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MINIMALLY INVASIVE
PANCREATIC SURGERY

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MINIMALLY INVASIVE PANCREATIC SURGERY

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Room C 16F, Kings Wing Plaza 1, NO. 3 on Kwan Street, Shatin, NT, Hong Kong

Information on this title: www.amegroups.com
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First published in 2019
Printed in China by AME Publishing Company

Editors: Bing Peng, Edoardo Rosso, Ammar A. Javed

Minimally Invasive Pancreatic Surgery
(Hard Cover)
ISBN: 978-988-78919-3-2
AME Publishing Company, Hong Kong

Minimally Invasive Pancreatic Surgery (FIRST EDITION)

HONORARY EDITOR

A. James Moser
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

EDITORS

Bing Peng
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Edoardo Rosso
Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

Ammar A. Javed
Department of Surgery, The Johns Hopkins University School of Medicine, Baltimore, MD, USA

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AUTHORS

Amr I. Al Abbas
Division of Surgical Oncology, Department of Surgery, University of Pittsburgh, Pittsburgh, PA, USA

Bassan J. Allan
Division of Surgical Oncology, Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Hideo Baba
Department of Gastroenterological Surgery, Graduate School of Life Sciences, Kumamoto University, Kumamoto, Japan

Courtney E. Barrows
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Joal D. Beane
Division of Surgical Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Marc G. Besselink
Department of Surgery, Academic Medical Center Amsterdam, AZ Amsterdam-Zuidoost, The Netherlands

Yunqiang Cai
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

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Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Jai Young Cho
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Aslam Ejaz
Department of Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Lara Espin
Department of Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Ruifang Fan
HPB Surgical Unit, Department of Surgery & Cancer, Imperial College, Hammersmith Hospital Campus, London W12 0HS, UK

Abe Fingerhut
Section for Surgical Research, Medical University of Graz, Graz, Austria

Yuman Fong
Department of Surgery, City of Hope Medical Center, Duarte, California, USA

Michele Maiko Gage
Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Tamara M. H. Gall
HPB Surgical Unit, Department of Surgery & Cancer, Imperial College, Hammersmith Hospital Campus, London W12 0HS, UK

Daniel Galvez
Department of Surgery, The Johns Hopkins Hospital Baltimore, MD, USA

Pan Gao
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Jonathan Greer
Division of Surgical Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Jeroen Hagendoorn
Department of Surgery, University Medical Center Utrecht, CX Utrecht, The Netherlands

Ahmad Hamad
Division of Surgical Oncology, University of Pittsburgh, Pittsburgh, PA, USA

Ho-Seong Han
Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea

Alina Hasanain
Department of Surgery, The John L. Cameron Division of Hepatobiliary and Pancreatic Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Jin He
Department of Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Melissa E. Hogg
Division of Surgical Oncology, Department of Surgery, University of Pittsburgh, Pittsburgh, PA, USA

David A. Iannitti
Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA

Jae Seong Jang
Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea

Ammar A. Javed
Department of Surgery, The John L. Cameron Division of Hepatobiliary and Pancreatic Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Long R. Jiao
HPB Surgical Unit, Department of Surgery & Cancer, Imperial College, Hammersmith Hospital Campus, London W12 0HS, UK

Yen-Yi Juo
Department of Surgery, Center for Advanced Surgical and Interventional Technology (CASIT) at UCLA, Los Angeles, CA, USA; Department of Surgery, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Viktor Justin
Hospital of Saint Elisabeth, Vienna, Austria

Chang Moo Kang
Division of HBP Surgery, Department of Surgery, Yonsei University College of Medicine, Seoul, Republic of Korea; Pancreatobiliary Cancer Clinic, Yonsei Cancer Center, Severance Hospital, Seoul, Republic of Korea

Mehmet Kaplan
Department of General Surgery, Bahcesehir University School of Medicine, Istanbul, Turkey

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Jonathan C. King
Department of Surgery, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Russell C. Kirks Jr
Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA

Bas Groot Koerkamp
Department of Surgery, Erasmus Medical Center, Rotterdam, CE Rotterdam, The Netherlands

Ioannis T. Konstantinidis
Division of Surgical Oncology, Department of Surgery, City of Hope National Medical Center, Duarte, CA, USA

David A. Kooby
Department of Surgery, Emory University School of Medicine, Atlanta, GA, USA

Seong Uk Kwon
Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea

Yongbin Li
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Xubao Liu
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Alberto Manzoni
Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

John B. Martinie
Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA

Laleh G. Melstrom
Division of Surgical Oncology, Department of Surgery, City of Hope National Medical Center, Duarte, CA, USA

Lingwei Meng
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

I. Quintus Molenaar
Department of Surgery, University Medical Center Utrecht, CX Utrecht, The Netherlands

A. James Moser
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Carolijn L. Nota
Department of Surgery, University Medical Center Utrecht, CX Utrecht, The Netherlands; Department of Surgery, City of Hope Medical Center, Duarte, California, USA

Stephanie M. Novak
Division of Surgical Oncology, Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Ana Sofia Ore
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Nicola Passuello
Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy

Bing Peng
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Elisa Sefora Pierobon
Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy

Alberto Ponzoni
Departiment of Radiology, Hospital of Padua, Padua, Italy

Lauren M. Postlewait
Division of Surgical Oncology, Department of Surgery, Winship Cancer Institute, Emory University, Atlanta, GA, USA

Gioia Pozza
Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy

Sean M. Ronnekleiv-Kelly
Department of Surgery, The Johns Hopkins University School of Medicine, Baltimore, MD, USA

Edoardo Rosso
Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

Nelson A. Royall
Department of General Surgery, Digestive Disease Institute, Cleveland Clinic Foundation, Cleveland, Ohio, USA

Bulent Salman
Department of General Surgery, Gazi University School of Medicine, Ankara, Turkey

Jessica Shaker
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Jonathan Ghing-Chi Sham
Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Mikael H. Sodergren
HPB Surgical Unit, Department of Surgery & Cancer, Imperial College, Hammersmith Hospital Campus, London W12 0HS, UK

Richard Sola Jr
Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA

Monica Solis-Velasco
The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Rebecca Sorber
Department of Surgery, The Johns Hopkins Hospital Baltimore, MD, USA

Cosimo Sperti
Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy

Selman Uranues
Section for Surgical Research, Medical University of Graz, Graz, Austria

Michele Valmasoni
Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy

Dionisios Vrochides
Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA

R. Matthew Walsh
Department of General Surgery, Digestive Disease Institute, Cleveland Clinic Foundation, Cleveland, Ohio, USA

Xin Wang
Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu, China

Junfeng Wang
Department of Hepatobiliary Surgery, The First People's Hospital of Yunnan Province, Kunhua Hospital Affiliated to Kunming University of Science and Technology, Kunming, China

Matthew J. Weiss
Department of Surgery, The John L. Cameron Division of Hepatobiliary and Pancreatic Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Yo-ichi Yamashita
Department of Gastroenterological Surgery, Graduate School of Life Sciences, Kumamoto University, Kumamoto, Japan

Tonguc Utku Yilmaz
Department of General Surgery, Kocaeli University School of Medicine, Kocaeli, Turkey

Yoo-Seok Yoon
Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea

Herbert J. Zeh
Division of Surgical Oncology, Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Giuseppe Zimmitti
Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

Amer H. Zureikat
Division of Surgical Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Maurice J. Zwart
Department of Surgery, Academic Medical Center Amsterdam, AZ Amsterdam-Zuidoost, The Netherlands

Executive Typesetting Editor:

Xiaoting Xu, AME Publishing Company

The Annals of Cardiothoracic Surgery, one of AME's peer-reviewed journals, is lucky to have an author from Rochester, USA. He is left-handed. When he began his training in surgery, he encountered huge obstacles. For example, when using scissors or knotting during a surgery, his actions were the opposite of what was described in textbooks. Therefore, he often "took a beating" from his mentors when performing a surgery.

Later, he summarized his experience and published it in a journal in an attempt to find other surgeons that "suffer from the same fate". Surprisingly, after his article was published, many surgeons e-mailed him, asking him how left-handed doctors should undergo surgical training, and so on. Then he met Professor Tristan D. Yan, the editor-in-chief of Annals of Cardiothoracic Surgery, who happens to be a left-handed doctor. Tristan encouraged him to become a heart surgeon because there are steps in cardiac surgery that require the use of the left hand to complete the suture threading technique. Tristan's view was that it was better if surgeons were trained to use both their left and right hands.

A few days ago, on my daughter's first day of kindergarten, I chatted with her teacher for a while; finally, she asked me if there was anything about my daughter that she should take note of . "Please do not correct my daughter's left-handedness," I said, "Just let it be." "Why?" the teacher asked in wonder.

On December 7, 2013, we held the second AME Academic Salon in the Hospital Affiliated to Nantong University. After dinner, Dr. Shen Yaxing from the Department of Thoracic Surgery of Shanghai Zhongshan Hospital invited several attendees to have tea in his room. The elevator was in the middle of the hotel. After we walked out of the elevator, he led us to the left, then to the left, then to the left, then to the left, and finally to the door of his room. Although we were somehow confused and disoriented, some of us did find out that the door was just diagonally across the elevator. We all burst into laughter. Yaxing shared that he took this route the first time he entered his room, and so he decided to bring us on the same route on the second time. Yaxing then said that this was the behavior of a 'typical' surgeon!

During the training to be a surgeon, each step and each action are done under the strict direction and supervision of a senior surgeon. Thus, many surgeons like to affectionately address their mentors as their "masters".

How, then, can you become a master of surgery? In addition to your own intelligence and diligence, the expertise and mentorship offered by a "master" is also very important. Just like in the world of martial arts, there are many different schools that are independent from each other and have their own strength and weakness, and the surgical world is very much the same.

Therefore, it is important for a young surgeon to gain knowledge and skills from different masters by taking in only the essence and discarding the dregs. Therefore, we have planned to publish the AME Surgery series, in an attempt to share with our readers the surgical skills of some prominent surgical teams in China and abroad, as well as their philosophical thinking and some interesting stories. We sincerely hope that our colleagues in the surgical departments find these books insightful and helpful.

Stephen D. Wang
Founder and CEO,
AME Publishing Company

This book highlights the revolution started by intraoperative video as a tool for surgical innovation, education, and research (1).

The era of "see one, do one, teach one" in surgery is rapidly giving way to a high-definition, three-dimensional platform for visualizing both the operative field and its related anatomy. Video and operative guidance have become both teacher and quality improvement tool even for procedures performed at low incidence. This path was discovered by JD Birkmeyer and others by using video to prove a link between technical proficiency and patient outcomes (2).

The confluence of evolving three-dimensional/4k video, 3-D imaging, and computer-assisted technologies is radically transforming surgery beyond the original Greek *cheirourgia*, "work done by hand," into a minimally-invasive landscape populated by robots, virtual reality, and simulation. It is hard to imagine how the "old ways" can long co-exist with these powerful forces for change.

Every chapter in *Minimally Invasive Pancreatic Surgery* is written, illustrated, and beautifully demonstrated by modern experts in the field of pancreatic surgery. This book proves that resourcefulness remains a strong character trait among surgeons who will figure out how to disseminate even the most difficult minimally-invasive procedures to peers around the world so that patients with pancreatic disease may find relief of their pain and avoidance of disability after surgery.

I sincerely hope this book is a further step toward re-defining adverse public perceptions of open surgery which have persisted since its invention more than one hundred years ago.

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A. James Moser, MD, FACS
Associate Professor of Surgery, Harvard Medical School;
Co-Director, Pancreas and Liver Institute;
Co-Director, Pancreatic Cancer Research Program;
Beth Israel Deaconess Medical Center;
Boston, MA, USA

Since the first successful laparoscopic cholecystectomy (LC) by doctor Mouret in 1987, the concept of minimally invasive surgery (MIS) has been gradually accepted by surgeons. MIS has become one of the main directions of surgery in 21st century with obvious advantages in the diagnosis and treatment of diseases. And in recent years, MIS represented by laparoscopy has been extensively and deeply developed in various fields of surgery. It has been the first choice of surgeons as also as patients because of its small incision, clear vision, less intraoperative bleeding, less postoperative pain and quick recovery. As a matter of fact, laparoscopic technique is the most influential progress made in the modern field of surgery worldwide. Laparoscopic surgery has penetrated into all fields of surgery and has also brought unprecedented changes to abdominal surgery. Along with social progress and the continuous development of medical technology, surgical operations increasingly focus on MIS which need more specialized too.

With the development of modern surgical techniques, laparoscopic surgery such as LC has gradually become the preferred surgical treatment for many abdominal surgical diseases. However, the role of laparoscopy was difficult to assess for complex hepatobiliary and pancreatic surgery, because the size of incision is not as significant as that of cholecystectomy. Later, with the in-depth study of the laparoscopic technique especially in the department of surgical oncology, surgeons found that the laparoscopic surgery had some other advantages in addition to small incision and fast recovery. On the one hand, laparoscopic surgery had more benefit for tumor patients as it could reduce postoperative inflammatory response, reduce the patient's immunosuppression and was more compliance with the no-touch principle. On the other hand, the enhanced intraoperative visualization facilitate precise and accurate manipulation, which was beneficial to the exposure of vessels, the dissection of lymph nodes and surrounding tissue and finally reduce the intraoperative bleeding. In conclusion, MIS can be widely accepted and sustained as patients ultimately benefited from it. Compared with open surgery, the goal of laparoscopic surgery is not only faster postoperative recovery, but also a quest for a better outcomes

In the recent thirty years, despite continuous progress had been made in MIS, the development of MIS in pancreatic surgery was very slow. Laparoscopic techniques for pancreatic disease were first attempted in the 1960s, although a wide variety of pancreatic laparoscopic resections, ranging from enucleations to distal resections, had since been performed with limited successful outcomes. The difficulties of this technique are because of retroperitoneal location, complicated surrounding anatomy, and high rate of dangerous complications such as pancreatic fistula (PF). Therefore, laparoscopic pancreatic surgery is the most challenging operation in the department of general surgery.

Throughout the history of laparoscopic pancreatic surgery, hard work and sweat were still paid by several generations of laparoscopic surgeons. In 1992, Ganner and Pomp performed the first laparoscopic pancreatoduodenectomy (LPD) for a patient with chronic pancreatitis. The operation lasted 10 hours. The postoperative period was complicated by a jejunal ulcer and delayed gastric emptying necessitating a prolonged hospitalization and intravenous hyperalimentation. No fistulas occurred, a follow-up CT scan revealed no pancreatic abnormalities, and the patient was discharged in good condition on the 30th postoperative day. In 1994, doctor Soper reported animal experiments of LPD and laparoscopic distal pancreatectomy (LDP). In the same year, doctor Cuschieri reported the clinical study of LDP as it didn't need to reconstruct the digestive tract which means lower difficulty and risk, easier to master and spread. In the following 10 years, with more LDPs reported, it was further confirmed that LDP has significant advantages compared with open surgery.

In 1997, Ganner reported 11 cases of LPD, which supporting LPD was safe and feasible without increasing the perioperative mortality and complications while prolonging postoperative hospital days. For quite a long time, there were only a few reports of LPD let alone normalization. During this period, laparoscopic surgery was more commonly used for staging of pancreatic cancer and palliative surgery for periampullary carcinoma.

In the next 14 years (from 1997 to 2011), only 341 LPDs were reported in 14 English articles worldwide. The technical complexity, the inherent instrument limitations, and a requirement of a long learning curve delayed the widespread acceptance and application of this challenging surgery. Therefore, it is not difficult to understand that the interval between the first and the second large series reports (n ≥10 cases) of LPD approached 8 years. Afterwards, an increasing number of studies have been published, indicating the safety and acceptable outcomes of this technique. However, these results were limited by highly selected patients, specialized surgeons, and high-volume institutions. And the comparison between LPD and OPD was still a concern. With the development of techniques and instruments in 14 years, LPD entered a stage of rapid development after 2012. From 2012 to 2016, in a short period of 5 years, there were more than 100 reports of LPD including large series reports which comparing LPD with OPD worldwide and LPD combined with resection and reconstruction of blood vessels had also been reported.

In addition, laparoscopic central pancreatectomy and total pancreatectomy are far behind the other laparoscopic pancreatectomy, which are related to the complicated reconstruction of the digestive tract and the limited indication. However, with the rapid development of LPD, the implementation of these two operations are safe and feasible for surgeons with skilled laparoscopic techniques to achieve well short-term and long-term results.

With the improvement of surgical technique and the development of laparoscopic and robotic surgery technology, more and more robot-assisted surgeries are used in patients underwent pancreatic surgery. Compared with the traditional laparoscopic surgery, the robot-assisted surgery is more expensive, because of its advantages of anastomosis and reconstruction. The robotic platform provides a magnified three-dimensional image, 7 degrees of freedom, and eliminates hand tremor and the fulcrum effect of rigid laparoscopic instruments—allowing for precise suturing, easier tissue handling, better control of large blood vessels, and the ability to work at angles not possible with the laparoscopic surgery. With the increasing number of robotic pancreatic operations and the accumulation of surgical experience, the robot surgery technology almost covers all pancreatic operations. In the past, the forbidden area of laparoscopic pancreatic surgery has now become a routine procedure in some high-volume robotic pancreatic surgery centers. However, the expensive cost and traditional operation concept of robot surgery in our country not only restrict more patients to experience the technological innovation advantages brought by robot surgery, but also restrict the development of robot surgery in China. However, with the extensive application of robot surgery and the actual benefits of patients, more and more patients have accepted the revolutionary surgical method of robot. Although robotic pancreatic surgery has started late in China, the number and quality of pancreatic surgery in some robot surgery centers in China has been at the international advanced level. With the increasing number of robot applied in our country and the establishment of more robot pancreatic surgery team, the application of robot to treat pancreatic cancer will have a good prospect in our country.

Bing Peng, MD, PHD, FACS
Department of Pancreatic Surgery, West China Hospital, Sichuan University,
Chengdu 610041, China

Minimally invasive pancreatic surgery is not any more in its infancy and is currently an established approach for many patients. Worldwide, HPB surgeons and HPB team, are approaching, more and more, by minimally invasive techniques tumors once reserved exclusively to open surgery.

The present book is an excellent companion for the young as well as the experimented surgeons; it's a collection of technical articles and videos written by the most experimented leaders in the field of minimally invasive pancreatic surgery. The book covers not only basic interventions such as standard distal pancreatectomy and standard pancreaticoduodenectomy but even vascular resections and complex cases.

Interestingly, the book reports both laparoscopic and robotic interventions, moreover, different techniques and approaches are proposed for the same intervention (ex. distal pancreatectomy) according to the strategies adopted by each surgical team.

The reader can go through book from the first to the last page or read separately the chapters, indeed, each section is independent and it include a complete and up dated list of references.

It is a practical book rich of tips and tricks of priceless value for the HPB surgeons, moreover, the authors share their experience for the implementation of a minimally invasive program for pancreatic surgery including training.

The magic in reading a surgical book consists in the impression of getting all the solutions for technical challenges and pitfalls, the present manuscript gives to the reader such a feeling.

It is with pleasure that I suggest to the HBP community to get and read the present book.

Edoardo Rosso, MD

Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

(*Email: edoardo.rosso@poliambulanza.it*)

The first edition of *Minimally Invasive Pancreatic Surgery* provides an excellent resource for all trainees and surgeons looking for a book that can help them review the field of minimally invasive pancreatic surgery. Over the last two decades, the minimally invasive approach has become well established in pancreatic surgery and is frequently employed for distal pancreatectomies. Furthermore, it is now being utilized by experienced surgeons at high volume centers to perform more complex pancreatectomies including the Whipple procedure and pancreatectomies requiring vascular resections. I believe that over the next decade minimally invasive approach will become a standard approach for most pancreatic resections. It is therefore vital for all trainees and practicing surgeons performing these procedures to be well-versed in this approach.

Fittingly, the book starts with an article by Dr. Kooby, a leading expert and thought leader in the field. Therein, he provides a commentary on a report from the Dutch Pancreatic Cancer Group (DPCG) on their experience disseminating a nationwide training program for minimally invasive distal pancreatectomy. Two other chapters in the book provide detailed insight into establishing training programs for training surgeons in laparoscopic and robotic pancreatic surgery. These, together are an excellent resource for all planning to establish minimally invasive pancreatic surgery programs at their centers.

For the ease of reading, the book has been divided into two broad sections; laparoscopic surgery and robotic surgery. The book is short, easy to review and focuses on a pancreatic resection alone, unlike a majority of other textbooks available of minimally invasive surgery that are currently being used by trainees, and practicing surgeons. The book can be reviewed by readers from cover to cover to get an in depth understanding of the field. Alternately, it can be reviewed by them as individual chapters if they are interested in the preoperative planning, surgical approach, and management of patients undergoing a particular procedure.

Three aspects of this book make it unique. Firstly, in addition to frequently performed pancreatectomies i.e. the Whipple procedure and distal pancreatectomy, it discusses other forms of pancreatic resections including central pancreatectomy, enucleation, and pancreatectomy requiring complex vascular resection or multiorgan resection. Secondly, for a better understanding of the techniques, a majority of the chapters are accompanied with videos. In the case of laparoscopic and robotic surgery, these serve as excellent visual tools for study. The list of references provided at the end of each chapter provide additional resources for further learning. Lastly, various aspects of the same procedure are discussed by experts on minimally invasive pancreatic surgery from across the world. Reading each chapter will allow readers to appreciate the nuances in surgical techniques and patient management across various centers around the world.

It is with great pleasure that I introduce this book to the surgical community and hope that it will prove valuable to trainees and practicing surgeons globally.

Ammar Asrar Javed, MD
Lead Postdoctoral Research Fellow, Division of Hepatopancreatobiliary Surgery,
Department of Surgery, The Johns Hopkins School of Medicine, Baltimore, Maryland, USA
(*Email:ajaved1@jhmi.edu*)

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Introduction

Impact of a nationwide training program in minimally invasive distal pancreatectomy (LAELAPS)

David A. Kooby

Department of Surgery, Emory University School of Medicine, Atlanta, GA, USA

Correspondence to: David A. Kooby, MD, FACS. Professor of Surgery, Emory University School of Medicine, Atlanta, GA, USA. Email: Dkooby@emory.edu.

Provenance: This is a Guest Editorial commissioned by Editorial Board Member Marc Besselink (Department of Surgery, Academic Medical Center, AZ, Amsterdam, The Netherlands).

Comment on: de Rooij T, van Hilst J, Boerma D, *et al.* Impact of a Nationwide Training Program in Minimally Invasive Distal Pancreatectomy (LAELAPS). Ann Surg 2016;264:754-62.

Received: 05 October 2016; Accepted: 06 October 2016; Published: 23 November 2016.

doi: 10.21037/ales.2016.10.07

View this article at: http://dx.doi.org/10.21037/ales.2016.10.07

de Rooij and colleagues from the Dutch Pancreatic Cancer Group (DPCG) report on their experience disseminating a nationwide training program for minimally invasive distal pancreatectomy (MIDP) called LAELAPS (1). This effort included 32 surgeons at 17 medical centers in the Netherlands. The perioperative results prior to and following LAELAPS are compared, and conversion rate (38% *vs.* 8%, P<0.001), blood loss (350 *vs.* 200 cc, P=0.03) and length of hospital (9 *vs.* 7 days, mean, P<0.001) were all improved significantly presumably as a result of the training and experience. The assessment was made according to STROBE guidelines (2). Robotic and laparoscopic procedures were included, as performed using the same techniques, and patient selection was according to the criteria of Yonsei (3).

I congratulate the DPCG for their systematic approach and clear reporting of results with what appear to be direct cause and effect improvements. Innovation in surgery is both crucial and complex. Acceptance of innovation is a process, which takes time. Innovators and early adopters are often ridiculed and condemned as heretics and showmen by non-adaptors. Moving the process forward requires dedication and careful introspection to ensure that said innovation is not inferior to the original way of doing things, and that it may add additional value. Innovation may also raise concern, as innovators and early adopters may have abilities and access beyond what the general population can achieve, such as unusual skill and/or use of limited available technology. As we move along the innovation curve and more surgeons perform the newer technique, risks rises that inadequate training will lead to poor outcomes, increased patient risk, and loss of progress.

Laparoscopic colectomy is a commonly performed operation. In 2004, the results of the COST trial were presented and the concerns of surgeons who perform colon surgery were assuaged (COST), as the trial demonstrated non-inferiority of the laparoscopic approach to right, left, and sigmoid colectomy as compared with their open counterparts for the surgical removal of colon cancer (4). Industry supported training courses to increase technology sales and minimally invasive colectomy is a standard approach for appropriate patients with colon cancer.

Distal pancreatectomy is a less-commonly performed procedure than is partial colectomy, and the pancreas is a deep-seated retroperitoneal organ adjacent to foreboding vasculature. Merging experience in pancreatic resection with advanced laparoscopic technique for a relatively uncommonly performed procedure made systematic dissemination of MIDP slower than for colectomy. Coordinated efforts like LAELAPS are necessary to achieve this endpoint.

What we do not gain from this study is a true appreciation for the actual contribution of the training program. It could be that the "tipping point" was reached and more surgeons in the Netherlands gained comfort with MIDP, and that some of the post-LAELAPS improvement are circumstance. This is probably unlikely as the number of cases performed doubled in the 22 months after training as compared with the previous 9 years. The DPCG is unique in that it is a nationwide organization which demonstrates unusual collaborative spirit, as has been demonstrated in the Netherlands through various collaborative randomized studies. Problem with comparing longitudinally is that the surgeons already have increased experience, which can affect the significance. The B/C fistula rate of 30% seems higher than reported in other studies, but did not change following LAELAPS (5,6). I would not have included robotic procedures in this report, as robotic experience is even more reliant on a team approach and some important differences exist between robotic and laparoscopic distal pancreatectomy (7).

Overall, this study represents an important step in patient safety and collaboration. Current practice in the United States is to learn technique as a trainee during fellowship, or as faculty from course, mentorship, and/or trial and error. Systematic training programs for surgical innovation are crucial to achieve these results. LAELAPS and the collaborative effort from the Netherlands is a great example of this.

