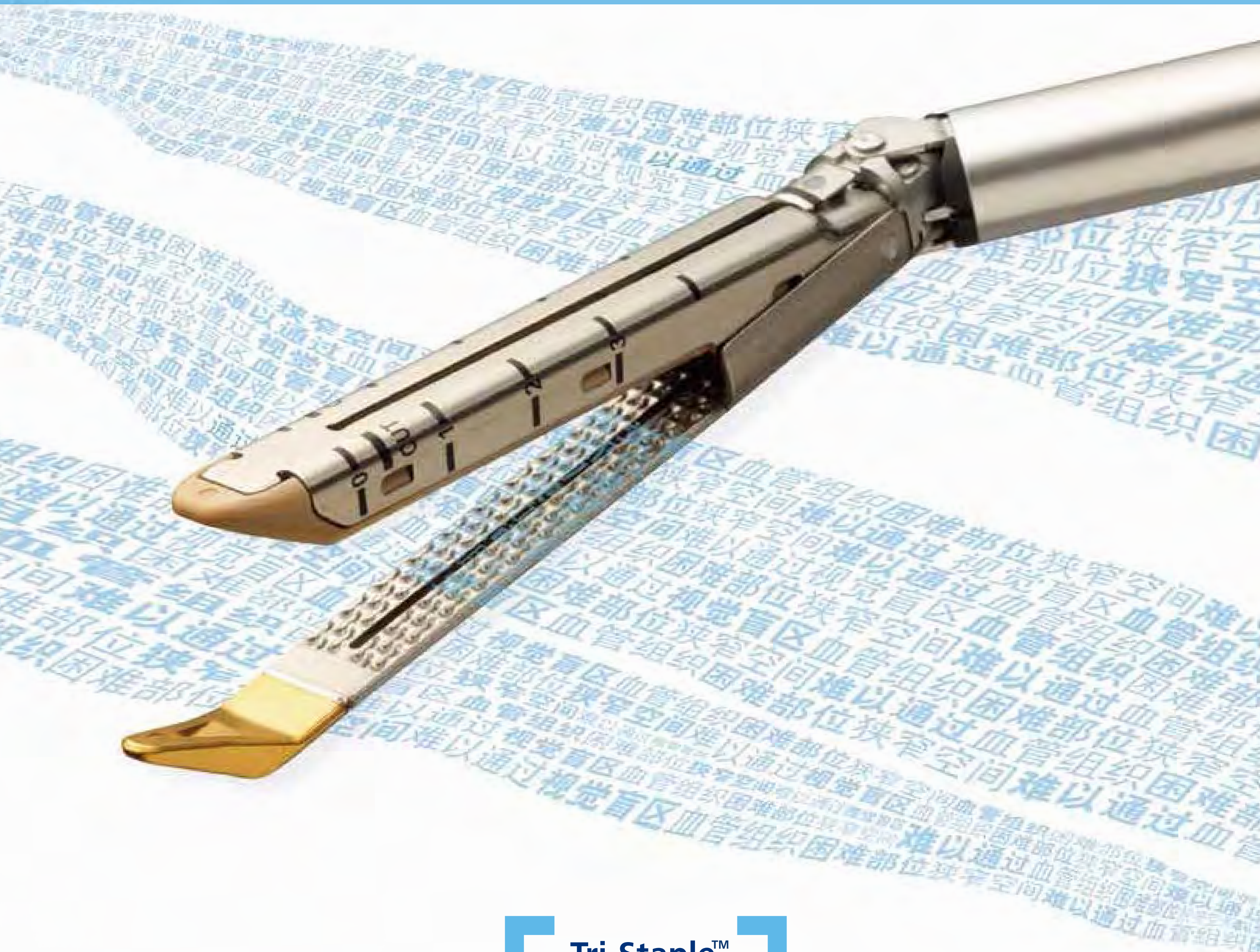

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