Acknowledgements

None.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

doi: 10.21037/ales.2016.10.07
Cite this article as: Kooby DA. Impact of a nationwide training program in minimally invasive distal pancreatectomy (LAELAPS). Ann Laparosc Endosc Surg 2016;1:27.

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Technique of “mini-invasive radical antegrade modular pancreatosplenectomy” for pancreatic cancer

Giuseppe Zimmitti, Alberto Manzoni, Marco Garatti, Valentina Sega, Edoardo Rosso

Department of General Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

Correspondence to: Edoardo Rosso. Department of General Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy. Email: edoardo.rosso@poliambulanza.it.

Abstract: Pancreatic cancer spreads preferentially into the retroportal lamina that is frequently invaded at the celiac trunk (CT) and/or superior mesenteric artery (SMA) margins. In 2007, for the first time, it has been proposed by the team of Prof. Strasberg SM an innovative surgical technique for open surgery called radical antegrade modular pancreatosplenectomy (RAMPS) which allows to increase the circumferential resection margins in case of pancreatic cancer of the body of the pancreas and it is associated to a high rate of R0 resection. Currently, it is possible to perform such intervention mini-invasively. The present manuscript reports our technique.

Keywords: Pancreatic cancer; laparoscopic; radical antegrade modular pancreatosplenectomy (RAMPS); pancreatosplenectomy

Received: 21 September 2018; Accepted: 27 September 2018; Published: 30 October 2018.

doi: 10.21037/dmr.2018.09.06

View this article at: http://dx.doi.org/10.21037/dmr.2018.09.06

Introduction

The main purpose of surgical resection for pancreatic cancer is to obtain an R0 resection at each pancreatic surgical margin (1-5). Only recently, it has been shown by Verbaiccke (1-5) that the most frequently invaded margin is the retro-portal one, therefore to surgeons need to concentrate their efforts on peri-adventitial dissection around the superior mesenteric artery (SMA) and celiac trunk (CT) in order to remove *en-block* with the pancreatic cancer the retro-portal lamina.

In case of pancreas cancer located in the body and the tail of the pancreas, Prof. Strasberg described in 2007 (6) an original technique, for open surgery, called radical antegrade modular pancreatosplenectomy (RAMPS). Such technique, differently from the standard left spleno pancreatectomy, includes: (I) an extensive dissection around the CT and SMA, (II) and the extension of the poster pancreatic margin at the Gerota fascia increasing the circumferential margin. Several studies confirmed that RAMPS allows to obtain a high rate of R0 resection (7,8).

Currently, it is possible to perform RAMPS laparoscopically or robotically, hereby you we reported our technique described step by step with the assistance of shorts videos (9-12).

Step by step approach to RAMPS

During laparoscopic RAMPS, we usually use 6 to 7 trocars: the camera is inserted in the abdomen through a supraumbilical 10 mm trocar, further 10 mm trocars are inserted para-rectal right and left, slightly higher than the previous one. Additional 5 mm trocars are inserted in the right and left abdomen, lateral to the previous ones, and below the xiphoid process. A final 10 mm trocar is inserted between the two left trocars previously placed.

Following abdominal cavity exploration, after the presence of peritoneal carcinosis or metastases at the glissonean surface have been excluded, the operation starts with the dissection of the gastrocolic ligament, keeping the omentum attached to the transverse colon and carefully preserving the gastroepiploic vessels on the greater curvature. Retrogastric adhesions with the pancreas are dissected, from left to right, moving towards the posterior wall of the gastric antrum.

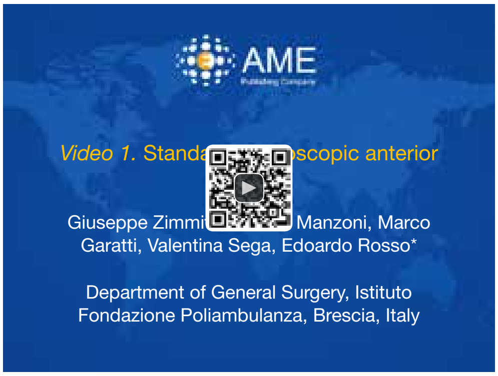

Figure 1 Standard laparoscopic anterior RAMPS (13). RAMPS, radical antegrade modular pancreatosplenectomy.
Available online: http://www.asvide.com/article/view/27984

Figure 2 Venous resection in case of posterior RAMPS (14). RAMPS, radical antegrade modular pancreatosplenectomy.
Available online: http://www.asvide.com/article/view/27985

At this point the gastroduodenal artery is identified on the left side of the duodenum and dissected upwards until its origin from the common hepatic artery (CHA). When the anterior wall of the pancreatic isthmus is fully exposed, a laparoscopic ultrasound is performed in order to better identify the tumor, assess its relation with close structures, and identify peritumoral lymphadenopathies or tumor infiltration of the retropancreatic fat tissue.

The operation continues with careful dissection of the caudal border of the pancreas from the transverse mesocolic root, at the pancreatic isthmus, until identifying the superior mesenteric vein (SMV). At this point, the CHA is identified, dissected, and encircled with an elastic tape at the superior margin of the pancreatic isthmus. Such dissection is extended to right, with dissection and elastic tape encircling of the proper hepatic artery (PHA), behind which the portal vein (PV) is identified.

Once the retropancreatic space is carefully dissected and the pancreas is encircled at the isthmus, the tissue at the left side of the hepatic pedicle is dissected free from the PHA and from the PV and pulled to the left. The dissection continues left, until identification and transection of the left gastric vein and identification, dissection, and encircling of the left gastric artery and splenic artery (SA) at the origin from the CT. The SA is then ligated but not transected.

The dissection moves now below the transverse mesocolon: the Treitz ligament is identified and dissected below the inferior mesenteric vein (IMV), until fully mobilization of the first jejunal loop and exposure of the anterior aortic wall. The dissection continues inframesocolic, above the IMV, until the left renal vein (LRV) is identified. The IMV transection allows now a complete exposure of the anterior wall of the LRV at its origin: it represents an important landmark for the identification of the left side of the SMA. Here, the SMA is encircled with an elastic tape and dissected free, upwards and downwards, from the surrounding tissue which will be removed *en-bloc* with the specimen.

The dissection of the inferior pancreatic margin is then continued to the left and deep, in order to remove the perirenal fat, with the exposure of the left renal capsule of the superior renal half. According to the tumor posterior extension, the left adrenal gland can be left in place (anterior RAMPS) (*Figure 1*) or, in case of tumor contact/infiltration, removed (posterior RAMPS) (*Figure 2*), following left adrenal vein closure and transection. The operation continues with the transection of the short gastric vessels and the complete separation of the stomach from the spleen.

The dissection moves back to the CT, whose left side is dissected upwards until its origin from the aorta. The SA, previously ligated, is now transected. Completing the dissection of the CHA from the pancreas, the presence of a dorsal pancreatic artery needs to be sought: its ligation and transection are mandatory, in order to achieve a complete lymphadenectomy of left side of the hepatic pedicle. The dissection moves now at the inferior pancreatic margin, where the SMA, while pulled to the left, is carefully dissected free at its anterior-right side from the retropancreatic lamina. During this maneuver, the retropancreatic tissue is dissected upward from the origin of the SMA, until the anterior aortic wall between the CT and the SMA is fully exposed.

The pancreas is then transected at the isthmus through an Endo Gia black reload tri-staple reload: prefiring pancreatic compression is used during transection, in order to minimize traumatism to pancreatic capsule and parenchyma. The splenic vein transection at the confluence with the SMV is performed with an Endo Gia vascular reload and is followed by the pancreatic body and tail mobilization from the posterior plane and the dissection of the splenic peritoneal connections. Finally, the mobilized specimen is extracted with an endobag through a Pfannenstiel incision, the hemostasis checked, and two drains are placed: one close to the pancreatic stump and the other in splenic space.

Post-operative care

Patients are allowed to drink from the first post-operative day (POD), oral re-alimentation is introduced gradually from the POD 2. Amylase are measured in the drains on POD 1, 3 and 5, which are removed on POD 5 in absence of pancreatic fistula (PF), however, if PF occurs, the drains are kept in place and eventually replaced by percutaneous pig tail according to the finding of post-operative CT scan, and they are gradually removed in outpatient clinics.

Oral pancreatic enzymes are administered systematically for at least 3 months. Post-operative persistent diarrhea occurs frequently and is treated with oral loperamide at escalating doses, the patients are closely monitored in combination with a nutritionist to prevent malnutrition till the improvement of diarrhea (usually between for 4 to 8 weeks).

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Informed Consent: Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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doi: 10.21037/dmr.2018.09.06
Cite this article as: Zimmitti G, Manzoni A, Garatti M, Sega V, Rosso E. Technique of "mini-invasive radical antegrade modular pancreatosplenectomy" for pancreatic cancer. Dig Med Res 2018;1:21.

Laparoscopic pancreatic resection—a review

Viktor Justin[1], Abe Fingerhut[2], Igor Khatkov[3], Selman Uranues[2]

[1]Hospital of Saint Elisabeth, Vienna, Austria; [2]Section for Surgical Research, Medical University of Graz, Graz, Austria; [3]Moscow Clinical Scientific Center, Moscow, Russia

Contributions: (I) Conception and design: A Fingerhut, S Uranues; (II) Administrative support: V Justin, S Uranues; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: V Justin, S Uranues, A Fingerhut; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Selman Uranues, MD, FACS. Section for Surgical Research, Department of Surgery, Medical University of Graz, Auenbruggerplatz 29, 8036 Graz, Austria. Email: selman.uranues@medunigraz.at.

Abstract: Contrary to many other gastrointestinal operations, minimal access approaches in pancreatic surgery have gained ground slowly. Laparoscopic distal pancreatectomy has gained wide acceptance. It is associated with reduced blood loss and shorter duration of stay (DOS) while oncologic results and morbidity are similar to open surgery. In recent years the number of laparoscopic pancreatoduodenectomies has also increased. While oncological outcome seems comparable to the open approach, operative times are longer while DOS and blood loss are reduced. One added advantage of the laparoscopic approach to pancreatic cancer seems to be that adjuvant treatment can start earlier. Minimal access total pancreatectomy, only reported in small numbers (mostly robot assisted), has also been shown to be feasible and safe. Enucleation (EN) of small pancreatic lesions is the most common tissue sparing resection. Although no reconstruction is necessary, the risk of pancreatic fistula is high, related to excision margins equal or smaller than 2 mm to the main pancreatic duct. Compared to the open approach, laparoscopic EN has shown comparable results in terms of morbidity, pancreatic function and fistula rate, with shorter operation times and faster recovery. Experience in robot assisted pancreatic surgery is increasing. However reports are still small in numbers, lacking randomization and mostly limited to dedicated centers. The learning curve for minimal access pancreatic surgery is steep. Low patient volume leads to longer DOS, higher costs and negatively impacts outcome.

Keywords: Minimal access surgery (MAS); pancreas; pancreatic resection; laparoscopy

Received: 08 March 2016; Accepted: 11 April 2016; Published: 04 May 2016.
doi: 10.21037/tgh.2016.04.02
View this article at: http://dx.doi.org/10.21037/tgh.2016.04.02

Introduction

In the last decades minimal access surgery (MAS) has gained wide spread use both for benign and malignant disease in gastrointestinal surgery (1). Oncological adequacy has been shown in a variety of indications, including colonic (2,3) and gastric cancer (4). Laparoscopic pancreatic surgery, however, has been slow to gain momentum. Since the first description of minimal access cases reported in 1994 (5), the proportion of laparoscopic pancreatic resections remains low: according to the US Nationwide Inpatient Sample database from 2000 to 2011, only 5% of all resections were performed via a minimal access approach (6). However, with progress in laparoscopic equipment, increasing numbers of cases have been reported in all indications (6,7). Our aim was to review the literature concerning the major advances in minimal access pancreatic surgery.

Definitions

The International Study Group on Pancreatic Fistula (ISGPF) (8) defined postoperative pancreatic fistula (POPF) as "drain output of any measurable volume of fluid on or

Table 1 ISGPF grading of POPF (8)

Grade	A	B	C
Clinical conditions	Well	Often well	Ill appearing/bad
Specific treatment*	No	Yes/no	Yes
US/CT (if obtained)	Negative	Negative/positive	Positive
Persistent drainage (after 3 weeks)**	No	Usually yes	Yes
Reoperation	No	No	Yes
Death related to POPF	No	No	Possibly yes
Sepsis	No	Yes	Yes
Readmission	No	Yes/no	Yes/no

*, partial (peripheral) or total parenteral nutrition, antibiotics, enteral nutrition, somatostatin analogue and/or minimal invasive drainage; **, with or without a drain *in situ*. ISGPF, International Study Group on Pancreatic Fistula; POPF, postoperative pancreatic fistula; US, ultrasonography; CT, computed tomographic scan.

after postoperative day 3 with amylase content greater than 3 times the serum amylase activity". Severity is graded from A to C (*Table 1*).

Distal pancreatectomy (DP)

DP accounts for about a third of all pancreatic resections (6). Indications include benign, pre-malignant and malignant lesions of the pancreatic body/tail such as chronic pancreatitis, endocrine tumors, intraductal papillary mucinous neoplasm (IPNM), pancreatic pseudocysts, mucinous and serous cystic neoplasia, metastases and also trauma with ductal injury (9-11).

MAS accounts for between 10.8% to 46.6% of DP (9,12,13). Several publications have found no statistically significant difference in operative times between laparoscopic DP (LDP) and open DP (ODP), ranging from 156 to 383 min and from 145 to 330 min in laparoscopic and open surgery, respectively (14-17). Conversion rate ranged from 0% to 34% (18,19), hemorrhage and failure to progress being the most common causes. Estimated intraoperative blood loss was found to be significantly lower in LDP (9,13,14,20,21).

Morbidity in LDP has been reported to range from 0% to 67% in single center studies (22,23). However, recent meta-analyses (9,18) described overall morbidity ranging from 34.0% to 37.4%. As morbidity is essentially related to POPF, one possible explanation for this wide range of morbidity may be the use of different definitions for POPF. Adhering to the ISGPF definition, systematic reviews have described the POPF incidence to range from 16.8% to 21.7% in LDP (9,11).

Similarly, reported mortality (range, 0.2–0.4%) (9,18) and reoperation rates (range, 2.1–6.0%) (18,24,25) did not differ from outcomes after open surgery. In spite of a variety of closure techniques available (suture, stapler, sealant, mesh), at the present time there is no proof that one closure technique is better than the other (26-30). Spleen preserving LDP has been described to be safe and feasible (10,22) and has been reported in 18.2% (16) to 60.4% (31) of LDPs.

In their 2015 meta-analysis of 34 studies, Mehrabi *et al.* (9) described a statistically significant difference in time to first oral intake (0–1.3 days) and duration of stay (DOS) (0–3.8 days). Of note, DOS after DP seemed to be shorter in the United States compared to centers outside of the United States, which might be attributed to differences in health care systems (18). More recently, Shin and colleagues (12) confirmed these reductions in their single center, propensity matched analysis.

Resection margin status was also studied in the meta-analysis by Mehrabi *et al.* (9): four studies (32-35) reported comparable R0 rates in both groups (592 patients) (OR: 1.63; 95% CI: 0.65–4.07; P=0.29), while the rate of R1 resections was lower in the LDP group (520 patients) (OR: 0.34; 95% CI: 0.14–0.83; P=0.02) (19,34-36).

The mean number of lymph nodes harvested did not differ significantly between LDP and ODP (12 to 13.8 LDP *vs.* 10 to 12.5 ODP) (12,13). However, the median number (10, range, 1–64) of lymph nodes harvested in the ODP group in one report (12) was less than 12, the recommended number for adequate disease staging (37).

Shin *et al.* observed a median postoperative survival of 33.4 months in LDP *vs.* 29.1 months in OPD (P=0.025) (12). In contrast a multicenter study by Kooby *et al.* found considerably shorter survival (16 months) in both groups (13).

While low long-term survival rates are typical for pancreatic cancer, the difference in survival between these last two studies might be attributed to the differences in median tumor size (3.0 *vs*. 3.5 cm) as well as the type of (monocenter *vs*. multicenter) study.

Pancreatoduodenectomy (PD)

Due to the anatomical position in the retroperitoneal space, the vicinity to large vessels and the need for three critical anastomoses, PD is considered one of the most challenging operations in GI surgery. Laparoscopic pancreatoduodenectomy (LPD) was described first by Gagner *et al*. over 20 years ago (5), but since then has not gained widespread use, as it was considered even more difficult (*vs*. the open approach) with questionable benefits to patients (38). However, with the advance of laparoscopic techniques and improved equipment, the number of LPD performed is continuously rising, as demonstrated by an increase of 50% from 2000 to 2010 according to Tran and colleagues (39).

Several studies have attempted to compare the operative and oncologic characteristics of open and laparoscopic pancreatic head resections, but none were randomized (38-52). Mean operative times have been reported to be significantly longer in LPD, ranging from 452 to 541 min for LPD compared to 372 to 401 min in OPD (40-42), although one center reported non-significant differences (465±86 *vs*. 465±98 min, respectively) (43). On the other hand, similar to what was observed in LDP, intraoperative blood loss has been reported to be significantly lower in LPD (492.4±519.3 to 841.8±994.8 mL in LPD *vs*. 866.7±733.7 to 1,452.1±1,966.7 mL in OPD) (43-45). DOS was significantly shorter in several comparative studies (6 to 8 *vs*. 9 to 12.4 days, respectively) (40,43,44) whereas other studies (7,41) found no statistically significant difference. Conversion to open surgery was reported in 9.1% to 30.0% of cases, mostly due to venous invasion and intraoperative bleeding (7,44,46). Overall morbidity in LPD has been reported to range from 35–52%, however this difference was not found to be statistically significant between the surgical approaches (43,47,48).

Postoperative mortality was recorded to range from 3.2% to 8.8% in LPD *vs*. 3.4% to 5.7% in OPD, difference which was not statistical significant (7,39,40,43). The reported incidences of clinical relevant POPF (grades B and C) described in several studies were fairly similar, ranging from 6.3% to 11.0% (45,49) in LPD and 5% to 9% (40,43) in open surgery. In their systematic review, Correa-Gallego *et al*. (44) described overall POPF rates of 21% (8% grade B and C) in LDP and 17% (7% grade B and C) in ODP. This is comparable with Boggi and colleagues (46), who found a 24.8% incidence (10.5% grade B and C) for POPF after LDP in their meta-analysis.

Given that the majority of PDs are performed for malignant or premalignant lesions (7,46,49), adequate oncological resection remains one of the key questions. The number of lymph nodes harvested has been reported to be similar (7,45) or even significantly higher in LPD (40,43,44) compared to PD. Comparisons of R0 resection rates showed that results between open and LPD did not differ significantly (7,40,43,45,50). Of note, however, margin status may not be the ideal parameter for comparisons because definitions of margin involvement vary and under-reporting of microscopic margin involvement has been described (51). Portal venous infiltration as such is not a contraindication for the LPD (52). Interestingly, Croome and colleagues (45) reported a significantly longer interval of progression free survival and a shorter median time to adjuvant chemotherapy in LPD. However, overall survival was not improved, consistent with what is generally observed in pancreatic cancer (43,49).

However, most results come from highly experienced centers for LPD and may not be generally applicable. Moreover, several studies (39,47,48) have indicated that the learning curve is steep, DOS is increased and total costs are higher in centers performing fewer PDs. According to Adam and colleagues in their analysis of 7,061 PD for cancer in the US from 2010–2011, 92% of LPD (14% of all PDs) were undertaken in hospitals performing 10 LPD or less over a 2-year period. They also found a significantly higher 30-day mortality rate in LPD compared to OPD, which was inversely correlated with the volume of LPD per hospital (7). This is in agreement with the OPD learning curves described by Tseng *et al*. (53) identifying a number of 60 interventions necessary for adequate experience.

Total pancreatectomy (TP)

TP is rarely performed, accounting for 5.4% to 6.7% of all pancreatic resections in high volume centers (54,55).

This may explain why only a few papers (56-60) with small numbers have been published on laparoscopic total pancreatectomy, and thus showing only that it was feasible and safe with apparently satisfactory oncologic outcome.

Parenchyma sparing resections

Parenchyma-sparing resections are indicated in small—benign or low grade malignant—lesions, thus reducing the risk of exocrine and endocrine insufficiency (61). Safety and feasibility of enucleation (EN) and middle pancreatectomy, the most common procedures performed laparoscopically, have been described (62-64).

Indications for parenchyma sparing approaches include mainly neuroendocrine neoplasms, serous cystadenoma and branch duct IPMN as well as solitary renal cell carcinoma metastasis (62,65,66). Depending on the location, tumor size should not exceed 3 to 4 cm in diameter for laparoscopic EN (67,68). Although EN does not include a reconstructive phase, the procedure is associated with a high risk for POPF. In their systematic review on 811 patients undergoing EN, Beger *et al.* found a 36.7% POPF rate, 16.3% of which were clinically relevant (ISGPF grades B and C) (64). A resection margin equal or less than 2 mm from the main pancreatic duct has been identified as a high risk factor for development of POPF (67).

Zhang and colleagues (61) found no difference between open and laparoscopic EN concerning preservation of pancreatic function, but described shorter operation time as well as lower intraoperative blood loss and faster recovery (in terms of time to first flatus and first oral intake; DOS) in the minimal access approach. A systematic review by Briggs *et al.* reported conversion rates ranging from 10.5% to 44.4% with a 29.3% POPF rate (31).

Robotic-assisted surgery

The first robotic-assisted pancreatic resections were reported in 2003 by Melvin *et al.* (69) for DP and by Giulianotti *et al.* (70) for PD. Since then several reports (71-73) have shown promising results, comparable to and at times better (conversion rate, DOS) than standard laparoscopy and open procedures. While most studies represent early experiences, there is a significant learning curve for robotic pancreatic surgery (74), as in other robotic-assisted procedures (75). Boone *et al.* (76) described a continuous learning effect with statistically significant improvement after 20 (conversion rate, blood loss), 40 (POPF incidence) and 80 (operative time) procedures.

Of note, the total cost per operation is higher in the robotic approach [$8,304 robotic DP (RDP) *vs.* $3,861 LDP; robotic PD +€6,200 *vs.* OPD] (77,78). Interestingly, however, in their single institution experience, Waters *et al.* (36) reported lower overall costs for robotic DP after adjusting for DOS ($10,588 RDP *vs.* $12,986 LDP *vs.* $16,059 ODP). Notwithstanding, hospital costs are most likely subject to substantial variations depending on different health care systems (79).

Conclusions

Laparoscopic pancreatic resections have been shown to be feasible and safe, with rising numbers being reported during the last decade. Most LPD have been performed in university and urban teaching hospitals, while DP seems to be more widely implemented (6).

Comparisons with open surgery have shown reductions in hospital stay and intraoperative blood loss as well as similar results in terms of oncological adequacy. However, none of the data included in this review derive from controlled randomized studies and often represent single center or even single surgeon's experience, thus underscoring a significant risk for bias. This stresses the need for RCTs wherever possible.

Another major issue is the steep learning curve associated with pancreatic surgery in general and specifically the minimal access approach. Low volume hospitals have been shown to be significantly associated with worse patient outcomes. Robotic assisted surgery is gaining popularity especially in the U.S.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/tgh.2016.04.02
Cite this article as: Justin V, Fingerhut A, Khatkov I, Uranues S. Laparoscopic pancreatic resection—a review. Transl Gastroenterol Hepatol 2016;1:36.

Laparoscopic suture training curricula and techniques

Xin Wang, Yongbin Li, Yunqiang Cai, Lingwei Meng, He Cai, Xubao Liu, Bing Peng

Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, China

Correspondence to: Bing Peng, MD, PhD, FACS. Department of Pancreatic Surgery, West China Hospital, Sichuan University, No. 37 Guoxue Alley, Chengdu 610041, China. Email: pengbing84@hotmail.com.

Abstract: With the development and ubiquitous use of minimally invasive surgery, the advanced laparoscopic skills such as suture is essential for performing gastrointestinal procedures. However, the steep learning curve and lack of standardized training make most residents underprepared for laparoscopic suture. Moreover, the current simulation-based training is inadequate for trainees to master these advanced skills. Thus, there is a need for laparoscopic suture training modeled with cognitive knowledge, approachable techniques and standardized steps. Here, we present a suture training curriculum with video demonstration. In this study, we developed a suture training curriculum, which are divided into two categories depending on its difficulty and application. Basic techniques are designed for novice to master the basic suture skills, and it also shortens the learning curve of advanced suture techniques. Advanced techniques focused on the application of suture in specific circumstances. Also, it could prepare residents for more complex procedures. In order to increase the efficacy of suture training, we recommend a learning method similar to Peyton's four-step approach, personalized video feedback and spaced learning in our curricula. This article demonstrates the various laparoscopic techniques and their applications from simple to complex, with a view to help residents in training. Also, the training curricula and recommendations will further help residents to improve efficiently. Thus, we recommend to incorporate the curricula into suture training courses and surgical programs.

Keywords: Laparoscopic suture; training techniques; laparoscopic knot

Submitted Apr 24, 2018. Accepted for publication May 04, 2018.
doi: 10.21037/atm.2018.05.17
View this article at: http://dx.doi.org/10.21037/atm.2018.05.17

Introduction

Due to the rapid development of laparoscopic surgery, master of laparoscopic suture techniques is essential for all the surgeons performing complex laparoscopic procedures. However, even in the developed country such as Canada, where over 87% residents had access to a skill lab that taught MIS techniques, there still exists a wide disparity between training lab and bedside, only 8% stated they would be comfortable performing advanced procedures at the end of their training (1), let alone the situations in developing countries such as China. Furthermore, despite having passed the Fundamentals of Laparoscopic Surgery (FLS) course, more than 50% surgery graduates beginning subspecialty training were considered to be unable to independently perform laparoscopic suture in the clinical environment (2). In order to increase the number of individuals who are competent to perform advanced laparoscopic suture, the authors, as a resident of an academic hospital in China, design a structured training curriculum and demonstrate its key techniques in this study.

Training and techniques description (*Figure 1*)

Instruments requirement

(I) Training box;
(II) Suture model;
(III) Tissue holder;
(IV) Laparoscopic needle holder;
(V) Laparoscopic Maryland forceps;
(VI) Laparoscopic scissors;

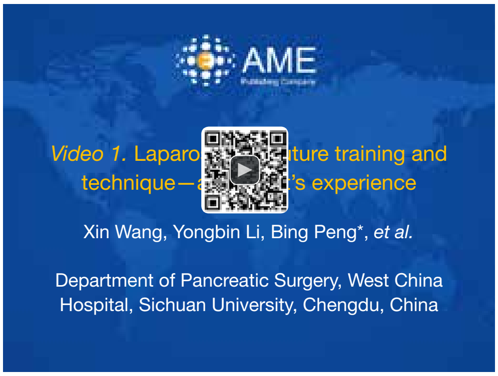

Figure 1 Laparoscopic suture training and technique—a resident's experience (3).
Available online: http://www.asvide.com/article/view/25307

(VII) Gloves;
(VIII) Camera: iPad;
(IX) Suture needles.

Techniques

Basic technique

Three-step needle maneuver

This maneuver could make the novices to master the needle handling technique quickly, and the novices could hold a needle at any position through this maneuver.

This technique is divided into three simple steps. First, grasp the suture 1 cm from the needle using the right-hand needle holder. The distance between needle holder and the needle could prevent needle wobbling. Then, grasp the needle at a point about one-third from the tip using the left-hand grasper, and the needle righting could be achieved by using the needle holder to gently tug on the suture so that the needle is correct positioned on the grasper. Last, when the needle is correctly positioned, hold the needle using the needle driver. Now the needle is ready for driving. In order to master the advanced skills later and improve our feedback for needle adjustment, "needle dancing" technique could be practiced as the video demonstrated.

Pre-knot training

Pre-knot could practice eye-hands coordination and get prepared for further intracorporeal knot. Besides, the pre-knot training could efficiently minimize the learning curve for other advanced knot techniques.

In order to facilitate throwing knot, place the curved sides of right-hand needle holder and left-hand grasper face to each other. First, suture is grasped with the needle side of the suture 6 cm from the tissue using the left-hand grasper, and lower the grasper near the tissue so that the suture could form a loop automatically. Then, make the double-coiled clockwise or counter-clockwise throw practice. The term clockwise or counter-clockwise refers to the tip of the needle holder related to the tip of the grasper. During the knot-throw course, the needle holder could approach the tail of the suture to improve the knot efficiency.

Surgical knot

Surgical knot is the most common and useful knot used in laparoscopic surgery. A qualified surgical knot achieves two aims: (I) it will ligate a blood vessel securely or appose tissue tightly; (II) it will resist untying, breaking, and slipping because the extra coil around the sutures in the first throw increases friction and reduces slippage.

First, like the pre-knot practice, make the double-coiled clock wise throw and grasp the suture tail using the right-hand needle holder. Then, the right-hand needle holder is now pulled caudally while the left-hand grasper is now pushed cephalad, after tighten the suture, the suture tail is placed cephalad for further throws. Finally, additional throws are added to secure the surgical knot.

Continuous "cis and trans" suture training

This training is a composite of forward/reverse needle adjustment and multiple needle driving/suture. It could be considered as the preparation of gastrointestinal anastomosis.

First, use three-step needle maneuver to hold the needle and drive it through the tissue forwardly. Second, grasp the needle tip and pull it out of the tissue using grasper, tug the suture using needle holder to place it in a reverse position, then grasp the needle and drive it through the tissue reversely. Repeated practice like this could improve the fluency of continuous suture.

Advanced technique

Slip knot

Slip knot is useful in situations where it is difficult to tighten knot under tension. Particularly, they are also very useful when tying monofilament suture, which has reduced friction compared with braided suture.

First, make one counter clockwise throw and place the suture tail cephalad without tightening it. Second, make a clockwise throw and then pull the needle side suture upward. Now, the square knot is transformed to slip knot automatically. Continue pulling the needle side suture upward until the knot is tightened. Finally, pull the two sutures evenly to transform the slip knot to square knot, extra knots are added to strengthen it.

Multi-angle suture

However, it could not fulfill all the situations in practice when merely mastering the forward and reverse suture technique. Therefore, the multi-angle suture is developed to improve the needle handling skills for residents in training.

In this training, the resident will suture a column from four different angles: 90°, 180°, 270°, 360°. As previously shown, the 90°, 180° and 270° angles could be achieved by tugging the suture to adjust needle. Actually, based on the "needle dancing" technique we have acquired, any angle between 45° and 315° could be achieved by this technique. The most difficult angle is 360°, a two-step needle righting technique as the video shown is applied to complete the suture.

Single hand needle maneuver

In some situations, only one hand could be spared to complete the suture. For example, in the event of hemorrhaging, the application of direct pressure by one hand to control bleeding is often the first maneuver. Then the other hand is used to suture the bleeding spot to achieve hemostasis. Therefore, the technique of single hand needle maneuver is very helpful.

The mechanism of single hand needle maneuver as follows, the needle lay flat on the "soft tissue", which would facilitate to handle the needle. The needle holder is used to press the needle to make it "stand up" automatically. The needle "stand up" practice would improve proficiency. In practice, open jaws of the needle holder and use the upper jaw to press the needle until it "stand up", then close the jaws to grasp the needle. Now the needle is ready to be drive.

Single hand knot

Like the single hand needle maneuver, single hand knot might be used in some particular situations.

During the whole procedure, keep long tail thread out through the trocar for further retraction. Take the long tail thread as reference, rotate alone the long tail thread using the needle to make a slip knot. Then retract the needle cephalad and long tail thread caudally respectively to approximate the tissue. Finally, additional throws are added to secure the knot.

"Finger" anastomosis training

The "finger" anastomosis is the last suture training, also it is the most technique demanding training. This training highly simulated the procedure of gastrointestinal anastomosis. It could not only train the skill of suture and knot, but also improve the capability of exposure and hands coordination.

The anastomosis is achieved by 15–18 interrupted suture. Every stitch is secured by 4–5 throws of knots. After a batch of practice, it will take less than 1 minute to complete one stitch and its knots. Therefore, this training will dramatically shorten the learning curve of laparoscopic anastomosis.

Discussion

Surgical training has traditionally been one of apprenticeship, where the surgical trainee learns to perform surgery under the supervision of a trained surgeon. With the advent and development of laparoscopic technique, an increasing number of surgeries are being done laparoscopically. However, laparoscopic training is different from open surgery because the increased requirement for hand-eye coordination, indirect visualization, manual dexterity and so on, therefore, surgical trainees always faced a long and steep learning curve (4), which further made them lacking of procedure exposure. In order to solve these problems, video-box training, as a cost-effective training, was applied a few years ago. This box model training has demonstrated to improve technical skills compared to no training in trainees with no previous laparoscopic experience in a Cochrane database study (4). Nowadays, more and more complex laparoscopic procedures, such as liver, biliary and pancreatic surgery, could be performed laparoscopically. Master advanced laparoscopic suturing skills has become the prerequisite for residents to access to these advanced laparoscopic surgeries. Current training curricula focus on basic laparoscopic skill learning such as the FLS. Therefore, there are still a lot of training gaps for acquiring laparoscopic suture techniques (5). Specialized and well-designed suture training curricula are needed.

In this study, we developed a suture training curriculum, which are divided into two categories depending on its difficulty and application. Basic techniques, including three-step needle maneuver, pre-knot training, surgical knot and continuous “cis and trans” suture, is designed for novice to master the basic suture skills, and it also shortens the learning curve of advanced suture techniques (6). Advanced techniques, including slip knot, multi-angle suture, single hand needle maneuver, single hand knot and “finger” anastomosis, more focused on the application of suture in specific circumstances. Also, it could prepare residents for more complex procedures. In order to increase the efficacy of suture training, we recommend a learning method similar to Peyton’s four-step approach in our curricula (7). This method consists of four major aspects: (I) demonstration: trainee observes a specific procedure with normal pace to form a general impression quickly; (II) deconstruction: trainee repeatedly observe every detailed action in a specific procedure to master how it works; (III) comprehension: with the help of the description and comments, trainee could understand why it works; (IV) performance: trainee has to practice it repeatedly to achieve proficiency. In addition, there are also some other recommendations for laparoscopic training. A latest research (8) from Mayo clinic demonstrated that personalized video feedback could efficiently improves laparoscopic knot-tying performance and perceived workload, which recommend novice to record and analyze the manipulations during their learning curve. Another study (9) indicated that the spaced learning, based on the repeated temporal patterns of highly condensed laparoscopic training for creating long-term memories, is very suitable for complex motor skill acquisition like laparoscopic suture and knot tying.

In summary, this article demonstrates the various laparoscopic techniques and their applications from simple to complex, with a view to help residents in training. Also, the training curricula and recommendations will further help residents to improve efficiently. It is very likely that the learned skills are transferrable into a clinical setting and will translate into improved laparoscopic performance in the operating room. Thus, we recommend to incorporate the curricula into suture training courses and surgical programs.

Acknowledgements

The authors would like to thank Shashi Shah, for providing language help.
Funding: This study was supported by the National Institutes of Health of China (W2017ZWS07).

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Wang X, Li Y, Cai Y, Meng L, Cai H, Liu X, Peng B. Laparoscopic suture training curricula and techniques. Ann Transl Med 2018;6(11):215. doi: 10.21037/atm.2018.05.17

Minimally invasive central pancreatectomy and pancreatogastrostomy: current surgical technique and outcomes

Sean M. Ronnekleiv-Kelly, Ammar A. Javed, Matthew J. Weiss

Department of Surgery, The Johns Hopkins University School of Medicine, Baltimore, MD, USA

Contributions: (I) Conception and design: SM Ronnekleiv-Kelly, MJ Weiss; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Matthew J. Weiss, MD, FACS. Assistant Professor of Surgery and Oncology, Surgical Director, Pancreas Cancer Multidisciplinary Clinic, Program Director, Complex Surgical Oncology Fellowship, Department of Surgery, The Johns Hopkins Hospital, 600 N. Wolfe Street, Halsted 608, Baltimore, MD 21287, USA. Email: mweiss5@jhmi.edu.

Abstract: Recent improvements in imaging techniques and more frequent use of cross-sectional imaging have led to an increase in the identification of benign and low-grade lesions of the pancreas. Patients with resectable cancers are commonly treated by either a Whipple procedure or distal pancreatectomy (DP) based on the location of the tumor. Central pancreatectomy (CP) is a less commonly performed operation that has recently been utilized for resection of these now more frequently diagnosed low-grade and benign lesions located in the mid pancreas. Lesions that may have a relatively more indolent nature include branch-type intraductal papillary mucinous neoplasm (IPMNs), mucinous cystic neoplasms, neuroendocrine tumors, and solid pseudopapillary tumors. The goal of a CP is complete extirpation of the lesion, while preserving pancreatic parenchyma to reduce the risks of developing diabetes and exocrine insufficiency (EI). Although open CP has been shown to be safe and efficacious, the outcomes of a minimally invasive approach are still relatively underreported and therefore unknown. In this paper, we describe our surgical approach to performing a CP with an accompanying video demonstration of the key portions of the operation.

Keywords: Central pancreatectomy (CP); minimally invasive; robotic surgery; pancreatogastrostomy

Received: 18 June 2016; Accepted: 18 July 2016; Published: 10 August 2016.
doi: 10.21037/jovs.2016.07.22
View this article at: http://dx.doi.org/10.21037/jovs.2016.07.22

Introduction

With improvements in surgical techniques and perioperative care, the mortality associated with pancreatic resection (PR) has decreased dramatically; however the morbidity associated with this procedure remains high. Centrally located lesions pose a particular challenge due to the variety of options available for surgical resection. Patients may undergo pancreaticoduodenectomy (PD), distal pancreatectomy (DP) or central pancreatectomy (CP) depending on the size, location and malignancy potential of the lesion (1). CP (also known as middle pancreatectomy or median pancreatectomy) was first ascribed to Ehrhardt in 1908 (2,3). Guillemin and Bessot performed the first CP with pancreato-enteric reconstruction in 1957 for chronic pancreatitis, and subsequently Dagradi and Serio described the operation for resection of a benign lesion (insulinoma) in 1982 (1,4-6). The primary aim of performing a CP is the preservation of both endocrine and exocrine function of the pancreas while still maintaining oncologic efficacy (7). Specifically, for centrally located low-grade lesions, a DP or PD obligates a substantial volume of the pancreas removed, placing patients at higher risk of post-operative diabetes and exocrine dysfunction (7-9). In comparison to DP, CP also allows for preservation of spleen (7). Advantages of CP over PD include reduced mortality and preservation of the duodenum and bile duct, with only a single anastomosis needed for reconstruction as opposed to

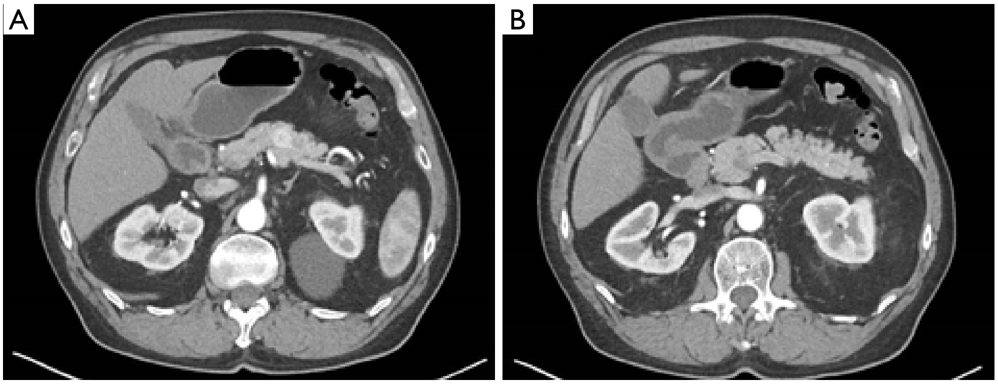

Figure 1 Pancreatic neuroendocrine tumor. (A) Cross sectional imaging demonstrates the characteristic appearance of a neuroendocrine tumor (arrow) located in the central pancreas. Given the location of the tumor, enucleation would not be an appropriate option; (B) the patient could potentially undergo a distal pancreatectomy (DP), however, there would be a significant volume of normal pancreas resected (box). Therefore, a central pancreatectomy (CP) would be a reasonable option for this patient.

multiple anastomoses required for restoring continuity of the hepatic duct, pancreatic duct and intestinal tract (1,10). The concerns surrounding CP include high incidence of post-operative pancreatic fistula (POPF) and potentially inadequate oncologic resection in cases of malignancy (9). However, studies have shown that although the rates of POPF after CP are relatively high (20–50%), oftentimes these patients possess soft glands and small ducts, which are both well-established risk factors for POPF (9). Also, in most cases the POPF is clinically insignificant [International Study Group on Pancreatic Fistula (ISGPF) grade A] (9). Therefore, CP is a reasonable approach for centrally located, benign or low-grade pancreatic lesions that allows preservation of pancreas parenchyma and adjacent organs.

With increasing utilization of laparoscopic and robotic pancreatectomy, patients can now undergo either an open or minimally invasive surgery (MIS) procedure. Laparoscopic and robotic PD has gained interest due to comparable morbidity, mortality and oncologic outcomes versus open PD when performed in select patients (11-15). For DP, MIS approach has now become the standard of care due to its favorable outcomes in comparison to open DP (11,16). In a recent meta-analysis comparing 1,814 patients undergoing open versus laparoscopic DP, the laparoscopic approach resulted in less blood loss, shorter hospital length of stay (LOS), fewer surgical site infections and lower morbidity (17). Similarly, a MIS approach for CP has become increasingly common with the goal of decreasing the impact of morbidity related to the decreased size of incisions, shorter hospital stays, and shorter time until return to work. While both laparoscopic and robotic CP are being performed, laparoscopy may be somewhat limited given the restricted workspace and the inability to articulate instruments in a manner requisite for these complex procedures (18-21). These limitations are potentially alleviated by the use of robotic surgery. Herein, we report our technique of performing an MIS CP, with accompanying video demonstration of the key portions of the operation. Indications for CP and a brief summary of outcomes following CP are also discussed.

Indications for CP

Pancreatic lesions of the central pancreas can be extirpated via numerous operative approaches depending on their size, location and pathology. Extended PD or near-total DP are performed for pancreatic ductal adenocarcinoma (PDAC) or main-duct-type intraductal papillary mucinous neoplasm (IPMN) with potential invasive component, in order to achieve adequate resection of the tumor and also the surrounding lymph nodes, which is not always achievable with CP (7,8). However, for low-grade malignant tumors or benign lesions, use of PD or DP would consequently remove much of the normal pancreatic parenchyma which is likely of no therapeutic benefit (*Figure 1*). Enucleation can also be considered; however, this should not be the procedure of choice for malignant tumors or benign lesions greater than 2 cm, or location adjacent to the main pancreatic duct (19). Therefore, CP may be an appropriate alternative for a subset of patients possessing low-grade malignant tumors or benign lesions restricted to the central pancreas (19). The most common indications for

Table 1 Indications for CP

Tumor type
Cystic lesions
Branch-type IPMN*
Cystic neuroendocrine tumor
Serous cystadenoma
Lymphoepithelial cyst
Mucinous cystic neoplasm
Solid lesions
Solid pseudopapillary tumor
Nonfunctional neuroendocrine tumor
Functional neuroendocrine tumor
Select metastases

*, main duct intraductal papillary mucinous neoplasm (IPMN) is often cited as a contraindication. CP, central pancreatectomy.

CP include neuroendocrine tumors followed by cysts that display indeterminate characteristics such as branch-duct-type IPMNs, and solid pseudopapillary neoplasms (*Table 1*) (1,7,8,19). Contraindications to this procedure include PDAC, main-duct-type IPMN, neoplastic involvement of adjacent organs, and large lesions where it is impossible to preserve the left pancreatic stump (2).

Surgical technique and technical aspects of MIS CP

All patients should be evaluated for a pancreatic lesion using a pancreas protocol CT or MRI and serum CA19-9 levels when deemed necessary. If a patient is found to have a lesion amenable to resection via an MIS CP, a preoperative assessment by an anesthesiologist is performed and medical clearance should occur similar to an open approach.

After surgical consent has been obtained, the patient is placed in a supine position with right arm extended to 90º and the left arm is tucked. Intravenous access, monitoring lines, and a Foley catheter are placed. A nasogastric tube is inserted for stomach decompression. The abdomen is prepped and draped in the standard manner. Safe entry to the abdomen is obtained via the Hassan technique (supraumbilical) or a Veress needle. The abdomen is then insufflated to 15 mmHg and a camera port is placed in the periumbilical position (12 mm). A 5 mm port for the liver retractor is placed in the right anterior axillary line. Subsequent ports include two right-sided abdominal robotic ports (8 mm) and a left-sided abdominal port (8 mm). The exact location of the robotic ports depends on whether a Si or Xi robot (da Vinci® Surgical System) will be used. The assistant port is placed in the left lower quadrant and should be 12 mm in order to accommodate a laparoscopic stapler. The robot is then docked over the patient's head or towards their left in case of the SI or XI robot (da Vinci® Surgical System) respectively.

Although the indications for MIS CP are generally low-grade neoplasms or benign tumors, inspection of the abdominal cavity and surface of the liver is performed to identify any pathologic implants. Subsequently, the lesser sac is entered with the vessel-sealing device and the gastrocolic omentum is dissected free from the stomach while preserving the gastroepiploic vessels. This dissection is carried from the pylorus up along the greater curvature of the stomach to allow elevation of the stomach and adequate exposure of the anterior surface of the pancreas. At this stage, if the lesion cannot be readily visualized, ultrasound can be used to delineate the extent of the tumor and its relationship to the surrounding structures. The inferior border of the pancreas is mobilized and SMV is identified coursing posterior to the pancreatic neck. The superior border of the pancreas is also mobilized, and the common hepatic artery, gastroduodenal artery and portal vein are identified. Once both the inferior and superior borders of the pancreas have been mobilized, tunneling is performed behind the neck of the pancreas to dissect the pancreas free from the superior mesenteric vein/portal vein. Dissection is then performed in a medial-to-lateral manner to free the undersurface of the pancreas from the splenic vein. The splenic artery may follow a tortuous course behind the pancreas or through the pancreas, highlighting the necessity for a meticulous dissection to avoid injury to this vessel or the underlying splenic vein. While dissecting the central pancreas free from the splenic artery, caution must be taken to identify the overlying coronary vein (left gastric vein), which in our experience serves as a critical anatomic landmark of the celiac trunk. This vein can be ligated if necessary. The dissection of the central pancreas from the splenic vein and artery is continued until the distal extent of the tumor has been reached. Liberal use of intraoperative ultrasound can confirm the location of the tumor and a duplex can also confirm arterial/venous anatomy. The plane of transection of the pancreas to the left of the tumor is identified and marked to represent the distal margin of the specimen during pathological examination, and the transverse pancreatic arteries are suture ligated. The pancreatic neck to the right of the tumor is routinely divided with a GIA stapler. The parenchyma located to the

Figure 2 Robotic central pancreatectomy operative video (22). This video demonstrates a robotic central pancreatectomy (CP) performed for a neuroendocrine tumor. After port placement and exploration of the abdominal cavity, the lesser sac is entered by dividing the gastrocolic omentum. This exposes the anterior surface of the pancreas. The caudal aspect of the pancreas is then dissected by dividing the inferior attachments, which exposes the superior mesenteric vein. The pancreas is then divided with an energy device at the neck of the pancreas, overlying the superior mesenteric/portal vein. Once the neck of pancreas is divided, the inferior edge and superior edge of the pancreas is mobilized until beyond the extent of tumor. The distal extent of pancreas transection is marked here, and transected with an energy device. The specimen is removed from the abdominal cavity. Subsequently, the right side of the pancreas is oversewn while the left side of the pancreas is drained through a pancreatogastrostomy. The pancreatogastrostomy is completed with a two-layer closure, approximating the transected surface of the pancreas with the posterior aspect of the stomach.
Available online: http://www.asvide.com/articles/1097

left of the tumor is then transected with cautery scissors or a thermal device in order to allow for identification of the pancreatic duct, which will later be sewn to the intestinal mucosa. The specimen is placed in a 15 mm Endo Catch™ (Covidien, New Haven, CT) bag and removed through the accessory left lower quadrant port. The specimen is then sent to confirm pathological diagnosis and ensure adequate margins. At this point, if the pathology is confirmed as a benign tumor or a low-grade neoplasm, we proceed with the reconstruction. However, if the pathology is found to be malignancy or high-grade neoplasm, we believe a PD or DP should be performed.

Reconstruction following CP can be performed by either a pancreatogastrostomy or a Roux-en-y pancreaticojejunostomy. Pancreatogastrostomy is favored at our institution due to the formation of a single anastomosis (in comparison to roux-en-y pancreaticojejunostomy) and maintenance of physiologic drainage (7). The transected surface of the pancreatic head is oversewn using a running V-Loc™ (Medtronic, Minneapolis, MN, USA) suture to ensure hemostasis. Attention is then paid to the reconstruction of the pancreatogastrostomy. The stomach is allowed to lie flat in the retroperitoneum and an optimal location in close proximity to the transected pancreas is marked with a marking pen. At this stage the pancreatic tail should be mobilized further to ensure enough mobility out of the retroperitoneum for a tension free anastomosis. Corner sutures are placed to anchor the pancreas to the stomach on the cranial and caudal aspect of the pancreas. The anterior surface of the pancreas is sutured to the posterior surface of the stomach to create the 'back row' of the pancreatogastrostomy, using a running V-Loc™ suture. A small gastrotomy is created and duct-to-mucosa anastomosis is performed with simple interrupted 5–0 absorbable monofilament sutures over a 5-Fr pediatric feeding tube as a stent in the pancreatic duct. The posterior surface of the pancreas is then sutured to the stomach using a running V-Loc™ suture, completing the outer layer of the anastomosis. All layers of the pancreatogastrostomy are performed using running V-Loc™ sutures except the duct-to-mucosa layer, which we perform in an interrupted manner with 5–0 absorbable monofilament sutures. In the event that the non-dilated pancreatic duct is too small to visualize, we perform an invagination by making a larger gastrotomy and suturing the entire face of the gland into the stomach itself (similar manner to description above), utilizing two layers.

There are multiple members of the team that are critical for success of this operation. This includes anesthesiologists and anesthetists that monitor the airway and stability of the patient, the surgeon who is at the console following port-placement, and the surgical trainee or assistant who is at the bedside, and is responsible for assisting with port-placement, docking of the robot, instrument exchanges and providing help during the operation through the assistant port. Additionally, a scrub nurse is important for providing the appropriate instruments and suture as well as a circulator nurse who maneuvers the robot patient cart to the bedside and is able to acquire any instruments or suture that is not on the operative field. This multi-disciplinary approach ensures a cohesive and safe operation (*Figure 2*).

Table 2 Summary table of published series regarding open CP and outcomes

Authors	Year	N	Morbidity (%)	Mortality (%)	Return to OR (%)	POPF (%)	DM (%)	EI (%)	Recon PG/PJ	OR time, min (mean)	Mean LOS (days)
Ikeda *et al.* (24)	1995	24	3 (13.0)	0 (0.0)	0 (0.0)	3 (13.0)	0 (0.0)	2 (8.0)	—/14	NR	NR
Sauvanet *et al.* (1)	2002	53	22 (41.0)	1 (2.0)	3 (5.7)	16 (30.0)	1 (2.0)	4 (8.0)	26/25	NR	NR
Balzano *et al.* (25)	2003	32	20 (62.0)	0 (0.0)	1 (3.1)	16 (50.0)	3 (10.0)	2 (6.2)	—/22	207	13.5
Goldstein *et al.* (33)	2004	12	3 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (17.0)	0 (0.0)	12/—	226	6.5
Efron *et al.* (29)	2004	14	7 (50.0)	0 (0.0)	0 (0.0)	5 (36.0)	0 (0.0)	1 (7.0)	14/—	229	11.1
Iacono *et al.* (30)	2005	20	7 (35.0)	0 (0.0)	0 (0.0)	5 (25.0)	0 (0.0)	0 (0.0)	—/20	NR	NR
Brown *et al.* (28)	2006	10	6 (60.0)	0 (0.0)	0 (0.0)	4 (40.0)	0 (0.0)	0 (0.0)	4/6	255	9
Crippa *et al.* (9)	2007	100	58 (58.0)	0 (0.0)	0 (0.0)	44 (44.0)	4 (4.0)	5 (5.0)	5/95	248	13
Allendorf *et al.* (10)	2007	26	8 (31.0)	0 (0.0)	0 (0.0)	2 (7.7)	0 (0.0)	0 (0.0)	26/—	226	6.9
Adham *et al.* (27)	2008	50	23 (46.0)	0 (0.0)	6 (12.0)	4 (8.0)	0 (0.0)	11 (22.0)	44/6	201	19.3
Sudo *et al.* (7)	2010	19	10 (53.0)	0 (0.0)	0 (0.0)	9 (47.0)	0 (0.0)	1 (6.0)	19/—	215	NR
Shikano *et al.* (26)	2010	26	10 (38.0)	0 (0.0)	3 (11.5)	8 (31.0)	0 (0.0)	1 (4.0)	26/—	295	NR
DiNorcia *et al.* (8)	2010	77	30 (39.0)	0 (0.0)	2 (2.6)	15 (20.0)	7 (9.1)	5 (6.5)	74/3	254	6
LaFemina *et al.* (32)	2010	23	16 (70.0)	0 (0.0)	2 (8.7)	6 (26.0)	0 (0.0)	0 (0.0)	23/—	191	5
Goudard *et al.* (31)	2014	100	72 (72.0)	3 (3.0)	6 (6.0)	63 (63.0)	2 (2.0)	6 (6.0)	98/—	245	25
Total	—	586	50.3	0.7	3.9	34.1	3.2	6.5	—	—	—

CP, central pancreatectomy; POPF, post-operative pancreatic fistula; OR, operating room; DM, diabetes mellitus; EI, exocrine insufficiency; LOS, length of stay.

Outcomes of MIS CP

With a recent increase in the use of cross-sectional imaging, there has been a concomitant increase in the identification of low-grade and benign pancreatic lesions which are amenable to a CP (23). Therefore, an increasing number of patients are now undergoing CPs and have been reported. In select higher volume series on open CP, mean morbidity was found to be 50.3% and mortality 0.7% (1,7-10,24-33) (*Table 2*). The mean re-operative rate was 3.9%. Rates of POPF (34.1%) are comparable to those reported for PD and DP (8,34), while postoperative diabetes mellitus (DM) (3.2%), and exocrine insufficiency (EI) (6.5%) are a relatively infrequent complication. In comparison to open series, the quantity of patients reported in MIS series of CP is even more limited (20,21,35,36). The largest series on laparoscopic CP was performed by Rotellar and colleagues, which included nine patients (20). In this group of patients, morbidity was 44% including one reoperation (11%) and two patients who developed POPF (22%); there were no mortalities and no patients experienced endocrine or EI. The largest series of robotic CP was reported by Abood and colleagues, and also included outcomes for 9 patients with low-grade neoplasms (19). In this series, there was one conversion to an open procedure and 78% of patients experienced a POPF, with clinically significant pancreatic fistula occurring in 22%. This coincides with the rates published for open CP (median =21.2%), where most often only clinically significant fistulas were noted (1,7,9,10,25-27,37). There were no cases of EI or endocrine dysfunction, and Clavien grade III or higher complications occurred in one patient (11%) with no reoperations or mortality. Similar outcomes were seen in additional reports of robotic CP, indicating it is a viable approach to select central pancreas lesions in specialized centers (18,19,23,38,39) (*Table 3*).

Conclusions

Robotic CP is safe and efficacious for lesions located in the central pancreas. This approach is likely to gain acceptance for select patients that have benign or low-grade neoplasms in the central pancreas given preservation of pancreatic volume and avoidance of adjacent organ resection. Furthermore, robotic CP can achieve similar outcomes with comparable rates of mortality and morbidity as the open approach.

Table 3 Summary of published series regarding MIS CP

Authors	Year	N	Morbidity (%)	Mortality (%)	Return to OR (%)	POPF (%)	DM (%)	EI (%)	Recon PG/PJ	OR time, min (mean)	Mean LOS (days)
Laparoscopic CP											
Ayav *et al.* (36)	2005	1	NR	NR	NR	NR	NR	NR	NR	NR	NR
Orsenigo *et al.* (35)	2006	1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	—/1	330	10
Sa Cunha *et al.* (21)	2007	6	2 (33.0)	0 (0.0)	0 (0.0)	2 (33.0)	0 (0.0)	0 (0.0)	6/—	225	18
Rotellar *et al.* (20)	2008	9	4 (44.0)	0 (0.0)	1 (11.0)	2 (22.0)	0 (0.0)	0 (0.0)	—/9	435	4
Total	—	17	35.3	0.0	5.9	23.5	0.0	0.0	—	—	—
Robotic CP											
Giulianotti *et al.* (39)	2010	3	1 (33.0)	0 (0.0)	0 (0.0)	1 (33.0)	0 (0.0)	0 (0.0)	3/—	320	15
Kang *et al.* (22)	2011	5	1 (20.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	5/—	480	12
Abood *et al.* (19)	2013	9	8 (89.0)	0 (0.0)	0 (0.0)	7 (78.0)	0 (0.0)	0 (0.0)	7/2	425	10
Zureikat *et al.* (18)	2013	13	13 (100.0)	0 (0.0)	1 (8.0)	12 (92.0)	NR	NR	NR	394	8
Total	—	30	76.7	0.0	3.3	70.0	0.0	0.0	—	—	—

OR, operating room; POPF, post-operative pancreatic fistula; DM, diabetes mellitus; EI, exocrine insufficiency; LOS, length of stay; NR, not recorded; CP, central pancreatectomy; MIS, minimally invasive surgery.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2016.07.22
Cite this article as: Ronnekleiv-Kelly SM, Javed AA, Weiss MJ. Minimally invasive central pancreatectomy and pancreatogastrostomy: current surgical technique and outcomes. J Vis Surg 2016;2:138.

Simultaneous laparoscopic resection of distal pancreas and liver nodule for pancreatic neuroendocrine tumor

Nicola Passuello[1], Michele Valmasoni[1], Gioia Pozza[1], Elisa Sefora Pierobon[1], Alberto Ponzoni[2], Cosimo Sperti[1]

[1]Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, Padua, Italy; [2]Departiment of Radiology, Hospital of Padua, Padua, Italy

Contributions: (I) Conception and design: N Passuello, M Valmasoni, ES Pierobon, C Sperti; (II) Administrative support: C Sperti; (III) Provision of study materials or patients: C Sperti; (IV) Collection and assembly of data: N Passuello, A Ponzoni; (V) Data analysis and interpretation: M Valmasoni, ES Pierobon, C Sperti; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Cosimo Sperti, MD. Department of Surgery, Oncology and Gastroenterology, 3rd Surgical Clinic, University of Padua, via Giustiniani 2, 35128 Padua, Italy. Email: csperti@libero.it.

Abstract: Laparoscopic distal pancreatectomy (LDP) with or without splenic preservation is increasingly performed for benign or border-line neoplasms of the body and tail of the pancreas. Pancreatic neuroendocrine tumors appear as an excellent indication for laparoscopic resection and this procedure is becoming the gold standard for the surgical treatment of such neoplasms. The safety and advantage of laparoscopic resection over open distal pancreatectomy (ODP) have been proven. In this video, we present a LDP with splenectomy for a neuroendocrine tumor of distal pancreas, with associated wedge resection of a liver nodule. Technical considerations were also discussed.

Keywords: Laparoscopy; distal pancreatectomy; splenectomy; liver wedge resection; pancreatic neuroendocrine tumor

Received: 31 October 2016; Accepted: 03 November 2016; Published: 06 December 2016.
doi: 10.21037/jovs.2016.11.08
View this article at: http://dx.doi.org/10.21037/jovs.2016.11.08

Introduction

Laparoscopic distal pancreatectomy (LDP) was first described by Cuschieri *et al*. (1) for benign diseases in 1996; in the same year, Gagner *et al*. (2) reported their early experience with eight LDP performed in patients with islet cell tumors. Nowadays, LDP is the procedure of choice for small lesions of the pancreatic body-tail of various nature.

In the literature there are many papers that demonstrate the advantages of LDP versus open distal pancreatectomy (ODP) in terms of severe complication reduction according to Clavien-Dindo classification (3), reduction of blood loss and shorter length of hospital stay (4-8). There are no differences between the two techniques in terms of postoperative pancreatic fistula (POPF) development.

Published data on oncologic radicality are limited as the mininvasive technique is mainly reserved to benign or borderline disorders, leading to relevant biases on the results.

Randomized controlled trials are needed to validate the effective advantages of LDP over ODP (9-11).

Patient selection and work-up

A 65-year-old woman, with no previous medical history, underwent a CT scan for living organ donation evaluation that showed a 3 cm hypervascular lesion in the pancreatic tail and a 3 cm slightly hypervascular nodule in segment 2 of the liver. Magnetic resonance imaging (MRI) with extracellular contrast confirmed the presence of both pancreatic and hepatic lesions (*Figures 1,2*). The pancreatic lesion was hypointense on both T1w and T2w phases, slightly hyperintense on T2w phase, high signal in DWI sequence, hyperintense on postcontrast arterial phase and isointense on venous phase. The hepatic lesion appeared isointense on precontrast T1w phase, very slightly hyperintense on T2w fs phase, hyperintense on postcontrast

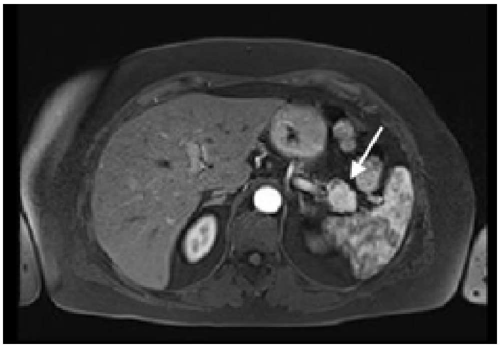

Figure 1 Magnetic resonance imaging (MRI) on postcontrast arterial phase shows a 3 cm hyperintense lesion in the pancreatic tail (arrow).

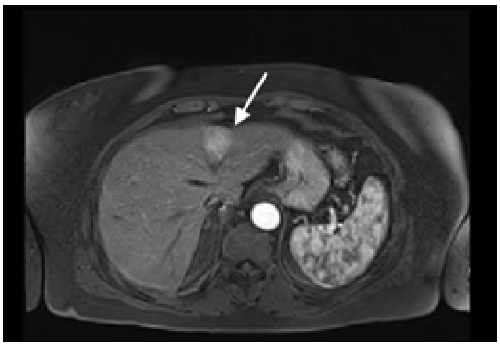

Figure 2 Magnetic resonance imaging (MRI) on postcontrast arterial phase shows a 3 cm hyperintense liver lesion in segment 2 (arrow).

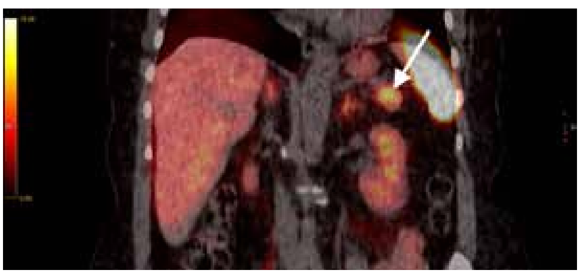

Figure 3 ^{68}Ga-DOTATOC-PET revealing the uptake of the radiotracer in a 30 mm area of pancreatic tail (arrow).

T1 phase and it showed slightly restricted diffusion. Scans were suggestive of neuroendocrine tumor of the pancreas with undetermined liver nodule. ^{68}Ga-DOTATOC-PET revealed high uptake of the radiotracer in a 30 mm area of the pancreatic tail (*Figure 3*). Laparoscopic exploration and

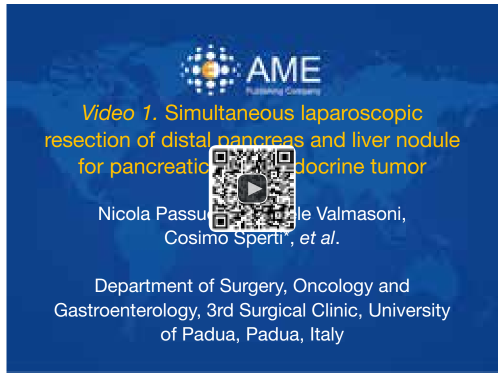

Figure 4 Simultaneous laparoscopic resection of distal pancreas and liver nodule for pancreatic neuroendocrine tumor (12).
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resection of both pancreatic and liver lesions was planned.

Pre-operative preparation

The patient fasted for 12 hours before surgery. The operation was performed under general anesthesia with endotracheal intubation. A 16 F gastric decompression tube and urinary catheter were placed. Prophylactic third generation cephalosporine was administered intravenously on induction.

Equipment preference card

High definition laparoscopic video system, pneumoperitoneum system, ultrasonic dissector, laparoscopic instruments including atraumatic graspers, scissors, clipping devices, surgical stapler and plastic specimen bag were prepared.

Procedure (*Figure 4*)

The patient was placed in a supine position with abducted spreaded legs. The chief surgeon stood between the legs. The first assistant and camera operator stood on the right side of the patient, the second assistant stood on the left side of the patient as well as the laparoscopy screen. A 10-mm trocar was placed in periumbilical region and pneumoperitoneum was created with open technique. The intra-abdominal pressure was maintained at 12 mmHg. The other trocars were placed at right-upper and left-upper quadrants (15 mm) and in epigastric region (5 mm).

Laparoscopic exploration was performed and the gastrocolic ligament was opened with ultrasonic dissector. An intraoperative ultrasound confirmed the body-tail lesion and the hepatic 3 cm nodule in segment 2 of uncertain nature. The peritoneum under the inferior margin of the pancreas was dissected and pancreas was mobilized, splenic vein was discovered and section was performed after clips positioning (Weck® Hem-o-lok® Teleflex Incorporated, Morrisville, NC, USA). The splenic artery was identified at the superior edge of the pancreas and sectioned after clips positioning. Furthermore the pancreas was sectioned with a laparoscopic stapler (EndoGIA Covidien Inc., Mansfield, MA, USA) and mobilized from the body to the tail. Splenic isolation completed the distal pancreatectomy. The surgical specimen was immediately put into a plastic specimen bag and retrieved through a small Pfannenstiel incision. Haemostasis of the surgical field was secured.

The hepatic lesion in S2 was entirely resected with safe margins with ultrasonic dissector with a satisfying haemostasis. Prophylactic cholecystectomy was performed.

Three drainages were placed: one in the subhepatic region, one in the splenic region and one close to the pancreatic stump.

Role of team member

- Dr. Nicola Passuello: Trainee;
- Dr. Michele Valmasoni: Surgeon;
- Dr. Gioia Pozza: Trainee;
- Dr. Elisa Sefora Pierobon: Surgeon;
- Dr. Alberto Ponzoni: Radiologist;
- Dr. Cosimo Sperti: Surgeon.

Post-operative management

Short course 3rd generation cephalosporin was administered. Gastric tube was removed on POD 2 and the patient started eating on the same day. Drain amylase levels were checked on POD 1, 3 and 5 and were always negative. Both the subhepatic and splenic drains were removed on POD 4 while the remaining was removed on POD 6. The patient was discharged on the same day.

Histopathological examination of the pancreatic specimen showed a neuroendocrine G2 tumor with no lymph node metastasis. Immunohistochemistry examination showed MIB1 3%, chromogranin A, beta-catenin and synaptophysin positivity. The hepatic nodule analysis demonstrated focal nodular hyperplasia.

Tips, tricks and pitfalls

Gastrocolic ligament opening must to be large in order to have space to insert the ultrasonic probe. Attention must be paid to right and left gastroepiploic arteries preservation, section of the short gastric vessels need to be carried out in order to mobilize the spleen from the stomach.

Ultrasound examination must be accurate in order to define the characteristics of the tumor, the relationship of the lesion with the Wirsung duct and, above all, with the splenic and mesenteric vessels.

The most challenging part of the procedure is the splenic vessels isolation: splenic vein must be isolated with caution at the inferior edge of the pancreas, and a sufficiently long portion of vein need to be dissected in order to clip the vessel in two points reducing the risks of bleeding. Furthermore, it is important to identify and section all the small single venous branches that come off the pancreas into the splenic vein.

An appropriate drainage positioning is eventually needed: in fact, a correct drainage of the pancreatic stump is a useful way of access for a radiological treatment in case of POPF development.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2016.11.08
Cite this article as: Passuello N, Valmasoni M, Pozza G, Pierobon ES, Ponzoni A, Sperti C. Simultaneous laparoscopic resection of distal pancreas and liver nodule for pancreatic neuroendocrine tumor. J Vis Surg 2016;2:176.

Laparoscopic distal pancreatectomy

Bulent Salman[1], Tonguc Utku Yilmaz[2], Kursat Dikmen[1], Mehmet Kaplan[3]

[1]Department of General Surgery, Gazi University School of Medicine, Ankara, Turkey; [2]Department of General Surgery, Kocaeli University School of Medicine, Kocaeli, Turkey; [3]Department of General Surgery, Bahcesehir University School of Medicine, Istanbul, Turkey

Contributions: (I) Conception and design: B Salman, TU Yilmaz; (II) Administrative support: All authors; (III) Provision of study materials or patients: K Dikmen, M Kaplan; (IV) Collection and assembly of data: B Salman, TU Yilmaz, K Dikmen; (V) Data analysis and interpretation: M Kaplan; (VI) Manuscript writing: TU Yilmaz, B Salman; (VII) Final approval of manuscript: All authors.

Correspondence to: Bulent Salman, MD, FACS. Associated Professor, Department of General Surgery, Gazi University School of Medicine, C Block, 7.Floor, Emniyet Mahallesi, Besevler, 06500, Ankara, Turkey. Email: bsalman@gazi.edu.tr; bulentsalman@gmail.com.

Abstract: After technological advances and increased experiences, more complicated surgeries including distal pancreatectomy can be easily performed with acceptable oncologic results, and decreased mortality and morbidity. Laparoscopic distal pancreatectomy (LDP) has been shown to have several advantages including less blood loss, less hospital stay, less pain. Several studies comparing open distal pancreatectomy (ODP) and LDP resulted that both techniques have similar results according to pancreas fistulas, oncological results, costs and operation indications. Morbidity is very low in high volume centers, for this reason at least ten cases should be performed for the learning curve. Several authors remarked important technical points in LDP in order to perform safe and acceptable LDP in several studies. Here in this review, we aimed to overview the results of previous studies about LDP and discuss the technical points of LDP.

Keywords: Pancreas; distal pancreatectomy; laparoscopic; pancreatic resection

Received: 18 June 2016; Accepted: 18 July 2016; Published: 12 August 2016.
doi: 10.21037/jovs.2016.07.21
View this article at: http://dx.doi.org/10.21037/jovs.2016.07.21

Introduction

Despite the developments in minimally invasive surgery for intraabdominal pathologies, laparoscopic pancreatic surgery has lagged behind because of its limitations, such as major vascular proximity, retroperitoneal location, and adjacent organs (1). However, with improvements in laparoscopic skills and surgical technology, laparoscopic distal pancreatectomy (LDP) has been proven to be safe and have better outcomes (2). In the present study, we compared LDP with the traditional method of open distal pancreatectomy (ODP).

Early series of LDP consisted of benign lesions, such as premalignant lesions, benign pancreatic strictures, and neuroendocrine pancreatic lesions (3). In these early series, LDP reduced postoperative morbidity and hospital stay and increased quality of life in young patients. Then, the number of LDP procedures performed for malignant disease increased (2,4). It has been shown in several studies that tumors can be resected with adequate lymph nodes using LDP, with similar pancreatic fistula rates (4). On the other hand, technically demanding spleen-preserving distal pancreatectomies have been performed (5). In this article, we describe current concepts of LDP.

Indications

Symptomatic benign lesions, premalignant lesions, and cancer located in the body or tail of the pancreas are candidates for distal pancreatectomy. Until recently, the number of distal pancreatectomy procedures performed was limited because of the low incidence of pancreatic lesions and the high proportion of lesions unresectable at first presentation. Today, however, new diagnostic tests are available that are capable of providing an early diagnosis of pancreatic lesions with high quality, and the number of indications for distal pancreatectomy has increased. Since the first series of LDP cases published in 1996, the benefits and safety of LDP have been proven (4,6). During preoperative assessment, medical comorbidities, tumor size, organ involvement, and major vascular involvement are evaluated.

Recent studies show that there is no absolute indication about how the type of surgery (open or laparoscopic) is decided. Consideration of individual patients' features to decide on the type of operation has been reported in several studies (7-11). There were no differences between LDP and ODP cases in terms of patient age, gender, American Society of Anesthesiologists score, body mass index (BMI), or presence of diabetes mellitus (7-11). Cho *et al.* showed that no preoperative evaluable variables were associated with a higher likelihood of significant fistula after LDP *vs.* ODP (12). Greater BMI, larger specimen size, and increased blood loss were much more important risk predictors for postoperative complications after ODP as compared with LDP (12).

In selected studies, the ratios of ODP and LDP were 14.2% and 8.8% for endocrine tumors, 16.8% and 9.7% for mucinous cystic neoplasias, 9.7% and 6.7% for chronic pancreatitis, 7% and 8% for pseudocysts, 8.5% and 6.2% for intraductal papillary mucinous neoplasms, 7.8% and 17.5% for ductal adenocarcinomas, 7.3% and 16.5% for pancreatic tumors, and 16.1% and 17% for cystic lesions, respectively. These results show that LDP and ODP have been performed in similar ratios for cystic lesions, chronic pancreatitis, intraductal papillary mucinous neoplasms, and pseudocysts. Ductal adenocarcinomas and pancreatic tumors, however, have been treated more often with ODP. Mucinous cystic neoplasias have been treated much more often with LDP (13). Because of the concern about achieving good oncological outcomes, LDP has been thought to be contraindicated in patients with malignant disease. Trocar site metastasis, promotion of neoplastic growth by pneumoperitoneum, and wound recurrence have not been proven to be risks of LDP (14,15). However, no evidence has been presented in the literature that the use of the laparoscopic technique increases the risk of neoplastic dissemination, and none of the patients in recent studies developed any trocar site or peritoneal metastasis (4,16-19). The results described above show that there is no exact preoperative indication for ODP or LDP.

Distal adenocarcinomas of the body and tail of the pancreas comprise only 20–25% of all diagnosed pancreatic adenocarcinomas, and surgical resection remains the only potentially curative therapy (20). In pancreatic cancer, negative surgical margins and adequate lymph node harvesting are crucial. These factors lead to long survival. To achieve these oncological outcomes, radical antegrade modular pancreatosplenectomy (RAMPS) seems superior to conventional distal pancreatectomy (21). It has been hypothesized that improved oncological resection could be achieved with RAMPS, with a higher likelihood of obtaining negative tangential margins (89%) and increased rates of R0 resection (81%) (22). Use of the RAMPS approach can increase R0 rates. The RAMPS technique has been adopted for laparoscopic surgery and is an option for the laparoscopic resection of distal pancreatic adenocarcinomas (19,23). Advanced laparoscopic operations, such as RAMPS can be easily performed. Also, additional organ resections are not contraindications to LDP. Colectomy, gastrectomy, cholecystectomy, and repair of colovesical fistulas have been laparoscopically performed with LDP (19,24).

Surgical techniques

Since Gagner first described the LDP method, this operative technique has been modified at different centers. LDP is usually performed with the patient supine or on the left side (25,26). The advantages of the supine position are ease of setup, clearer airway access for anesthesia, and ability to access the pancreatic head and neck. Four or five trocars are placed in a semicircular fashion around an umbilical camera. Alternatively, trocar sites are placed under direct visualization, depending on the patient's body habitus and the location of the lesion. A left lateral decubitus position facilitates exposure of the left upper abdominal quadrant (1). A lateral position allows gravity retraction of the stomach and spleen, more direct visualization of the body and tail of the pancreas, and superior ergonomics and comfort for the surgeon (27).

In our practice, the patient is placed supine. The hand-guided approach has been defined by several authors (28,29). The advantages of the hand-guided approach include preserving the surgeon's ability to perform direct palpation of the tumor and anatomy, ease of removal of larger malignant specimens through the hand port, use of manual dissection, increased surrounding inflammation, improved ability to operate on obese patients, and opportunity to apply direct pressure in case of bleeding. It is not necessary for the surgeon's hand to feel the borders of the lesion. Most authors advocate the use of intraoperative laparoscopic ultrasound to localize the lesion and define the extent of the resection (30). If the lesion is obvious, dissection is initiated by mobilizing the lower pancreatic margin 2 cm proximal to the lesion. However, for malignant lesions, a formal left pancreatectomy is performed at the level of next to the junction of the superior mesenteric vein (SMV) and the portal vein.

There is controversy about splenectomy in LDP. Some authors believe splenectomy should be performed routinely because splenic artery preservation is hazardous for oncological radicality in distal pancreatectomy (31). In order to ensure extensive resection of lymph nodes located along the splenic artery and splenic hilum, splenectomy with splenic artery resection is advised (32). Distal pancreatectomy with splenic vessel preservation may lead to remnant pancreatic tissue on the splenic vessel, and therefore it is not advised in patients with malignant disease. However, in chronic pancreatitis or benign diseases, the number of cases with spleen preservation is high (33,34). Spleen preservation was shown to be associated with reductions of postoperative infection and length of hospital stay. In benign disease, attempts to preserve the spleen are important. In cases of chronic pancreatitis, however, pancreatic calcification, marked edema and fibrosis may occur in splenic vessels, and splenic vessel preservation in those cases may not be possible.

The Warshaw technique has been used with LDP to resect and preserve the spleen (35). It is unclear whether the Kimura or the Warshaw technique is superior. However, spleen-related complications are seen much more often after use of the Warshaw technique than with the Kimura technique, such as postoperative splenectomy (2% *vs.* 0%, respectively), splenic infarction (20.8% *vs.* 2%, respectively), and chronic abdominal pain (38% *vs.* 0%, respectively) (36,37). Symptomatic splenic infarctions have been reported to be significantly less common after vessel-preserving splenectomies. Interestingly, none of these infarcts evolved to an abscess, and they were all conservatively treated (37). In the study of Baldwin *et al.*, only four patients treated with splenic vessel ligation developed symptomatic splenic infarcts, and three patients underwent splenectomy (38). Patients were routinely monitored postoperatively with computed tomography (CT) in only a limited number of previous studies. For this reason, the number of splenic infarcts might be underestimated. Also, the patients in the Baldwin *et al.* study were elderly. It is possible that short gastric vessels do not supply enough collateral circulation to support the splenic mass (38). Moreover, supplying enough blood to the spleen might be difficult in patients with large spleens. Thus, it is of paramount importance to evaluate the spleen's dimensions during surgery when deciding on the type of operation to perform.

During spleen-preserving procedures, the spleen should be checked for extensive splenic ischemia, which may be seen in 10% of patients. Splenic infarction is seen mostly in the early period. It is reasonable to prefer a distal pancreatectomy with splenectomy to splenic vessel ligation when vessel preservation fails intraoperatively. Perigastric varices and related gastric mucosal bleeding are risks after distal pancreatectomy. In the study of Hwang *et al.*, four patients treated with distal pancreatectomy with splenic vessel ligation had perigastric varices, and only three patients developed submucosal varices (39). Butturini *et al.* reported perigastric varices in 60% of patients treated with splenic vessel ligation and 22% of patients treated with splenic vessel preservation (40); however, bleeding was not seen.

Thus, perigastric varices are not a risk after splenic vessel ligation. The Kimura technique is more demanding, as the splenic vessels are preserved. LDP with splenic vessel preservation is much more time-consuming. However, authors of several systemic reviews have shown that spleen-preserving LDP is much more preferred (7,12). The enhanced surgical view during laparoscopic surgery, with better visualization of splenic vessels, has contributed to these findings. Only 14 patients were converted from vessel preservation to vessel ligation in one study (37). The presence of small breakage of tributary vessels from splenic vessels could potentially obscure the surgical field and result in intraoperative bleeding, splenectomy, or conversion. In spleen-preserving LDP, the pancreas is separated from the splenic vessels. However, this maneuver might be bloody, and it is difficult to manipulate the pancreas.

Velanovich has described the lasso technique, in which a Penrose drain around the neck of the pancreas is used to manipulate the dissection (41). LDP with splenic vessel ligation is 27 min shorter than LDP with splenic vessel preservation. Eom *et al.* reported significantly prolonged operative time in spleen preservation compared with splenectomy (194 *vs.* 251 min; P=0.02) (42). The mean operative time for LDP ranges from 156 to 383 min, whereas the mean operative time for ODP ranges from 145 to 330 min. The endpoint showed a nonsignificant extension of 9.21 min of the operative time (13). Blood loss during splenic preservation is reported to be much more than that in LDP with splenectomy (225 *vs.* 495 mL) (23). However, intraoperative blood loss was reported to be less in LDP than in ODP (13). Spleen preservation is much more time-consuming, technically more demanding, and leads to much more bleeding in LDP than in ODP. The conversion rate for LDP with splenectomy ranges from 0% to 43% and LDP with splenic preservation ranges from 72% to 100% (1). With increasing experience and specialized centers, the

Figure 1 Port placement.

Figure 2 Presentation of laparoscopic distal pancreatectomy (LDP) (43). Available online: http://www.asvide.com/articles/1100

Figure 3 Opening lasser sac.

conversion rates are expected to decrease. The most common reasons for conversion are obesity, dense omental fat, intraoperative bleeding, malignant disease requiring lymph node dissection, inability to detect the tumor, bulky tumors, and peritoneal adhesions due to previous surgery (30).

Figure 4 Identification of superior mesenteric vein (SMV).

The patient should be positioned with legs apart or in the left lateral or supine position. The surgeon stands between the patients' legs. An assistant stands on the left side of the patient for camera and a scrub nurse stands on the opposite side. A 10-mm trocar is inserted at the umbilicus for use of the 30° telescope. A second trocar is inserted in the xiphoid area for retraction of the stomach. A third trocar is inserted in the left subcostal area on the midaxillary line and in the left subcostal area to the midclavicular line (*Figure 1*).

The patient is placed in a reverse Trendelenburg position to facilitate displacement of the transverse colon and small bowel from the operative field. Video presentation of one of LDPs is given (*Figure 2*). The patient has a mass with irregular borders in the tail of the pancreas. The lesser sac is opened using an energy device through the avascular plane while preserving the gastroepiploic vessels (*Figure 3*). Short gastric vessels are dissected to the superior part of the stomach as far as possible. The stomach is grasped and elevated with a nontraumatic grasper introduced through the xiphoid port to enable investigation to the entire neck, body, and tail of the pancreas.

At this step, we routinely use intraoperative laparoscopic ultrasonography to identify the precise location of the tumor and its relation to the splenic vessels and to demarcate its extent. We routinely explore SMV at the inferior border of the pancreas for resectability before starting the dissection. This maneuver requires finding SMV and developing a space between the pancreatic neck and vein. SMV is then readily identified at the inferior margin of the pancreatic neck with a blunt dissector (*Figure 4*). If there is no invasion, a tunnel is developed easily between the pancreatic neck and splenic vein. Next, the pancreas is hanged with nylon tape for manipulation. After determining resectability, deciding on the dissection begins at SMV and is carried

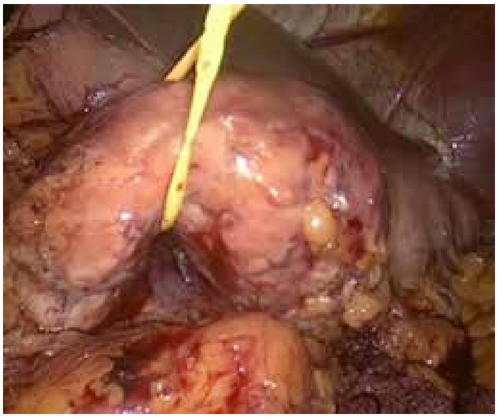

Figure 5 Hanging pancreas.

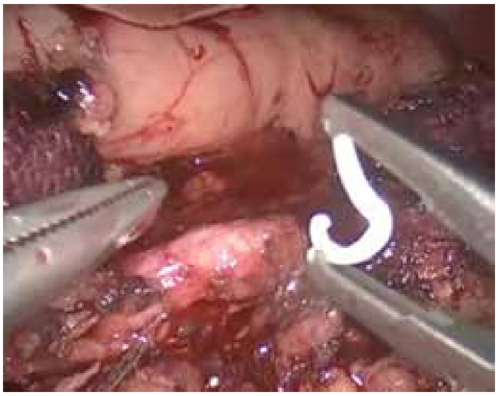

Figure 6 Division of the splenic artery.

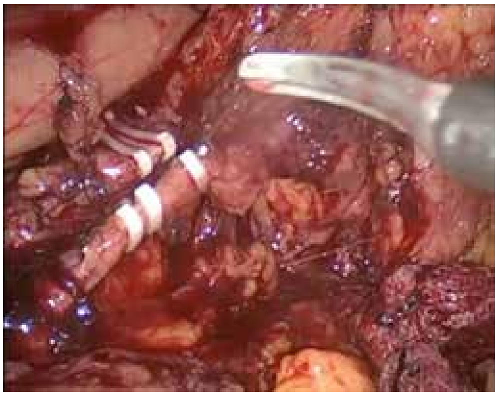

Figure 7 Division of the splenic vein.

laterally along the inferior border of the pancreas, allowing elevation of the posterior margin of the pancreas out of the retroperitoneum (*Figure 5*).

The splenic flexure of the colon must be mobilized so that the colon does not require continuous retraction to expose the pancreas. At this step, the venous mesentericoportal axis is visualized, and typically, the inferior mesenteric vein can be divided between Weck clips. Then, to start initial mobilization of the spleen, care must be taken regarding progression into the splenic hilum; instead, the dissection should be directed to the inferior pole of the spleen. Complete mobilization requires division of the lateral colon attachments. The splenic artery is controlled on the superior border of the pancreas. Retracting the pancreas inferiorly and laterally reveals the splenic artery and celiac truncus. Circumferential dissection is achieved with a blunt dissector, and initially the splenic artery is divided, usually with a vascular load Endo GIA (Covidien Surgical Boulder, CO, USA) or, on occasion, between Weck clips (*Figure 6*). At our center, we do not use energy devices for dividing the splenic artery at this step. The artery transection precedes transection of the vein to avoid splenic congestion and bleeding from the transected short gastric vessels.

Because of its fragility and close relation to the pancreas, splenic vein dissection is difficult. The splenic vein is dissected circumferentially, with care taken to identify insertion into both the inferior mesenteric vein and the coronary veins. Then the splenic vein is dissected and divided with the vascular Endo GIA, or, on occasion, between Weck clips, after transection of the pancreas (*Figure 7*).

The splenic vein has multiple braches that drain the body of the posterior pancreas. Therefore, the pancreas neck must be transected before continuing the dissection. To transect the pancreatic neck, the portal vein must be exposed at the superior margin of the pancreas by identifying the hepatic artery. After clearing a space superiorly and inferiorly, an endoscopic linear stapler can be inserted. Selection of the correct stapler cartridge depends on gland thickness. The goal is to avoid fracturing the gland with a staple length that is too short. If necessary, two staplers can be used for transecting the pancreas. After the splenic vessels are divided, the posterior retroperitoneal space can be dissected easily with the pancreas retracted anteriorly (*Figure 8*). The spleen is mobilized by continuing the posterior dissection laterally, although the most lateral diaphragmatic attachment may require rotating the spleen medially. This dissection is accomplished with energy devices.

The spleen and pancreas are usually detached at the splenic hilum with ultrasonic shears so that the pancreas can be delivered as an intact specimen and the spleen as a morcellated specimen. The specimen is placed in an Endo Catch bag and extracted through a Pfannenstiel incision.

Figure 8 Division of the pancreas.

Pancreatic fistulas

The most common and clinically relevant complication after distal pancreatectomy is the pancreatic fistula, which may lead to further complications, such as intraabdominal abscess, sepsis, wound infection, delayed gastric emptying, ileus, and lethal bleeding. Treatment of pancreatic fistulas after distal pancreatectomy has not changed for more than 15 years, despite progress in other areas of pancreatic surgery. Several surgical techniques and instruments have been studied with the goal of decreasing pancreatic fistulas. These include hand-sewn sutures, different kinds of staplers, combinations of staplers and sutures, pancreaticojejunal anastomosis, transection by harmonic scalpel, and fibrin glues (44). The experience and results in ODP were the same as those in LDP. Unfortunately, LDP did not decrease the rate of pancreatic fistulas. In a meta-analysis, postoperative pancreatic fistulas were found to occur in 21.7% of the patients, with no difference between LDP and ODP.

Hand-sewn closures and stapler closures are both used in LDP. As shown in the DISPACT trial, stapler closure is not superior to hand-sewn closure (45). In LDP, stapler closure is the most commonly performed technique. Use of a stapler with 2.5 staple cartridges is associated with fewer pancreatic fistulas than the 4.5 staple cartridges (46). Also, gradual closing of the staple over the course of approximately 2–3 min could reduce the fistula rate (47). In the study by Johnston *et al.*, reinforcement of the staple line with mesh was shown to reduce the fistula rate from 25% to 10% (48). Fibrin glue, sealant patches, and seromuscular patches have been used during LDP (25,49,50). However, these modalities were not confirmed in the randomized study of Oláh *et al.* (51).

As mentioned, LDP can be performed according to oncological principles and with comparably safe procedures. Shorter hospitalization, less intraoperative blood loss, and decreased pain are advantages of LDP over ODP. On the other hand, cost and the learning period are important factors related to LDP. LDP is a complex abdominal operation and requires experience in laparoscopy. With increasing experience with LDP, operative time is shortening, postoperative pancreatic fistula rate is declining, and operative blood loss is decreasing. Braga *et al.* found substantial reduction of the conversion rate, operative time, and operative blood loss after experience with the first ten procedures (52). The results of last 20 cases of Braga *et al.* were similar to the results of high-volume centers (52). The operative time in the learning period was 254 min, but it decreased to 183 min after the learning period. However, hospitalization time did not show any difference after the learning period. The learning period is usually shorter in high-volume centers than in low-volume hospitals.

Several studies have been performed to compare the costs of LDP and ODP. Korean, Italian, and British studies have shown that LDP is more expensive than ODP (42,53,54). However, decreased length of hospital stay after LDP led to equivalent total hospital costs in the British and Italian studies (42,53,54). In a North American study, overall hospital costs related to LDP were less than those for ODP (55). These studies showed that LDP is a financially reasonable approach to resection. In experienced centers, shorter operative time and decreased complications led to less cost.

Conclusions

LDP can be safely performed and may produce similar oncological results compared with ODP. Length of hospitalization and intraoperative blood loss in LDP are less when performed at experienced centers. Pancreatic fistula rates are similar with open cases in high-volume centers. Costs of LDP are reasonable in experienced centers. Although LDP surgery is complex, it can be performed safely when standard steps are carefully followed.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2016.07.21
Cite this article as: Salman B, Yilmaz TU, Dikmen K, Kaplan M. Laparoscopic distal pancreatectomy. J Vis Surg 2016;2:141.

Laparoscopic spleen preserving distal pancreatectomy

Ho-Seong Han, Yoo-Seok Yoon, Seong Uk Kwon, Jai Young Cho, YoungRok Choi, Jae Seong Jang

Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea
Correspondence to: Seong Uk Kwon. Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Sungnam, Republic of Korea. Email: kwonryuk@gmail.com.

Abstract: Minimal invasive surgery is growing rapidly in vast fields of abdominal surgery. Nowadays, due to the development of laparoscopic instruments and improvement of surgical technique, laparoscopic pancreas surgery is becoming more widely adopted. Laparoscopic distal pancreatectomy has now become a standard procedure for the benign or borderline malignant tumor located in body or tail of pancreas, but laparoscopic spleen and splenic vessel preserving distal pancreatectomy is still a technically demanded operation. In this multimedia article, we will demonstrate our technique of laparoscopic spleen and splenic vessel preserving distal pancreatectomy.

Keywords: Spleen and splenic vessel preserving distal pancreatectomy; minimal invasive pancreatic surgery; laparoscopy

Received: 28 July 2016; Accepted: 11 August 2016; Published: 23 August 2016.
doi: 10.21037/jovs.2016.08.03
View this article at: http://dx.doi.org/10.21037/jovs.2016.08.03

Introduction

Minimal invasive surgery is growing rapidly in vast fields of abdominal surgery. Nowadays, due to the development of laparoscopic instruments and improvement of surgical technique, laparoscopic pancreas surgery is becoming more widely adopted (1,2). Laparoscopic distal pancreatectomy has now become a standard procedure for the benign or borderline malignant tumor located in body or tail of pancreas (3-6). Splenic preservation is associated with a reduction in perioperative infectious complications (7,8), postoperative pancreatic fistula (9), and cancer recurrence (10,11). Therefore, in patients with benign or borderline malignant tumor in the body or tail of pancreas, spleen preserving distal pancreatectomy is preferred over combined splenectomy (12). Laparoscopic spleen and splenic vessel preserving distal pancreatectomy is still technically demanded operation (13). In this multimedia article, we will demonstrate our technique of laparoscopic spleen and splenic vessel preserving distal pancreatectomy.

Patient selection and work up

The patient is a 30-year-old female who has a 2 cm mass at the pancreas body. Pancreatic tumor was detected with the abdominal sonography for health checkup. The patient does not have any symptoms. CT showed a 2 cm subtle low attenuating lesion at the pancreas body-tail junction, and MRI showed a 1.9 cm well-demarcated low signal intensity tumor in the T1 weighted image, intermediate high signal intensity in the T2 weighted image. Laparoscopic spleen and splenic vessel preserving distal pancreatectomy was planned.

Equipment preference card

The equipment used in our hospital includes HD dual monitors with Endoeye Flex 3D articulating Videoscope (Olympus®). We used The ECHELON FLEX™ Powered vascular stapler with Gold cartridge (Ethicon®), and LigaSure energy device (Covidien®).

Procedure

Under general anesthesia, patient was positioned supine. We are using four ports: one 12-mm optical port at the umbilicus, two ports in the right abdomen. An additional

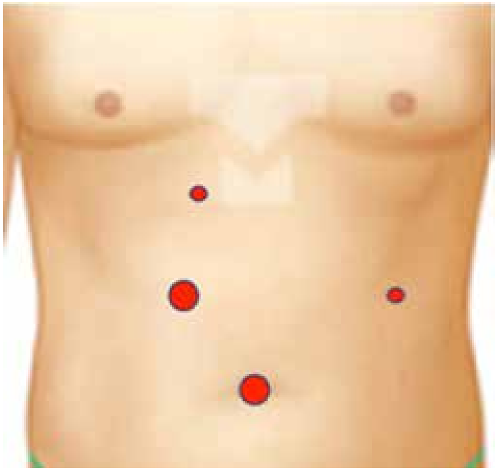

Figure 1 Trocar position.

Figure 2 Laparoscopic spleen preserving distal pancreatectomy (14). Available online: http://www.asvide.com/articles/1117

5-mm port is placed at cross point of anterior midclavicular line and left hypochondrium: it is used by the assistant surgeon (*Figure 1*).

The procedure starts with cutting of greater omentum using an energy device from middle to left until the spleen is exposed. Stomach is retracted cephalad by suturing its posterior wall and pulling out the string using a needle passer. Dissection is then continued at the inferior border of the pancreas. LigaSure is useful to control small vessel by sealing during dissection of pancreas. Medium sized vessels are clipped and divided. LigaSure and the suction tip are useful for dissecting between pancreas and splenic vein (*Figure 2*).

Then, the dissection is carried on at the superior border of pancreas in order to identify and isolate the splenic artery. After splenic artery isolation, retropancreatic space is made by dissection between pancreas and portal vein. Surgical tape is placed around the pancreas neck and gently lifted upwards by the assistant. Pancreas is transected by The ECHELON FLEX™ Powered vascular stapler (60 mm) with Gold cartridge (Ethicon®). The type of cartridge depends on the thickness and texture of the pancreas. Green cartridge is used for thick and hard pancreas or the pancreatic duct can be sutured intracorporeally. Dissection is then carried on from right to left. The LigaSure is frequently used to separate the splenic vessels from pancreatic parenchyma. Gradually, the dissection is continued all the way to the splenic hilum. Meticulous bleeding control and irrigation is done and fibrin glue is applied on the pancreatic resection margin. Specimen is pulled out through extended umbilical port by putting in the vinyl bag. Umbilical port and 10 mm port site fascia are closed by suture. Drain is placed at the pancreas resection margin through the left 5 mm port.

Role of team member

- Dr. Ho-Seong Han: Surgeon;
- Dr. Yoo-Seok Yoon: Surgeon;
- Dr. Seong Uk Kwon: Assistant Surgeon;
- Dr. Hyo Seok Na: anesthesiologist;
- Nr. Yu Jin Heo: scopist.

Tips, tricks and pitfalls

It is very important to acquire a proper view of the surgical field in laparoscopic surgery. To obtain the right surgical field, the assistant should lift the stomach at the cephalad direction as it interferes with the exposure of the pancreas and the celiac axis. So we have to add an extra port for the assistant to manipulate the stomach beforehand. Hence, if we anchor the stomach by suture and pull the string out of abdomen, the surgical field will remain stable during the whole operation time. If the stomach is large, one or two more sutures will be helpful.

Bleeding from small branches can occur easily while dissecting between the pancreas parenchyma and the splenic vessels. Using the sealing device, it is possible to control these small veins. When clips are used for small veins, it may easily fall off and bleed easily. The sealing device may be useful for secure control of small vessels and shortening operative time.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2016.08.03
Cite this article as: Han HS, Yoon YS, Kwon SU, Cho JY, Choi Y, Jang JS. Laparoscopic spleen preserving distal pancreatectomy. J Vis Surg 2016;2:146.

Is it possible to predict conversion during minimally invasive pancreatectomy?

Edoardo Rosso, Giuseppe Zimmitti, Alberto Manzoni

Department of Surgery, Istituto Fondazione Poliambulanza, Brescia, Italy

Correspondence to: Edoardo Rosso, MD. Department of Surgery, Istituto Fondazione Poliambulanza, via Bissolati, 57, 25124, Brescia, Italy. Email: edoardo.rosso@poliambulanza.it.

Provenance: This is an invited Editorial commissioned by the Editor-in-Chief Giovanni Battista Levi Sandri (Division of General Surgery, Santa Scolatisca Hospital, Cassino, Lazio, Italy).

Comment on: Hua Y, Javed AA, Burkhart RA, *et al.* Preoperative risk factors for conversion and learning curve of minimally invasive distal pancreatectomy. Surgery 2017;162:1040-7.

Received: 08 January 2018; Accepted: 15 January 2018; Published: 01 February 2018.

doi: 10.21037/ls.2018.01.01

View this article at: http://dx.doi.org/10.21037/ls.2018.01.01

The article entitled "Preoperative risk factors for conversion and learning curve of minimally invasive distal pancreatectomy" is an interesting retrospective study from the Johns Hopkins Hospitals Groups reporting clinical and practical risk factors for conversion during distal pancreatectomy.

I would like to highlight several of the results and discussion points in this manuscript.

First, surgical strategy can be planned mainly by in deep interpretation of the pre-operative workout. Indeed, Hua *et al.* underlined that commonly available preoperative data (diagnosis of malignant disease, need for multiorgan resection, surgeon experience, extent of visceral fat, vascular anatomy) are useful to predict the rate of conversion during mini-invasive distal pancreatectomy. We can imagine that if a patient presents several concomitant risk factors (e.g., malignant disease requiring a multi-organ resection in an obese patient) open surgery should be considered or a surgeon with large experience in mini-invasive surgery should perform the operation. On the opposite site, a benign lesion of the pancreas in a lean patient with a standard vessels anatomy may represent the safe case for a surgeon in training.

Visceral fat and the bulky fatty pancreas are the new enemies of the pancreatic surgeon rejoining the "deadly family" constituted by soft pancreas, thin Wirsung duct and high comorbidity patient. The worldwide epidemy of obesity is changing completely the profile of the typical "pancreatic" patient and we are moving from the lean patient with soft and tiny pancreas to the large patient with massive retroperitoneal fat and bulky friable pancreas (1,2). Hua *et al.* reported in the manuscript that the excessive intra-abdominal fat was one of the main cause of conversion. Interestingly, the authors confirmed that BMI was not an efficient predictor of conversion and that we should better rely on the pre-operative evaluation (CT scan, MRI) of the visceral abdominal fat.

In term of technique, we should accept that distal pancreatectomy for malignant and not malignant disease shares only a common denomination but they are largely different operations (3,4). Distal pancreatectomy for benign or borderline lesions is a simpler operation, indeed, it does not require complex lymphadenectomy or resection of the retro-portal lamina [radical antegrade modular pancreatosplenectomy (RAMPS) technique] (4). The present manuscript reported a significantly higher rate of conversion in case of distal pancreatectomy for malignant disease.

The "human factor" still be an important element for surgery, even in the setting of high volume hospital adopting standardized techniques. Hua *et al.* confirmed that more is the experience of the operating surgeon less is the rate of conversion.

In conclusion, the present article has shown, once again, that attentive interpretation of preoperative data can assist the surgeon to predict the difficulty of the intervention in case of distal pancreatectomy and that for the most difficult operations “two experienced surgeons are better than one” or at least they may reduce the chance of conversion.

Finally, the significantly different rate of conversion in case of distal pancreatectomy for malignant disease and not malignant disease should be interpreted has an advice to keep separate, in further, studies the two indications.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

doi: 10.21037/ls.2018.01.01

Cite this article as: Rosso E, Zimmitti G, Manzoni A. Is it possible to predict conversion during minimally invasive pancreatectomy? Laparosc Surg 2018;2:1.

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Minimally invasive versus open distal pancreatectomy for ductal adenocarcinoma (DIPLOMA)—a difficult question to answer

Jonathan Ghing-Chi Sham, Michele Maiko Gage, Jin He

Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Correspondence to: Jin He, MD, PhD, FACS. Assistant Professor of Surgery and Oncology, Johns Hopkins Hospital, 600 N Wolfe St, Halsted 614, Baltimore, MD 21287, USA. Email: jhe11@jhmi.edu.

Provenance: This is an invited Editorial commissioned by the Editor-in-Chief Giovanni Battista Levi Sandri (Division of General Surgery, Santa Scolatisca Hospital, Cassino, Lazio, Italy).

Comment on: van Hilst J, de Rooij T, Klompmaker S, *et al.* Minimally Invasive versus Open Distal Pancreatectomy for Ductal Adenocarcinoma (DIPLOMA): A Pan-European Propensity Score Matched Study. Ann Surg 2017. [Epub ahead of print].

Received: 08 January 2018; Accepted: 15 January 2018; Published: 07 February 2018.

doi: 10.21037/ls.2018.01.02

View this article at: http://dx.doi.org/10.21037/ls.2018.01.02

Since the introduction of laparoscopy as an adjunct to abdominal surgery in the 1980's, surgeons have sought to compare the clinical outcomes of minimally invasive procedures with their parent operations. Initial reports of technical feasibility (1,2) are classically followed by evaluations of safety and efficacy (3,4) and if applicable, oncologic outcomes (5,6). In their recently study, *Minimally Invasive versus Open Distal Pancreatectomy for Ductal Adenocarcinoma* (*DIPLOMA*) (7), van Hilst *et al.* attempt to compare technical and oncologic outcomes between these increasingly common pancreatic resections.

Open distal pancreatectomy (ODP) was originally described over 100 years ago and rarely performed, most often in the face of otherwise unsurvivable malignancy, due to the procedure's associated morbidity and mortality (8). As pancreatic surgery entered the modern era in the late 1990's, reports from high-volume centers described vastly improved safety and efficacy (9,10). renewing interest in the procedure for a wider array of patients. Ongoing technical refinements to the open approach were made into the early 2000's (11) demonstrating continued interest in methodologies to maximize the procedure's oncologic benefit. During this same period, laparoscopic distal pancreatectomy (MIDP) made its debut (12). Since that time multiple systematic reviews and cohort studies have indicated safety and efficacy with the minimally invasive approach (13-15). However, due to the relatively low incidence of the procedure globally, high quality randomized-controlled data are lacking.

On behalf of the European Consortium on Minimally Invasive Pancreatic Surgery (E-MIPS), van Hilst *et al.* aimed to address this lack of data by performing a large multi-institutional retrospective cohort study, evaluating over 1,200 patients for their analysis. Thirty-four institutions, primarily in Europe, each performed a median of 30 distal pancreatectomies per year, 14 for pancreatic ductal adenocarcinoma (PDAC). In an attempt to widen generalizability, the authors allowed broad histopathological inclusion criteria for patients with distal PDAC including mucinous non-cystic carcinomas, signet ring cell carcinomas, adenosquamous carcinomas, and undifferentiated/mixed-type carcinomas of the pancreas. However, the authors prudently excluded patients with celiac trunk involvement, those who had previously undergone pancreaticoduodenectomy, and those only became resectable after undergoing neoadjuvant chemotherapy.

Preoperative patient characteristics after propensity score matching were equivalent between ODP and MIDP, indicating relative intergroup homogeneity. Ninety-six percent of MIDPs were able to be matched with a corresponding ODP. Intraoperative blood loss was lower in the MIDP group, a finding consistent with other studies comparing laparoscopic and open approaches for intraabdominal resections (5,16) and is likely due to improved visualization with laparoscopic magnification as well as the hemostatic effects of pneumoperitoneum.

Serious postoperative morbidity and incidences of a pancreatic fistula were also equivalent in this study, supporting the findings of a recent Cochrane database review on this topic (17). The authors also demonstrated comparable overall survival (OS) between MIDP and ODP. The reported median OS of 28 months is consistent with other recent investigations evaluating modern adjuvant chemotherapeutic regimens (18), however this finding is somewhat surprising as similar patients with body/tail lesions have previously been shown to have a poorer prognosis (19).

The authors do focus on several key findings in their data including differences in margin status, lymph node retrieval, and Gerota's fascia resection. The R0 resection rate was significantly higher with MIDP when compared with ODP (67% *vs.* 58%, P=0.019), a finding at odds with three previous studies comparing these techniques (20-22). van Hilst and colleagues appropriately pointed out that margin status is a notoriously problematic outcome to measure, as the specifics of pathologic assessment and actual definitions of R0/R1 can differ significantly between studies. While this may be true, the authors failed to describe why ODP should be inferior to MIDP in this regard. As this was not a randomized study, it is not unreasonable to expect that patients selected for OPD may have had tumors placing them at lower chance for an R0 resection. While propensity matching did adjust for tumor size, tumor location (body/tail), and involvement of other organs, more subtle morphologic differences on preoperative imaging that may have affected treatment allocation were not controlled for and may have affected this result.

Lymph node retrieval was noted to be inferior in the MIDP group, as the median number of lymph nodes retrieved was nearly 60% higher (22 *vs.* 14, P<0.001) in patients who underwent an open operation. While this finding is statistically significant, the clinical significance is less clear. Recent reports have demonstrated that obtaining at least 10 or 11 lymph nodes in pancreatectomy specimens for PDAC is sufficient (23,24), with both groups in the DIPLOMA study meeting this benchmark. There are no recent data to suggest obtaining additional lymph nodes beyond this standard confers a prognostic or survival advantage. In fact, the lymph node ratio (LNR) has been reported as the strongest prognostic factor after resection for pancreas cancer (25). In this study both ODP and MIDP showed comparable LNR (0.06 *vs.* 0.08, P=0.403) corresponding with the equivalent observed OS. Rates of resection of Gerota's fascia are also reported, with ODP noted as superior to MIDP (60% *vs.* 31%, P<0.001). The authors suggest that removal of Gerota's fascia may be important in achieving an R0 resection, particularly in reference to the specimen's tangential margin. If this holds true, the study's finding of a lower R0 resection rate in the ODP group may be related to the higher rates of lymphovascular and perineural invasion observed in these patients. Moreover, a recent meta-analysis including six studies comparing radical antegrade modular pancreatosplenectomy (which includes Gerota's fascia) versus standard distal pancreatectomy showed no difference in recurrence rates, disease-free survival, or OS (26).

DIPLOMA is a well-performed study addressing a clinical question complicated by low disease incidence, heterogeneous biology, and subtle technical elements which make comparing ODP and MIDP exceedingly difficult. Despite its large size and multi-institutional nature, it is still at its core a retrospective cohort study. However, in utilizing propensity matching, the authors make a good-faith effort to reduce the impact of treatment allocation bias which is the most common pitfall in studies comparing open and minimally invasive approaches. MIDP most likely confers the same short-term clinical benefits (decreased pain, decreased length of stay, etc.) demonstrated across a multitude of other minimally invasive abdominal procedures. However, the oncologic benefits—or liabilities—of the approach have not been demonstrated with an acceptable level of certainty; an issue the authors suggest could be addressed with a randomized trial. Given the relatively high recurrence rates and low OS in patients with PDAC, demonstrating oncologic superiority between MIDP and ODP may be impossible, until modern systemic therapies enable these patients to live longer and facilitate distinction between these two surgical approaches.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/ls.2018.01.02
Cite this article as: Sham JG, Gage MM, He J. Minimally invasive versus open distal pancreatectomy for ductal adenocarcinoma (DIPLOMA)—a difficult question to answer. Laparosc Surg 2018;2:2.

The current role of staging laparoscopy for patients with radiographically resectable pancreatic adenocarcinoma

Yo-ichi Yamashita, Hideo Baba

Department of Gastroenterological Surgery, Graduate School of Life Sciences, Kumamoto University, Kumamoto, Japan

Correspondence to: Yo-ichi Yamashita, MD, PhD, FACS. Department of Gastroenterological Surgery, Graduate School of Life Sciences, Kumamoto University, 1-1-1 Honjo, Chuo-ku, Kumamoto 860-8556, Japan. Email: y-yama@kumamoto-u.ac.jp.

Provenance: This is an invited Editorial commissioned by Editor-in-Chief Giovanni Battista Levi Sandri (Division of General Surgery, Santa Scolatisca Hospital, Cassino, Lazio, Italy).

Comment on: Fong ZV, Alvino DML, Fernández-Del Castillo C, *et al.* Reappraisal of Staging Laparoscopy for Patients with Pancreatic Adenocarcinoma: A Contemporary Analysis of 1001 Patients. Ann Surg Oncol 2017;24:3203-11.

Received: 03 March 2018; Accepted: 12 March 2018; Published: 30 March 2018.

doi: 10.21037/ls.2018.03.01

View this article at: http://dx.doi.org/10.21037/ls.2018.03.01

We read with great interest the paper recently published in the *Annals of Surgical Oncology* entitled "*Reappraisal of Staging Laparoscopy for Patients with Pancreatic Adenocarcinoma (PDAC): A Contemporary Analysis of 1001 Patients*" written by Fong *et al.* of Harvard Medical School (1). In this study, 331 PDAC patients (33%) underwent a staging laparoscopy (SL). Unnecessary laparotomy was prevented for 44.1% of the patients during 2001–2008, and for 24% during 2009–2014. They identified 5 independent predictors for occult metastasis such as (I) male gender (OR 1.8; P<0.05); (II) preoperative resectability (borderline resectable OR 2.1; P<0.019, locally advanced OR 7.6; P<0.001); (III) CA19-9 levels higher than 394 U/L (OR 3.1; P<0.0001); (IV) no neoadjuvant chemotherapy (OR 2.7; P=0.012); and (V) pancreatic body and tail lesions (OR 1.8; P=0.063). In addition, they presented a "laparoscopic score" as follows; (1× male) + (1× borderline resectable) + (1× pancreatic body/tail lesion) + (1× no receipt of neoadjuvant chemotherapy) + (2× CA19-9 >394 U/L) + (4× locally advanced). A score cutoff at 4 based on the highest Youden index was able to predict 76.1% of occult metastasis. We honor their major and long-lasting contributions to the treatment of patients with PDAC. This study recruited the largest group of PDAC patients to undergo SL so far, and their work is clear and definite; however, I think there are several points that should be discussed further. We would like to address those points in this editorial.

First, regarding its clinical utility, SL can be applied as a minimally invasive procedure to improve the staging of PDAC. SL can prevent an unnecessary laparotomy by detecting occult metastasis. De Rosa *et al.* (2) reviewed 24 studies assessing the utility of SL for PDAC, and found sensitivities ranging from 44% to 93%, and specificities ranging from 59% to 93%. Fong *et al.* (1) demonstrated that SL could prevent an unnecessary laparotomy for 24.1% of patients with radiographically resectable PDAC. This rate represents a marked decrease from the 35% reported by the same group in 1986 (3); however, SL still prevents an unnecessary laparotomy for almost 1 in 4 patients, which is significant enough to warrant its use in contemporary times.

Needless to say, SL is less invasive than exploratory laparotomy (EL). In a review of 9 studies, Stefanidis *et al.* found that the morbidity of SL ranged from 0 to 3.7%, and mortality from 0 to 0.15% in patients with radiographically resectable PDAC (4). Studies comparing morbidity data of SL and EL are very limited. Conlon *et al.* (5) reported 0% morbidity and mortality for SL, and showed that patients who underwent SL had significantly shorter hospital stays than those undergoing EL (a median of 2 *vs.* 7 days; P<0.01); unfortunately, they did not report the morbidity of EL. In addition, the range of observation in the peritoneal space of SL would be wider than that of EL with a small incision. Washing cytology has been reported to have the important prognostic value in patients with radiographically resectable PDAC and no ascites (6), and laparoscopy would make it easier to collect washed saline during peritoneal lavage from various parts such as Douglas' pouch.

The reduced invasiveness of SL for patients with radiographically resectable PDAC should be evaluated by quality of life (QOL) after operations compared to EL. Morris *et al.* reported that SL produced significantly higher mean quality-adjusted life years (QALYs) per patient than EL (0.346 *vs.* 0.337) (7). The QALYs measure combines the length of life and QOL, and is a recommended outcome for use in economic evaluations. They also evaluated the cost-effectiveness of SL, and found that SL incurred similar mean costs per patients as EL (£7,470 *vs.* £7,480); the SL costs (£995) were offset by avoiding the cost of unnecessary laparotomy. This cost-effectiveness of SL disappeared if the SL was performed in the same admission, or in a patient with periampullary cancers. SL does add time and cost to an operation.

The Harvard group recently reported that SL not only saves patients an incision, but may also help them live longer using the same cohort (8). In that report, 151 PDAC patients (15%) had occult metastases. SL was performed in 89 patients (59%), while 62 patients (41%) underwent EL. The median overall survival (OS) for the SL group (11.4 months) was significantly longer than that for the EL group (8.3 months, P<0.001). Cox regression analysis revealed that SL was independently associated with OS (Hazard ratio 0.53, P=0.005). They attributed this survival advantage to the shorter interval for palliative chemotherapy of SL compared to EL (17.9 *vs.* 39.9 days, P<0.001). We have already reported that SL (n=14) leads to faster induction of palliative chemotherapy compared to the EL (n=10) (3 *vs.* 11 days; P=0.006) (9). The "less invasiveness" of SL would lead to a shorter interval to the starting of palliative chemotherapy, and lead to the better survival impact of SL in patients with radiographically resectable PDAC.

SL, of course, entails extra time and cost in addition to the curative surgery; therefore, we should identify which patients are not likely to have occult metastases before surgery. In short, indication criteria for SL in PDAC patients before surgery should be established. In their recent report (1), they presented a scoring index using 5 variables, and a score cutoff of 4 was able to predict 76.1% of occult metastasis. De Rosa *et al.* suggested an algorithm for selecting patients with radiographically resectable PDAC: CA19.9 ≥150 U/mL or tumor size >3 cm (2). A CA19-9 level ≥150 U/mL was chosen based the results of four large studies (10-13), which calculated cut-off values using ROC analysis. These reports presented cut-off values of 130, 150, 150, and 157 U/mL, respectively. Tumor size >3 cm was chosen based on the results from 2 studies (14,15) that showed that tumors >3 cm were significantly more likely to have occult metastases at exploration. Satoi *et al.* performed SL in patients with: CA19-9 level ≥150 U/mL; or tumor size ≥3 cm (15). They compared the frequency of unnecessary laparotomy in 16 patients (26%) selected for SL based on the above criteria, with 33 patients who underwent laparotomy prior to the SL policy. Of 16 patients, 5 patients (31%) had occult metastasis, and the frequency of unnecessary laparotomy decreased to 15%.

Alexakis *et al.* advocated that high serum CA19-9 but not tumor size should select patients for SL in radiological resectable PDAC (16). They emphasized that even small PDAC in the 2–3 cm range could have metastasis. The concept that patients with a high CA19-9 level should underwent SL to check occult metastasis before curative resection would be widely accepted but for the well-known fact that CA19-9 is undetectable in 4–15% of the population with a Lewis negative (a-, b-) phenotype (17), and is increased in the presence of obstructive jaundice (18). Thus, the scoring index (laparoscopy score) presented by Fong *et al.* (1) which includes 5 variables seems an improvement over previous systems; however, the diagnosis of "borderline resectable" and "locally advanced" sometimes has problems. These categories are clearly defined by the AHPBA/SSAT/SSO Expert Consensus Statement (19); however, actually, the definition of "resectability" for PDAC has changed over time and differs by institutions. Regardless, the clinical utility of this "laparoscopy score" should be validated using another cohort, perhaps one representing ethnic group, and be confirmed by a prospective study including a large number of patients.

The utility of SL for PDAC will decrease if imaging studies improve. The advantage of SL is its detection of small superficial liver metastasis or small peritoneal metastasis (20); therefore, improvements in contrast-enhanced F-18-fluorodeoxyglucose positron emission tomography (PET)/CT would restrict the indication for SL (21). Fong *et al.* reported a false negative rate of 4.2%, comprising mostly metastases located in the posterior segments of the liver (1). To decrease false-negative in SL for PDAC, indocyanine green fluorescence-guided imaging or laparoscopic ultrasound in SL would be a potent tool in detecting small superficial liver metastasis, small peritoneal metastasis, or deep parenchymal liver metastasis (22,23).

We honor again this major and what is likely to be a long-lasting contribution in clinical advancement for the treatment of patients with PDAC. As they say, the clinical utility of SL will change according to the advancement of imaging studies or neoadjuvant chemotherapies. However, SL still has important role, and is recommended for patients with radiographically resectable but relatively advanced PDAC, because it is difficult to detect small superficial liver metastases or small peritoneal dissemination radiographically. We should understand the merits and demerits of SL per se, and construct optimal indication criteria as soon as possible.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/ls.2018.03.01
Cite this article as: Yamashita YI, Baba H. The current role of staging laparoscopy for patients with radiographically resectable pancreatic adenocarcinoma. Laparosc Surg 2018;2:9.

Laparoscopic long sleeve pancreaticogastrostomy (LPG): a novel pancreatic anastomosis following central pancreatectomy

Long R. Jiao, Tamara M. H. Gall, Mikael H. Sodergren, Ruifang Fan

HPB Surgical Unit, Department of Surgery & Cancer, Imperial College, Hammersmith Hospital Campus, London W12 0HS, UK

Contributions: (I) Conception and design: LR Jiao; (II) Administrative support: R Fan; (III) Provision of study materials or patients: LR Jiao; (IV) Collection and assembly of data: TM Gall; (V) Data analysis and interpretation: TM Gall, R Fan, MH Sodergren; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Professor Long R. Jiao, MD, FRCS. Professor of Surgery, Chair of Hepatopancreaticobiliary Surgery, HPB Surgery, Department of Surgery & Cancer, Hammersmith Hospital, Imperial College, Du Cane Road, London W12 0HS, UK. Email: l.jiao@imperial.ac.uk.

Background: Central pancreatectomy (CP) is preferred to distal pancreatectomy (DP) for the excision of benign tumours at the neck or body of the pancreas, in order to preserve pancreatic function and the spleen. However, the pancreaticoenterostomy is technically difficult to perform laparoscopically and the postoperative pancreatic fistula (POPF) rate is high.

Methods: A novel laparoscopic reconstruction of the pancreatic stump during CP is described, the laparoscopic long sleeve pancreaticogastrostomy (LPG).

Results: Two males and two females with a median age of 49 years had a laparoscopic CP with LPG. After a median follow-up of 27.5 months, there was no mortality. One patient had a grade A POPF, managed conservatively.

Conclusions: The LPG is a safe and technically less demanding method to reconstruct pancreatic drainage laparoscopically.

Keywords: Laparoscopic pancreatic surgery; central pancreatectomy (CP); pancreatico-gastrostomy; distal pancreatectomy (DP); benign pancreatic lesions

Submitted Nov 20, 2015. Accepted for publication Dec 28, 2015.
doi: 10.21037/hbsn.2016.02.02
View this article at: http://dx.doi.org/10.21037/hbsn.2016.02.02

Introduction

Central pancreatectomy (CP) is preferred to distal pancreatectomy (DP) for patients with benign or neuroendocrine tumours located at the neck or distal body of the pancreas without vascular involvement, in order to preserve pancreatic parenchyma. Laparoscopic surgery is becoming more established in HPB surgery. However, following CP, pancreatic reconstruction of the pancreatic stump is difficult due to a soft pancreatic body and a normal, non-dilated pancreatic duct, leading to increased rates of postoperative pancreatic fistula (POPF). Conventional reconstructive techniques are either by pancreaticojejunostomy (1), with a Roux-en-Y loop anastomosis to either the end or side of the jejunum, or a pancreaticogastrostomy (PG) to the posterior wall of the stomach. For laparoscopic PJ, the formation of a Roux-en-Y loop has to be performed first before the pancreatic anastomosis, which is a technically challenging step that is also time-consuming. PG presents even further technical difficulties laparoscopically, as the pancreatic stump needs to be mobilised off the splenic vein for at least 4 cm in length before it can be safely reconstructed into the posterior wall of stomach. The latter requires an invagination of the pancreatic stump through gastrostomy in the posterior wall of stomach. It is extremely technically demanding to do this in a limited space and operative field laparoscopically.

In our centre, a novel technique has been described by a senior surgeon (Long R. Jiao), termed the laparoscopic long sleeve pancreaticogastrostomy (LPG) technique, a new laparoscopic method for reconstruction of the pancreatic

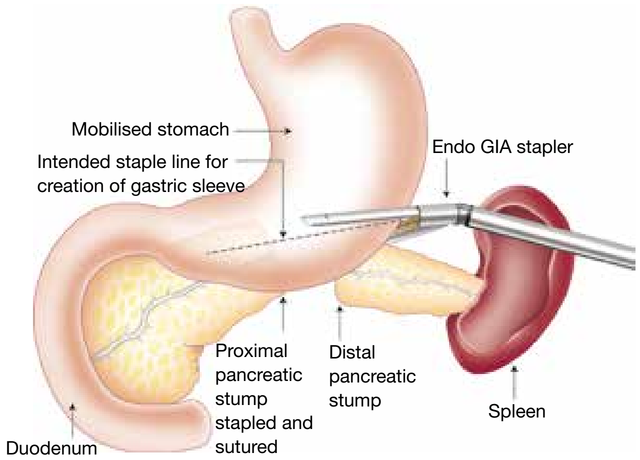

Figure 1 Schematic drawing showing the first part of the laparoscopic long sleeve pancreaticogastrostomy (LPG) technique. The central pancreatectomy has been performed and the proximal pancreatic resection margin (closest to the head of pancreas) has been created with the EndoGIA laparoscopic stapling device (45 mm, blue cartridge; Covidien, Hampshire, UK) and the pancreas oversewn with interrupted 2/0 prolene sutures. The intended staple line for the 60 mm Endo GIA (TriStaple™, tan cartridge; Covidien, Hampshire, UK), is shown to construct a long gastric sleeve measuring at least 6 cm in length.

stump during CP. It is envisaged that this technique avoids some of the technical challenges surrounding current methods of pancreatic stump anastomosis, without any increase in morbidity associated with the reconstruction. This may allow a greater proportion of surgeons to consider CP for appropriate patients.

Methods

The LPG is performed by one senior HPB surgeon (Long R. Jiao). With the patient in a Lloyd-Davies position, laparoscopic CP is carried out using a standard five port technique (one camera and 4 mm × 10 mm ports). In brief, the procedure starts with incision of the gastrocolic omentum to access the lesser sac and expose the pancreas. Following evaluation of the anatomy, an intraoperative laparoscopic ultrasound of the pancreas is performed to confirm the location of the lesion. Next, the posterior peritoneum is incised at the inferior and superior margins of the pancreas to further expose the segment of the pancreas for resection. The distal resection margin is identified, formed by the course of the superior mesenteric vein (SMV) posterior to the pancreas. Next, the splenic artery is identified superior to the pancreas and slung using a vessel loop. A tunnel is created by dissecting posterior to the pancreas over the SMV, with careful ligation of the small pancreatic veins by a combination of LigaSure (Covidien, Hampshire, UK) and LigaClips (Ethicon, Berkshire, UK). Following this, the splenic vein is identified and dissected off the posterior pancreas. The proximal transection at the neck is then carried out using an EndoGIA laparoscopic stapling device (45 mm, blue cartridge; Covidien, Hampshire, UK) and the pancreatic stump oversewn with interrupted 2/0 prolene sutures. The pancreas dissection is continued towards the tail aided by traction sutures on the pancreas. Following adequate dissection 2 cm away from the tumour, the distal resection margin at the body/tail is transected using a combination of laparoscopic scissors and cautery.

For the LPG, the pancreatic stump at body/tail is mobilized laparoscopically to free it at least 1 cm away from the splenic vein. The stomach is then brought down to measure and decide the position of LPG. A window is created at the point for gastroplasty in an avascular area of greater curvature of stomach. The gastroepiploic pedicle at this point is ligated with Hem-o-lok (Teleflex, NC, USA) and divided with laparoscopic scissors. Vertical band gastroplasty is then created with a 60mm EndoGIA stapler (TriStaple™, tan cartridge; Covidien, Hampshire, UK) over 3 cm away from the lesser gastric border to ensure gastric outlet patency (*Figure 1*). A long sleeve gastric tube measuring at least 6 cm in length in the greater curvature of stomach is then prepared and made ready for an end to end PG (*Figures 1,2*). A pancreatic stent is inserted into the pancreatic duct across the anastomosis whenever pancreatic duct is visible (*Figure 2*). A continuous running suture with 2/0 PDS is applied laparoscopically to the posterior wall and interrupted sutures to the anterior wall for an end-to-end LPG.

At the end of operation, a size 20 French Robinson drain is placed behind the anastomosis and the resected specimen is retrieved using an Endopouch specimen retrieval bag (Ethicon, Berkshire, UK), via either a Pfannenstiel incision or extension of the umbilical port incision, depending on the size of specimen.

Post-operatively patients are cared for on our hepatobiliary surgical ward with the introduction of clear fluids on day one and solid diet on day 3 as tolerated. Following discharge, patients are followed-up in the outpatient clinic 2 weeks post-operatively and then at three monthly intervals for the first year.

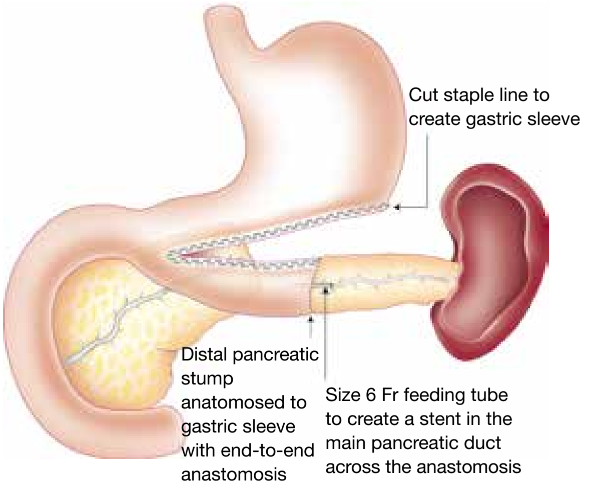

Figure 2 Schematic drawing showing the second part of the laparoscopic long sleeve pancreaticogastrostomy (LPG) technique. A stent (size 6 French infant feeding tube) is placed in the distal pancreatic duct. Next, an end-to-end anastomosis between the gastric tube and distal pancreatic stump is created with a continuous running suture with 2/0 PDS applied to the posterior wall and interrupted sutures to the anterior wall.

Results

Four patients underwent a laparoscopic CP using the LPG technique. There were 2 males and 2 females with a median age of 49 years (range, 30–65 years). All operations were completed laparoscopically with a mean operative time of 238.5±19.8 min. The length of time for reconstruction of LPG anastomosis was 37.6±7.6 min on average. Median length of stay was 5.5 days (range, 3.0–8.0 days). Final histology of these 4 cases revealed a side-branch IPMN with PanIN 2 (n=1), NET (n=1), metastatic melanoma (n=1) and MCN (n=1). Median tumour size was 23.4 mm (range, 28.3–30.0 mm). Median follow-up was 6.9 months (range, 2.0–18.0 months) with no mortality. One patient had a grade A POPF, as defined by the International Study Group on Pancreatic Fistula in 2005 (2). He had a high amylase level in the drain fluid (drained <30 mLs/24 hours), but was clinically well and was discharged with the drain *in situ* on the fifth post-operative day. The drain was removed 7 days after discharge in the outpatient clinic.

Discussion

CP was first described by Dagradi and Serio in 1984 and has since gained popularity amongst pancreatic surgeons. It has a lower risk of endocrine insufficiency and exocrine insufficiency than the alternative operation—DP (3-5). Laparoscopic central, rather than distal, pancreatectomy should be the operation of choice, when possible, for patients with benign or low-malignant pancreatic tumours at the neck or distal body of the pancreas to ensure pancreatic parenchymal and splenic preservation. However, worldwide there are few published reports on laparoscopic or robotic CP, with less than 40 cases in total and the largest series reporting only 11 cases (6-16) due to technical difficulties. We describe 4 cases of laparoscopic CP here with a novel reconstruction technique for the pancreatic stump. Laparoscopic LPG is a technically less demanding anastomosis, requiring just over half an hour of operative time in this series. There were no mortalities in our series, and one patient developed a grade A POPF, which was managed conservatively. In this case, the pancreatic duct could not be identified, nor stented intraoperatively. We have shown that the LPG technique is feasible with minimal morbidity. It may be technically easier to perform than conventional anastomotic methods. A randomized controlled trial is required to evaluate its operative outcomes, morbidity and mortality compared to current techniques.

Acknowledgements

We are grateful to Alliance Family Foundation for its support.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by institutional ethics board and informed consent was obtained from all patients.

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Cite this article as: Jiao LR, Gall TM, Sodergren MH, Fan R. Laparoscopic long sleeve pancreaticogastrostomy (LPG): a novel pancreatic anastomosis following central pancreatectomy. HepatoBiliary Surg Nutr 2016;5(3):245-248. doi: 10.21037/hbsn.2016.02.02

Laparoscopic distal pancreatectomy for adenocarcinoma: safe and reasonable?

Lauren M. Postlewait, David A. Kooby

Division of Surgical Oncology, Department of Surgery, Winship Cancer Institute, Emory University, Atlanta, GA 30322, USA

Correspondence to: David A. Kooby, MD. Division of Surgical Oncology, Winship Cancer Institute, 1365C Clifton Road NE, 2nd Floor, Atlanta, GA 30322, USA. Email: dkooby@emory.edu.

Abstract: As a result of technological advances during the past two decades, surgeons now use minimally invasive surgery (MIS) approaches to pancreatic resection more frequently, yet the role of these approaches for pancreatic ductal adenocarcinoma resections remains uncertain, given the aggressive nature of this malignancy. Although there are no controlled trials comparing MIS technique to open surgical technique, laparoscopic distal pancreatectomy for pancreatic adenocarcinoma is performed with increasing frequency. Data from retrospective studies suggest that perioperative complication profiles between open and laparoscopic distal pancreatectomy are similar, with perhaps lower blood loss and fewer wound infections in the MIS group. Concerning oncologic outcomes, there appear to be no differences in the rate of achieving negative margins or in the number of lymph nodes (LNs) resected when compared to open surgery. There are limited recurrence and survival data on laparoscopic compared to open distal pancreatectomy for pancreatic adenocarcinoma, but in the few studies that assess long term outcomes, recurrence rates and survival outcomes appear similar. Recent studies show that though laparoscopic distal pancreatectomy entails a greater operative cost, the associated shorter length of hospital stay leads to decreased overall cost compared to open procedures. Multiple new technologies are emerging to improve resection of pancreatic cancer. Robotic pancreatectomy is feasible, but there are limited data on robotic resection of pancreatic adenocarcinoma, and outcomes appear similar to laparoscopic approaches. Additionally fluorescence-guided surgery represents a new technology on the horizon that could improve oncologic outcomes after resection of pancreatic adenocarcinoma, though published data thus far are limited to animal models. Overall, MIS distal pancreatectomy appears to be a safe and reasonable approach to treating selected patients with pancreatic ductal adenocarcinoma, though additional studies of long-term oncologic outcomes are merited. We review existing data on MIS distal pancreatectomy for pancreatic ductal adenocarcinoma.

Keywords: Laparoscopy; adenocarcinoma; pancreatic neoplasm; distal pancreatectomy; outcomes

Submitted Dec 29, 2014. Accepted for publication Jan 28, 2015.
doi: 10.3978/j.issn.2078-6891.2015.034
View this article at: http://dx.doi.org/10.3978/j.issn.2078-6891.2015.034

Introduction

Pancreatic adenocarcinoma is the fourth leading cause of cancer-related mortality in men and women in the United States. In 2014, it is estimated that there will be 46,420 new cases and 39,590 deaths due to this disease (1). Surgical resection remains the only potentially curative therapy, and several randomized trials support administration of adjuvant chemotherapy or chemoradiation to improve survival outcomes (2-6). Preoperative chemotherapy with or without radiotherapy is recommended for patients with borderline resectable pancreatic adenocarcinoma, albeit no randomized data exist (7).

Distal pancreatic adenocarcinomas of the body or tail of the pancreas comprise only 20-25% of all diagnosed pancreatic adenocarcinomas (8). While more proximal periampullary tumors typically present with jaundice, malabsorption, and pancreatitis, distal tumors are usually

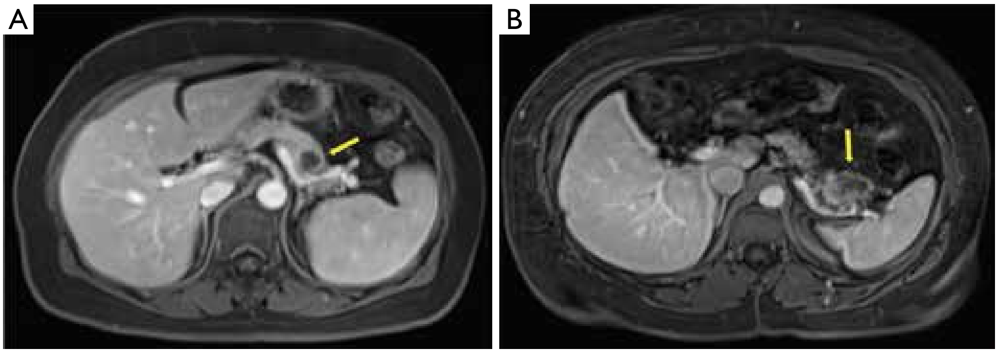

Figure 1 (A,B) Cross-sectional imaging of pancreatic adenocarcinoma of the distal pancreas.

Figure 2 Key operative steps in laparoscopic distal pancreatectomy and splencetomy for pancreatic adenocarcinoma (23).
Available online: http://www.asvide.com/articles/506

associated with vague symptoms including weight loss and abdominal pain (8); consequently, distal cancers present at later stages than proximal cancers and are more likely to be metastatic or locally unresectable at the time of diagnosis (9).

The surgical approach to pancreatic resection for adenocarcinoma is dependent on the location of the tumor along the length of the pancreas. While pancreaticoduodenectomy (Kausch-Whipple procedure) is used to treat select patients with cancers of the pancreatic head, neck, and uncinate process, the operative approach for patients with early stage pancreatic cancer of the body and tail is the distal (or left) pancreatectomy (3). *Figure 1* shows cross sectional images of pancreatic ductal adenocarcinoma requiring distal pancreatectomy. Distal pancreatectomy for adenocarcinoma is not commonly performed given the typically advanced stage of presentation of this disease. In an analysis of the Surveillance Epidemiology and End Results (SEER) database from 2003-2009, only 81 distal pancreatectomies for adenocarcinoma were performed on average each year in the United States (10), limiting the ability to study this patient population in a randomized fashion.

Over the last few decades, laparoscopic surgery has been adopted and is considered the standard approach for resection for many retroperitoneal and abdominal organs (11-15). The adoption of laparoscopic pancreatectomy by the surgical community has been slower to occur secondary to concerns of the technical difficulty and risk of complication; however, since the first series of laparoscopic distal pancreatectomies in 1996, these concerns have been addressed in multiple studies that have supported the safety and benefits of laparoscopic pancreatic surgery (16-20). This review examines patient outcomes after laparoscopic distal pancreatectomy for adenocarcinoma with a focus on the short and long term oncologic outcomes.

Surgical technique

The approaches to laparoscopic distal pancreatectomy are well described elsewhere (21,22), and key operative steps of this technique are shown in *Figure 2*. Variations of the technique will be discussed, such as: patient positioning, use of hand access ports, the role of splenic preservation, direction and extent of dissection, and role of robotics (which will be covered in a separate section). *Figure 3* shows intraoperative images of laparoscopic distal pancreatectomy for adenocarcinoma, and pancreatosplenectomy specimens are demonstrated in *Figure 4*.

Patients are typically positioned either in supine or lazy right lateral decubitus position depending on tumor location and surgeon preference. The advantages of supine position are ease of set up, clearer airway access for anesthesia, and ability to access the pancreatic head and

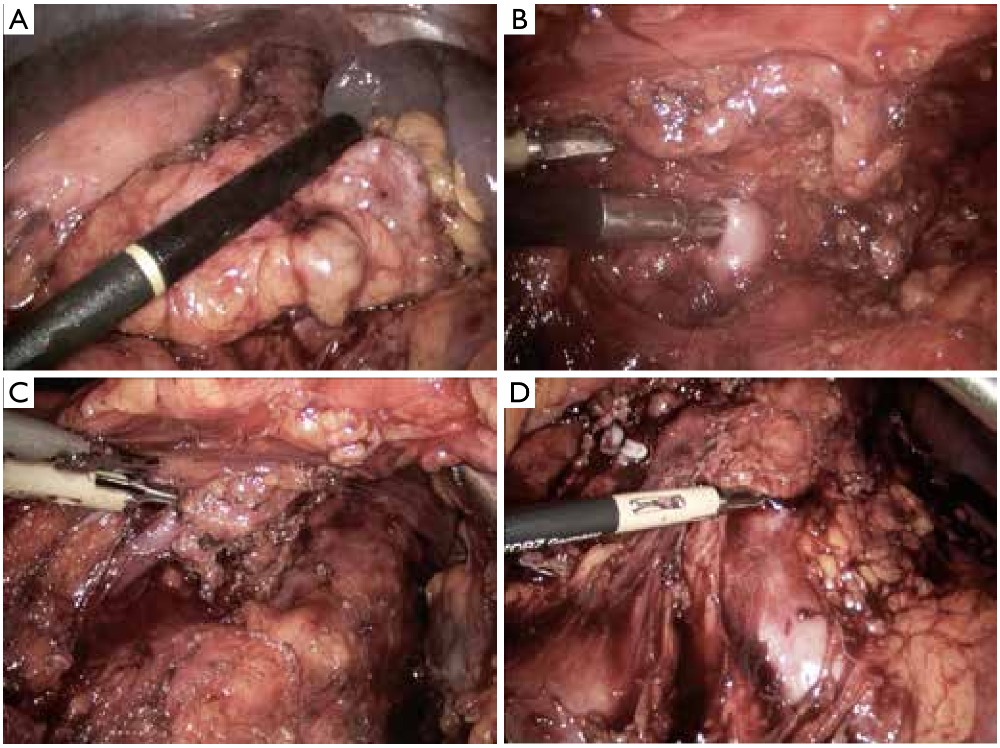

Figure 3 Intraoperative images of laparoscopic distal pancreatectomy for adenocarcinoma illustrating (A) the ultrasound probe over the pancreatic tail tumor; (B) the dissection of the splenic artery; (C) the dissection of the splenic vein; and (D) the splenic artery stump, left renal vein, and left adrenal vein after resection of the specimen.

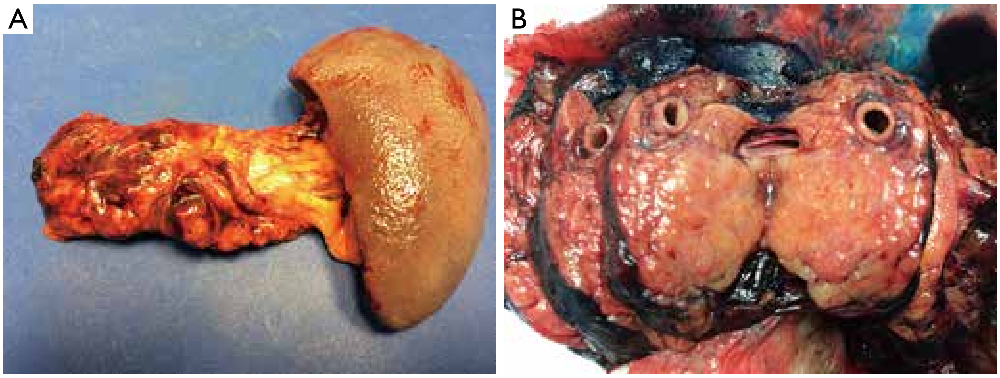

Figure 4 (A) Typical pancreatosplenectomy specimen from distal pancreatectomy for adenocarcinoma; (B) distal pancreatectomy specimen showing a section through the tumor of the pancreatic tail.

neck if necessary for tumors extending to this location. The benefits of the lateral position include gravity retraction of the stomach and spleen, more direct visualization of the body and tail of the pancreas, and superior surgeon ergonomics and comfort (24).

In the laparoscopic hand-access technique, an abdominal port is placed through which the surgeon's hand can access the peritoneal cavity during the laparoscopic procedure. Others have described the technical details of laparoscopic hand-assist distal pancreatectomy (18,25,26). Potential advantages to a hand-access approach include preserving the surgeon's ability of direct palpation of the tumor and anatomy, ease of removal of larger malignant specimens through the hand port, use of manual dissection, and opportunity to apply direct pressure in the case of bleeding. The largest comparative trial of hand access (n=61) compared to total laparoscopic (n=72) distal pancreatectomies is from the authors' institution (27). Though patients who underwent total laparoscopic procedures had shorter hospital stays (5.3±1.7 *vs.* 6.8±5.5 days; P=0.032), there was a trend that total laparoscopic procedures had higher rates of conversion to open procedure compared to hand assist (8.5% *vs.* 3.3%; P=0.21). In the same study, it was found that the hand-access approach was used less frequently in recent cases of laparoscopic distal pancreatectomy compared to earlier cases at a single intuition (25.6% *vs.* 68.1%; P<0.001) (27). Despite this temporal shift, the hand assist approach still plays an important role in more challenging cases of resection of larger tumors, tumors with increased surrounding inflammation, and in obese patients.

Another option in the laparoscopic approach to distal pancreatectomy is splenic preservation. This can be accomplished through preservation of the splenic vasculature or en bloc resection of the splenic vasculature with preservation of the short gastric vessels to supply the spleen, known as the Warshaw technique (28), although splenic function following this approach is not validated. Multiple studies have addressed the value of splenic preservation with regards to perioperative morbidity and mortality with no clear consensus on recommendations for benign disease (29-31). For patients with malignant disease, vessel-preserving splenic preservation may compromise radial resection margins, as residual pancreatic tissue likely remains following dissection; thus, splenic preservation is not recommended for these patients by the authors.

During a typical open distal pancreatectomy, surgeons mobilize the spleen and dissect under the pancreatic tail and proceed towards the pancreatic neck in a left to right direction, or lateral-to-medial approach, as the operating team is looking down on the target organ. The laparoscopic view is antero-caudal, lending itself to dissection under the gland and a medial-to-lateral approach giving the surgeon access to the splenic vessels first (24). No head to head comparison of these approaches exists.

Radical antegrade modular pancreatosplenectomy (RAMPS) represents an alternate surgical approach to distal pancreatectomy. In this procedure, first described in the context of an open approach in 2003, the surgeon performs the dissection of the pancreas from right to left taking a wider margin where possible, to include the lymphatic tissue surrounding the celiac axis, Gerota's fascia of the left kidney, and the left adrenal gland when necessary (32). In proceeding with the dissection in this manner, it was hypothesized that one could achieve an improved oncologic resection with a higher likelihood of obtaining negative tangential (mobilization) margins (89%; n=32), increased rates of R0 (microscopically negative) resections (81%; n=32), an improved N1 dissection [mean lymph node (LN) count =18], and a five-year overall survival similar to that of patients undergoing pancreaticoduodenectomy for adenocarcinoma (35.5%) (33,34). Later, the RAMPS technique was adapted for laparoscopic surgery and is an option in the laparoscopic resection of distal pancreatic adenocarcinoma (17).

As RAMPS is designed in part to improve tangential surgical margin clearance, one must consider the true value of the R0 resection, for which current data are conflicting. In a recent study comparing survival outcomes in patients who underwent RAMPS (n=38) to those who had traditional distal pancreatosplenectomies (n=54), Park *et al.* found that RAMPS was not independently associated with overall survival (HR: 1.502; 95% CI: 0.796-2.834; P=0.209) (35). Jamieson *et al.* analyzed outcomes of 148 cases of classic or pylorus-preserving pancreatoduodenectomies for pancreatic adenocarcinoma stratifying by margin status (36). Distinguishing between transection margins and tangential or mobilization margins, the study revealed that patients with R1 mobilization (tangential) margins had the same survival as patients with R0 resections (P=0.52), while R1 transection margins were independently associated with shorter survival (HR: 2.76; 95% CI: 2.12-3.91) (36). This suggested that while R0 transection margins were related to survival, the status of the mobilization margin was not; however, a meta-analysis of randomized controlled trials examining outcomes related to adjuvant therapy after pancreatic resection for pancreatic adenocarcinoma found that margin status, in general, was not an independent predictor of survival (R1: HR 1.10; 95% CI: 0.94-1.29; P=0.24) (37). Though this study challenged the value of negative resection margins, surgical doctrine currently recommends R0 resection, and the RAMPS approach can increase R0 rates.

Patient selection

In surgical planning, multiple factors must be considered in choosing candidates for laparoscopic distal pancreatectomy.

These include medical comorbidities, size of the tumor, adjacent organ involvement, and major vascular involvement. Differences between patient populations undergoing laparoscopic and open distal pancreatectomy were considered in a multi-institutional retrospective study from the Central Pancreas Consortium (CPC; representing a collaboration of academic US institutions with high volumes of pancreatic surgery) (38). In this study of patients who underwent distal pancreatectomy for all pathologies between 1999 and 2008, 439 patients underwent open-approach procedures while 254 patients had a laparoscopic procedure. There was no difference in age (>65 years: 30% *vs.* 31%; P=NS) or ASA class (>2: 54% *vs.* 49%; P=NS). Additionally, patients had similar BMIs (>27: 45% *vs.* 51%; P=NS). Open procedures were more frequently done for pancreatic adenocarcinoma (29% *vs.* 9%; P<0.001) and larger tumors (>3.5 cm: 58% *vs.* 40%; P<0.001) with longer postoperative specimens (>8.5 cm: 59% *vs.* 46%; P=0.002) and more frequent splenectomy (90% *vs.* 66%; P<0.001). For laparoscopic distal pancreatectomy, no assessed preoperative factor increased the risk of major complication or pancreatic fistula (38).

A study from the authors' institution compared patient populations undergoing laparoscopic distal pancreatectomy in the context of early experience and recent experience (27). One hundred thirty two patients over 11 years were divided into groups of 66 based on timing of resection representing the early and present experience of the institution. Eleven of these patients had pancreatic adenocarcinoma. There was no observed difference between the temporal groups in age, sex, and obesity rate. In more recent cases, patients had a higher rate of comorbidities (Charleston comorbidity score ≥3: 40.9% *vs.* 16.7%; P=0.003). There were increased tumors in the body and neck in the more recent experience (74.2% *vs.* 26.3%; P<0.001). Additionally, a trend was appreciated in increased mean size of tumors in the recent experience (4.0±2.8 *vs.* 3.3±1.5 cm; P=0.09). Despite the increase in more proximal tumors and increased comorbidities in the recent cohort undergoing laparoscopic distal pancreatectomy, there were no differences in perioperative complications rates between early and recent experience, thereby suggesting that this technique has acceptable morbidity in these higher risk patients (27).

The CPC studied patients who underwent laparoscopic distal pancreatectomy to create a risk score to predict development of post-operative complications (39). The preoperative factor that independently correlated with major complications and major pancreatic fistulas (class B or C) was increased BMI (>27: HR 3.27, 95% CI: 1.16-9.60, P<0.05; HR 6.49, 95% CI: 1.79-23.50, P<0.01). Other risk factors included length of pancreas specimen >8 cm and estimated blood loss >150 mL. The increased risk from higher BMI can be helpful in counseling patients pre-operatively (39). Conversely, Boutros *et al.* found that unselected patients undergoing laparoscopic distal pancreatectomy had similar outcomes to selected patients, implying that selection criteria for laparoscopic approach could be expanded (40).

Outcomes after laparoscopic distal pancreatectomy for adenocarcinoma

Open distal pancreatectomy has long been considered the standard approach to resection of distal pancreatic ductal adenocarcinoma with acceptable morbidity and a perioperative mortality of less than 1% (30). As advanced MIS techniques develop, a laparoscopic approach to managing pancreatic cancer is now an option. There are limited data comparing laparoscopic and open distal pancreatectomy for adenocarcinoma (*Table 1*). Here, we explore the postoperative outcomes as well as the short-term (nodes and margins) and long-term (recurrence and survival) oncologic outcomes after laparoscopic resection of distal pancreatic ductal adenocarcinoma.

Postoperative surgical outcomes of laparoscopic resection

The first studies to report postoperative outcomes after laparoscopic resections of pancreatic ductal adenocarcinoma had small samples sizes with no comparative element. In a retrospective, multi-centered European trial in 2005, 127 patients who underwent laparoscopic resection for pancreatic neoplasms were studied (19). Twenty-four patients underwent distal pancreatectomy with splenectomy, and only 3 patients had pancreatic adenocarcinoma on pathology. The conversion rate for the entire patient population was 14%, and there were no perioperative deaths. With laparoscopic distal pancreatectomy and splenectomy, the mean OR time was 195 minutes, and 27% of patients had postoperative pancreatic complications. Patients who underwent a laparoscopic procedure had shorter hospital stay compared to those where the procedure was converted to open (7 *vs.* 11 days; P<0.0021) (19). In 2006, in a single institution study of 16 patients in the US undergoing laparoscopic hand-assisted distal pancreatectomy, only one patient had adenocarcinoma. This patient had an

Table 1 Published studies comparing open with laparoscopic distal pancreatectomy for adenocarcinoma

Study	Total cases		Conversions	Mean estimated blood loss (mL)		Complication rate (%)		Peri-operative mortality (%)		Mean tumor size (cm)		Positive margin (%)		Mean number of harvested lymph nodes		Overall survival	
	Open	Lap		Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap	Open	Lap
Kooby *et al*. (41) [2010][a]	189	23	4	790*	422*	–	–	0.9	0	4.5	3.5	27	26	12.5	13.8	16 months[b,c]	16 months[b,c]
Magge *et al*. (42) [2013]	34	28	5	570*	290*	50	39	0	0	4.5	3.7	12	14	12[c]	11[c]	–	HR: 1.11 CI: 0.47-2.62
Rehman *et al*. (43) [2013]	14	8	0	650	306	42	37	0	0	3.2	2.2	14	12	14[c]	16[c]	3 year: 74%	3 year: 82%
Hu *et al*. (44) [2014]	23	11	0	150[c]	100[c]	–	–	0	0	3.1	2.8	0	0	16.1	14.8	54 months[c]	42 months[c]

[a], multi-institutional; [b], case-controlled data; [c], median value reported; –, data not available; *, P<0.05; Lap, laparoscopic.

operative time of 224 minutes with 1,250 mL of estimated blood loss. Post-operatively, the patient tolerated a general diet in 3 days and was discharged on post-operative day 4 without complication (18). Though these data suggest that laparoscopy could be performed for pancreatic adenocarcinoma resection in the distal pancreas, they fail to offer comparison between the laparoscopic approach and the standard open approach.

One of the first case-controlled comparative trials of laparoscopic versus open distal pancreatectomies was conducted in 2006 (45). In this study, 15 laparoscopic procedures were matched to 15 open procedures. Three of the 15 laparoscopic procedures were converted to open secondary to bleeding and retroperitoneal tumor adherence; these three cases represented the only pancreatic adenocarcinomas included. At that time the authors concluded that their results were unclear as to whether resection of distal pancreatic adenocarcinoma was "consistently feasible with the laparoscopic approach" (45).

In 2008 the CPC published the largest comparative trail to that date (16). This study of 667 patients who underwent distal pancreatectomy between 2002 and 2006 included 159 (24%) attempted laparoscopic resections with mixed pathologies. Twenty (13%) laparoscopic procedures were converted to open. Importantly, 150 patients had pancreatic adenocarcinoma in this study. Resections for pancreatic adenocarcinoma were performed open more frequently than laparoscopically in this population (26% *vs*. 10%; P<0.001). Cohorts were matched by age, ASA, tumor size, length of resected specimen, and pathology for open (n=200) or laparoscopic (n=142) resection. There was no difference in OR time (216 *vs*. 230 minutes; P=0.3), development of major pancreatic fistula (18% *vs*. 11%; P=0.1), major complication (17% *vs*. 10%; P=0.08), or 30-day mortality (1% *vs*. 0%; P=0.040). Open procedures had higher estimated blood loss (588 *vs*. 357 mL, P<0.01), increased wound infections (15% *vs*. 5%; P=0.004), increased need for drain placement post-operatively (15% *vs*. 6% P=0.02) and longer hospital stay (9.0 *vs*. 5.9 days; P<0.01). Laparoscopic resection was independently associated with shorter hospital stays (HR 0.33; CI: 0.19-0.56; P<0.01). From this study, it became clear that laparoscopic distal pancreatectomy is not only feasible, but it could also offer additional benefits as compared to the open approach; yet, the question of oncologic outcomes after laparoscopic resection remained (16).

Short term oncologic outcomes of laparoscopic resection

Resection margins

Though debated, one of the oncologic goals of resection in pancreatic adenocarcinoma is achieving microscopically negative margins (R0). Some small non-comparative studies have shown that laparoscopic resection can frequently achieve R0 resections for pancreatic adenocarcinoma (93-100%) (19,46,47). Multiple comparative studies have found that laparoscopic and open procedures have similar rates of R0 margins on final pathology (74-97% *vs*. 73-96%; P=NS)

(16,41,43,48). The CPC studied 212 patients with resected pancreatic adenocarcinoma and matched open (n=70) and laparoscopic (n=23) resections by age, ASA, and tumor size. They found no difference in positive margin (R1) rates (34% *vs*. 26%; P=0.61) (41). Few studies have found that laparoscopic margins are more likely to be negative than in open procedures, but DiNorcia *et al*. report in their series of distal pancreatectomies with mixed pathology that the laparoscopic approach was associated with decreased R1 resections (2.8% *vs*. 13%; P=0.01); however, the malignancies reported include neuroendocrine tumors and pancreatic adenocarcinoma. Additionally, patients who had procedures that were converted to open were analyzed in the open group, and the groups were not matched such that adverse pathologic factors that could have increased the risk of R1 margins were not considered (31).

In a study by Fernandez-Cruz *et al*., laparoscopic RAMPS for pancreatic adenocarcinoma was evaluated (17). As discussed previously, the RAMPS approach to distal pancreatectomy potentially offers increased rates of R0 resections with negative tangential margins. Of 13 attempted laparoscopic RAMPS in this study, 3 procedures were converted to open secondary to adhesions to the diaphragm and invasion of the colon. In the 10 RAMPS cases that proceeded laparoscopically, an R0 resection was achieved in 90%, whereas in the converted cases, the R0 rate was only 33%, suggesting that an R1 resection in these patients was associated with more invasive or adherent disease (17). This study does not offer comparison to the open technique. Other small studies of highly selected patients undergoing minimally invasive RAMPS for malignancy in the pancreatic tail reported R0 tangential and transectional margins in 100% of cases (49,50). Yet these patients who had R0 resections were highly selected only to include tumors that were confined to the pancreas, did not invade adjacent organs, and did not approximate the celiac axis (50). Therefore, in highly selected patient populations, MIS RAMPS can offer excellent resection margins.

LN harvest

Current data suggest that a minimum of 12 LNs should be harvested for resections of pancreatic adenocarcinoma based on single institution and SEER data (51,52). If fewer that 12 LNs are resected, the likelihood of underestimating the nodal stage becomes greater. Therefore, patients with fewer than 12 LNs resected who seemingly have N0 disease have shorter median overall survival than N0 patients with greater than 12 LNs resected secondary to occult nodal metastases (16 *vs*. 23 months; P<0.001) (52).

In the aforementioned non-comparative study of patients undergoing laparoscopic RAMPS, the mean LN harvest was 14.5 (6-20 range) for the ten laparoscopic distal pancreatectomies for pancreatic adenocarcinoma (17). Most studies comparing the number of LNs in laparoscopic and open cases found no significant differences in the number of LNs harvested (31,41,43,48,53). In a matched comparative study of distal pancreatectomies for pancreatic adenocarcinoma, the CPC found similar numbers of LNs for open compared to laparoscopic cases (12.3±8.3 *vs*. 14.0±8.6; P=0.46) (41). One single institution study of distal pancreatic resection for mixed pathology reported fewer LNs in the laparoscopic group (mean: 4 *vs*. 10; P=0.04); however, the laparoscopic cohort had fewer patients with pancreatic adenocarcinoma (4.1% *vs*. 21%; P<0.01), which could have influenced the surgeon's operative approach to nodal resection (54).

Long-term oncologic outcomes of laparoscopic resection

Few studies offer long-term data on patients after laparoscopic distal pancreatectomy for pancreatic adenocarcinoma. Below, the results from these few studies on recurrence and survival are summarized.

Data are scarce on recurrence of pancreatic adenocarcinoma after laparoscopic resection, and comparative data are limited. Most of our insights into recurrence outcomes originate from non-comparative studies. In 2005, Mabrut *et al*. conducted a multi-institutional European study of laparoscopic distal pancreatectomies that included 16 patients with a pancreatic malignancy, 4 of which were pancreatic adenocarcinoma (19). During the median 15-month follow up, 23% of patients with malignant tumors had a recurrence. Notably, no patients had evidence of trochar site recurrences (19). The following year, D'Angelica *et al*. reported a series of laparoscopic hand-assisted distal pancreatectomies, one of which was for adenocarcinoma (18). This patient presented six months post-operatively with liver metastases but no local recurrence (18). Larger comparative trials that report recurrence data are warranted.

In the study by Fernandez-Cruz of laparoscopic RAMPS, 3 of 10 patients died within a year with local recurrence and liver metastases with a median survival of 14 months (17). All patients who underwent laparoscopic RAMPS received adjuvant chemotherapy three weeks post-operatively (17). In a more recent study of patients undergoing laparoscopic distal pancreatectomy for adenocarcinoma, the median

Table 2 Cost-comparisons of open and laparoscopic distal pancreatectomies

Study	Total cases		Mean operative cost		Mean length of stay (days)		Mean total cost of care	
	Open	Lap	Open	Lap	Open	Lap	Open	Lap
Eom *et al*. (55) [2008]	167	31	–	–	13.5*	11.5*	\$3,401*	\$4,884*
Abu *et al*. (56) [2012]	16	35	£5,231*	£6,039*	11[a,*]	7[a,*]	£15,324	£10,587
Fox *et al*. (57) [2012]	76	42	\$4,510[a]	\$4,655[a]	7[a,*]	5[a,*]	\$13,656[a,*]	\$10,842[a,*]
Limongelli *et al*. (58) [2012]	29	16	€1,989*	€2,889*	8.8*	6.4*	€10,944	€9,603
Rutz *et al*. (59) [2014]	45	70	\$4,900*	\$5,756*	6	5	\$13,900	\$10,480

[a], median value reported instead of mean. –, data not available; *, P<0.05; Lap, laparoscopic.

survival after resection was 19 months (n=29) (47). In an unmatched single institution study of patients undergoing laparoscopic (n=8) or open (n=14) distal pancreatectomy for pancreatic adenocarcinoma, there was no difference in 3 year overall survival rates (82% *vs*. 74%; P=0.89) (43). The CPC reported a 16 month median survival after both laparoscopic (n=23) and open (n=70) approaches in matched cohorts (P=0.71) (41). The evidence to date suggests that the recurrence and survival outcomes of laparoscopic distal pancreatectomy for adenocarcinoma are similar to those of open procedures.

Cost outcomes

In evaluating comparative value of surgical techniques, cost must be considered. There are limited financial data on outcomes specific to pancreatic adenocarcinoma pathology after laparoscopic resection; therefore, the data on laparoscopic distal pancreatectomy including resection for all pathology are here reported and are summarized in *Table 2*.

A single institution Korean study in 2008 found that the total cost (operating room charges and hospitalization cost) for laparoscopic (n=31) distal pancreatectomies was more expensive than that of the open [167] approach (\$4,884.2±1,845.1 *vs*. \$3,401.4±1,247.5; P<0.001) (55). Subsequent studies in Britain and Italy in 2012 showed that though the operating room cost of laparoscopic distal pancreatectomy is higher than open (£6,039/€2,889 *vs*. £5,231/€1,989; P<0.05), decreased length of hospital stay after laparoscopic procedures (6.3-7 *vs*. 8.8-11 days; P<0.01) led to equivalent total hospital costs (£10,587/€9,603 *vs*. £15,324/€10,944; P=0.2) (56,58). Two recent North American studies reported that laparoscopic distal pancreatectomy was less expensive than open distal pancreatectomy in overall hospital cost (57,59). In a study from the author's institution, 115 patients who underwent uncomplicated distal pancreatectomies from 2009-2013 were assessed (laparoscopic: n=70; open: n=45) (59). Nineteen of these patients had pancreatic adenocarcinoma (laparoscopic: 16%; open: 18%). Again, the operating room cost was higher for patients undergoing laparoscopic procedures (\$5,756 *vs*. \$4,900; P=0.02), but the shorter length of stay after laparoscopy (5.2 *vs*. 7.7 days; P=0.01) led to decreased total variable costs (\$10,480 *vs*. \$13,900; P=0.06) (59). These studies show that laparoscopic distal pancreatectomy is a financially reasonable approach to resection. Future goals are aimed towards reducing intraoperative costs further.

Robotic approach to resection of distal pancreatic adenocarcinoma

Rates of robotic surgery have been increasing since its advent over a decade ago (60). Much like laparoscopic surgery initially, there are barriers to the universal adoption of this new approach including overall expense, a steep learning curve, and lack of tactile feedback to the operator. Yet, robotic surgery offers three-dimensional optics, increased freedom of motion, precision, and improved ergonomics for the surgeon (60-62). Consequently, robotic surgery is becoming widespread and versatile.

The surgical approach to robotic conventional distal pancreatectomy with splenectomy and the RAMPS procedure has been well described elsewhere (63-65). One of the first reports of robotics used in pancreatic surgery came from Italy in 2003 (66). In this study, 5 patients underwent robotic distal pancreatectomy, 3 of whom had pancreatic adenocarcinoma. The operating room time was 270 minutes. The mean length of stay was 11 days.

One patient had a complication of a pancreatic leak (20%), and there were no post-operative mortalities (66). A similar study from 2010 of 43 patients who underwent distal pancreatectomy by the same author had similar postoperative outcomes: pancreatic leak 20.9% and postoperative mortality of 1.5% (64). Choi *et al.* report on a case series of 4 patients who underwent robotic RAMPS for pancreatic adenocarcinoma in which 100% had R0 margins with a median LN count of 8.5 (range, 2-23) (65). Multiple other cases of robotic distal pancreatectomy and splenectomy have been reported (63,67-72). The results of these studies suggested that robotic distal pancreatectomy could be a feasible approach but were lacking in detailed oncologic and comparative data.

In a study comparing rates of splenic preservation in robotic distal pancreatectomy (n=20) and laparoscopic distal pancreatectomy (n=25), the success of spleen preservation was higher in the robotic group (95% *vs.* 64%, P=0.027) (68); however, in the case of pancreatic adenocarcinoma, splenic preservation is not recommended. A recent single-institution US study compared consecutive robotic resections (n=30) to an earlier cohort of laparoscopic (n=94) distal pancreatectomies (73). There were no differences in length of hospital stay, pancreatic fistula formation, rate of blood transfusion, or readmission between the two groups. The study included 27 cases of pancreatic adenocarcinoma representing 43% of the robotic and 15% of the laparoscopic patients (P<0.05). For the pancreatic adenocarcinoma cases, the rate of R1 resections was lower in the robotic group (0% *vs.* 36%; P<0.05), and the robotic procedure yielded more LNs (19 *vs.* 9; P<0.01) (73). Though this study offers promising short-term oncologic results, studies on long-term outcomes are warranted.

Data from a single institutional study suggest that robotic surgery may further shorten hospital length of stay, resulting in lower total hospital cost compared to open and laparoscopic approaches (LOS: 4 *vs.* 8 *vs.* 6 days, P<0.05; $10,588 *vs.* $16,059 *vs.* $12,986, P<0.05) (74). Though this offers insight into a single hospital's experience, it does not reflect financial outcomes universally or the monetary investment in the robotic technology and its upkeep. Further studies are needed.

Not enough data exist to evaluate the safety and long-term outcomes of robotic distal pancreatectomy for pancreatic adenocarcinoma. The robotic approach to distal pancreatectomy does offer the advantage of increasing the surgeon's ability to preserve the spleen, yet this is contraindicated in the case of pancreatic adenocarcinoma. Therefore, at this time, robotic surgery for distal pancreatic adenocarcinoma does not offer a definitive benefit.

Fluorescence-guided intraoperative tumor localization

Another emerging technology in oncologic surgery is fluorescence-guided tumor localization to aid in complete tumor resection. In this technique, tumor-specific fluorescent particles are administered to the patient that bind tumor. These particles can then be visualized or detected with an instrument, which allows surgeons to more easily distinguish between cancer cells and normal tissue during resection. In mouse models of pancreatic cancer, this technique has allowed for improved margins of resection, decreased local and distant recurrence, and longer disease-free survival after open and laparoscopic resections (75,76). In another study of a mouse model, a fluorescence-detecting device showed promise for use in the inspection of surgical margins for residual disease, which could increase rates of attaining negative margins (77). This technology could represent the next step to improving treatment of pancreatic cancer in open and laparoscopic resections.

Conclusions

Over the last two decades, laparoscopic distal pancreatectomy for pancreatic adenocarcinoma has become more common, though there are no randomized trials comparing this technique to open surgical technique. Data primarily from retrospective studies suggest that post-operative complication rates between open and laparoscopic distal pancreatectomies are similar. In exploring short-term oncologic outcomes after laparoscopic resection of distal pancreatic adenocarcinoma, there are no differences in the rate of achieving negative margins or in the number of LNs resected when compared to open surgery. There are limited recurrence and survival data on laparoscopic compared to open distal pancreatectomy for pancreatic adenocarcinoma, but in the few studies that assess long term outcomes, recurrence rates and survival outcomes appear similar; the need for randomized trials remains. Most recent studies have suggested that though laparoscopic distal pancreatectomy incurs a greater operative cost, the associated shorter length of hospital stay leads to decreased overall cost compared to open procedures.

Multiple new technologies are emerging to improve treatment of pancreatic cancer. Robotic pancreatectomy is feasible, but there are limited data on resection of pancreatic adenocarcinoma, and outcomes appear similar to laparoscopic approaches. Additionally fluorescence-guided surgery represents a new technology on the horizon that could improve oncologic outcomes after resection of pancreatic adenocarcinoma. Overall, laparoscopic distal pancreatectomy appears safe and reasonable, though additional studies of long-term oncologic outcomes are merited.

Acknowledgements

Funding: This work was funded in part by the Katz Foundation.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Postlewait LM, Kooby DA. Laparoscopic distal pancreatectomy for adenocarcinoma: safe and reasonable? J Gastrointest Oncol 2015;6(4):406-427. doi: 10.3978/j.issn.2078-6891.2015.034

Laparoscopic Roux-en-Y duodenojejunostomy for annular pancreas in adults: case report and literature review

He Cai[1,2], Xin Wang[1], Yun-Qiang Cai[1,2], Yong-Bin Li[1,2], Ling-Wei Meng[1,2], Bing Peng[1]

[1]Department of Pancreatic Surgery, West China Hospital of Sichuan University, Chengdu 610041, China; [2]Department of General Surgery, Chengdu Shangjin Nanfu Hospital, Chengdu 610041, China

Correspondence to: Bing Peng, MD, PhD. Department of Pancreatic Surgery West China Hospital, Sichuan University, No. 37, Guoxue Alley, Chengdu 610041, China. Email: 434784224@qq.com.

Abstract: Annular pancreas is in adults is a rare congenital anomaly which incidence varied from 0.005% to 0.015%. Although 33% of the cases are symptomatic, the symptoms are most commonly associated with gastric outlet obstruction. Here we presented an adult diagnosed with annular pancreas treated by laparoscopic Roux-en-Y side to side duodenojejunostomy.

Keywords: Annular pancreas; laparoscope; surgery; adult patients

Submitted Apr 24, 2018. Accepted for publication May 04, 2018.
doi: 10.21037/atm.2018.05.13
View this article at: http://dx.doi.org/10.21037/atm.2018.05.13

Introduction

Annular pancreas is a rare congenital anomaly which the second part of duodenum partially or completely surrounded by ring-like pancreatic parenchyma (1). For infants, it is usually diagnosed when the obstruction of the duodenum presents (2). But for adults, most of cases become symptomatic at ages between 20 and 50 years, and males occupied 65% of total cases (3). The diverse symptoms making its diagnosis difficult (4), usually include abdominal pain, nausea, vomiting and hematemesis (5). But modern imaging methods make it easier and more accurate, such as CT, MRI, MRCP and ERCP (6-8). However, surgery still remains necessary to confirm diagnosis and bypassing obstructed segment is strongly recommended (9). Pancreaticoduodenectomy could also been conducted when it is associated with obstructive jaundice, malignant diseases or pancreaticolithiasis (10). Laparotomy was the most widely used methods in the most published cases (11). With the development of laparoscopic instruments, minimally invasive surgery has gaining more and more popular with the benefits of less pain, shorter length of stay and rapid recovery, without compromising the efficacy (12). In this study, we presented an adult diagnosed with annular pancreas treated by laparoscopic Roux-en-Y side to side duodenojejunostomy and review the literature about annular pancreas.

Case presentation

A 27-year-old woman was referred for periodically severe episodic epigastric pain that radiated to her back without nausea, vomiting, fever and melena. It usually lasted for several hours, but could be relieved by body flexion. The patient's past medical history, family history and physical examination were unremarkable except for underweight (BMI 16 kg/m^2). Her laboratory tests were within the normal limits. Contrast enhanced CT indicated that the ring-like head of the pancreas surrounded the second part of the duodenum (*Figure 1*). Esophagogastroduodenoscopy (EGD) revealed narrowing between the second and third part of the duodenum with dilated upper part of the duodenum and food residue within the stomach, without any ulcer and neoplasm (*Figure 2*). After the initial stabilization and investigation, the laparoscopic approaches were discussed with the patient, and formal consent was obtained for laparoscopic surgery. Under general anesthesia, the patient was placed supine position with two legs apart. The first trocar (10 mm) was inserted bellow the umbilicus with the help of a Veress needle for the camera and CO_2 pneumoperitoneum with a pressure

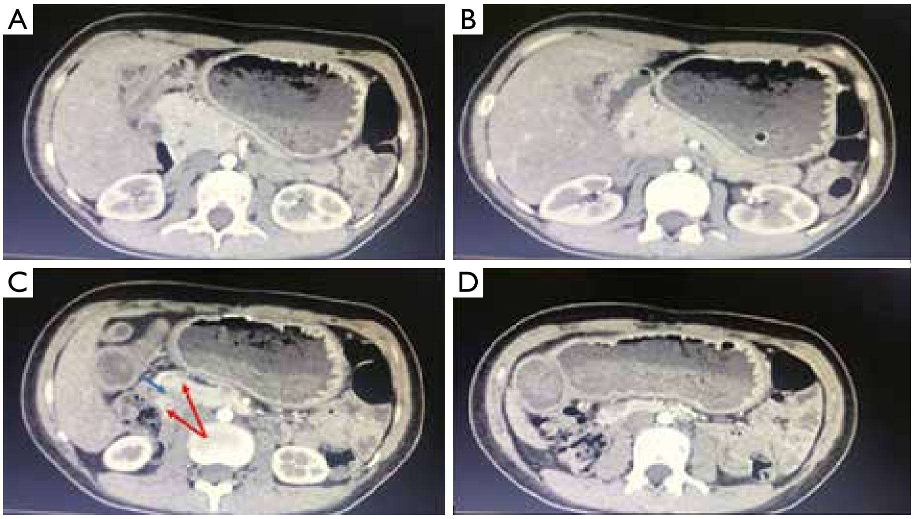

Figure 1 CT scan showing the ring-like head of the pancreas. (A) Dilated upper part of the duodenum; (B) pancreatic duct in the head of the pancreas; (C) single arrowhead: duodenum; double arrowheads: pancreas; (D) food residue within the stomach.

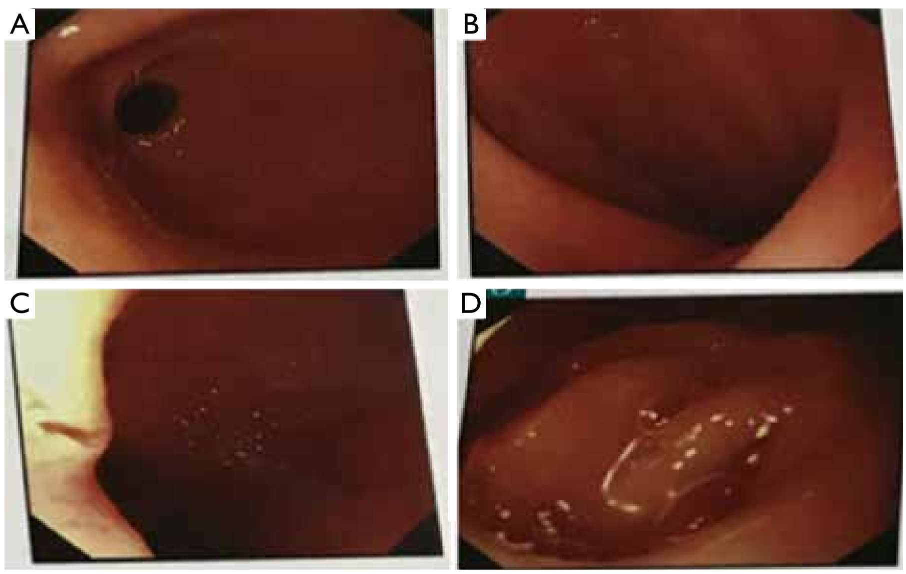

Figure 2 EGD. (A) Sinuses ventriculi; (B) dilated duodenal bulb; (C) dilated upper part of the second part of duodenum; (D) obstructive part of the duodenum. EDG, esophagogastroduodenoscopy.

of 12–14 mmHg was established, then four more trocars were inserted the same as we described history (13). Laparoscopic exploration confirmed the diagnosis of annular pancreas, the Kocher maneuver was performed to mobilization the narrowing duodenum surrounding by the head of the pancreas by using an ultrasonic dissector (*Figure 3A*). Then the proximal jejunum was transected 40cm distal to the ligament of Treitz using a linear stapler (*Figure 3B*). Another linear stapler was used to fashion the side-to-side enteroenterostomy, as it was fired between the opposing walls of the viscera (*Figure 3C*). The enterotomy was closed in 2 layers with 4-0 prolene sutures (*Figure 3D*). The area of external compression in the duodenum was bypassed by a side-to-side duodenojejunostomy with the proximal jejunum, it was begun by using 4-0 prolene sutures thread to fasten the jejunal loop to the duodenum

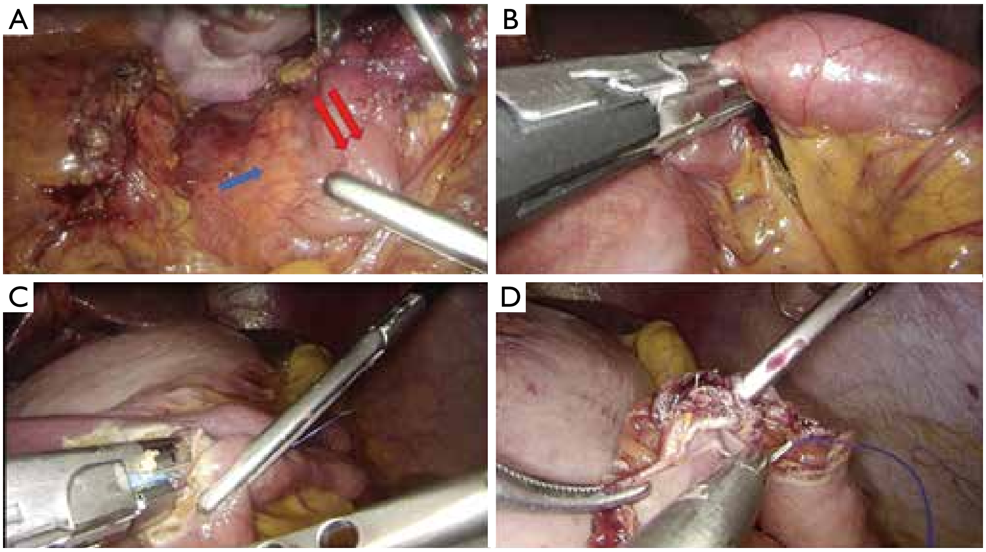

Figure 3 Exploration and enteroenterostomy. (A) Single arrowhead: pancreas; double arrowheads: duodenum; (B) transected jejunum; (C) fire the opposing walls of the viscera; (D) close the enterotomy.

with seromuscular stitches (*Figure 4A,B*). The jejunum and second duodenal portion were then opened using ultrasonic dissector (*Figure 4C*). The intestinal openings were sutured manually with a single continuous extramucous suture using 3-0 vicryl running sutures and second layer with 4-0 prolene sutures (*Figure 4D,E*). Operative time was 235 min with 50 mL blood loss. The patient made an uneventful recovery and was discharged 9 days after surgery. She remained at 29-month follow-up with better food tolerance.

Discussion

In adults, annular pancreas is an uncommon congenital condition which incidence varied from 0.005% to 0.015% (14). Most adulthood patients develop symptoms during the age of 20–50 years (15). Cases have also been reported in elder patients, which more usually associate with malignancy (16). There are many hypotheses concerning development of the annular pancreas, no clear consensus has yet been reached. Among them, two major hypotheses (Lecco's and Baldwin's theory) concerning development of the annular pancreas from the ventral pancreatic anlage were the most plausible (7). Although 33% of the cases are symptomatic, the symptoms in adult are quite variable (4), which are most commonly associated with abdominal pain and gastric outlet obstruction, secondary to duodenal stenosis (15). As the symptoms are not specific, auxiliary examination is important especially imaging studies. Ultrasonography or plain abdominal radiographs, which usually show the classic "double bubble" sign when a duodenal obstruction is present without the ability of differentiate carcinoma involving the head of the pancreas and chronic pancreatitis (17). EGD could also found gastric obstruction, peptic ulceration, and duodenal extrinsic compression. CT and MRI scan can illustrate the behavior of pancreatic tissue around the duodenum (18). MRCP and ERCP is specific in the diagnosis of annular pancreas which shows pancreatic duct (14,19). Endosonography is another useful tool for the adequate visualization of the pancreatic parenchyma (20). Despite all present diagnostic tools including ERCP diagnosis at best is made in only 60% of patients preoperatively reported by Maker in 2003 (14). Therefore, surgery is still the most accurate diagnostic maneuver (2). What's more, laparoscopic surgery is a good choice for adult patients with annular pancreas both in diagnose and treatment with less postoperative complications and a short recovery time (21).

Treatment for the symptomatic annular pancreas is still remain controversy which depends on the presentation, and in most cases the intervention will be the relief of the duodenal obstruction (14). Bypass is superior to local resection of the annular pancreas, which may cause postoperative pancreatitis, pancreatic fistula, or recurrent duodenal stenosis (22). But division may be possible in some cases of annular pancreas in the left anterior part

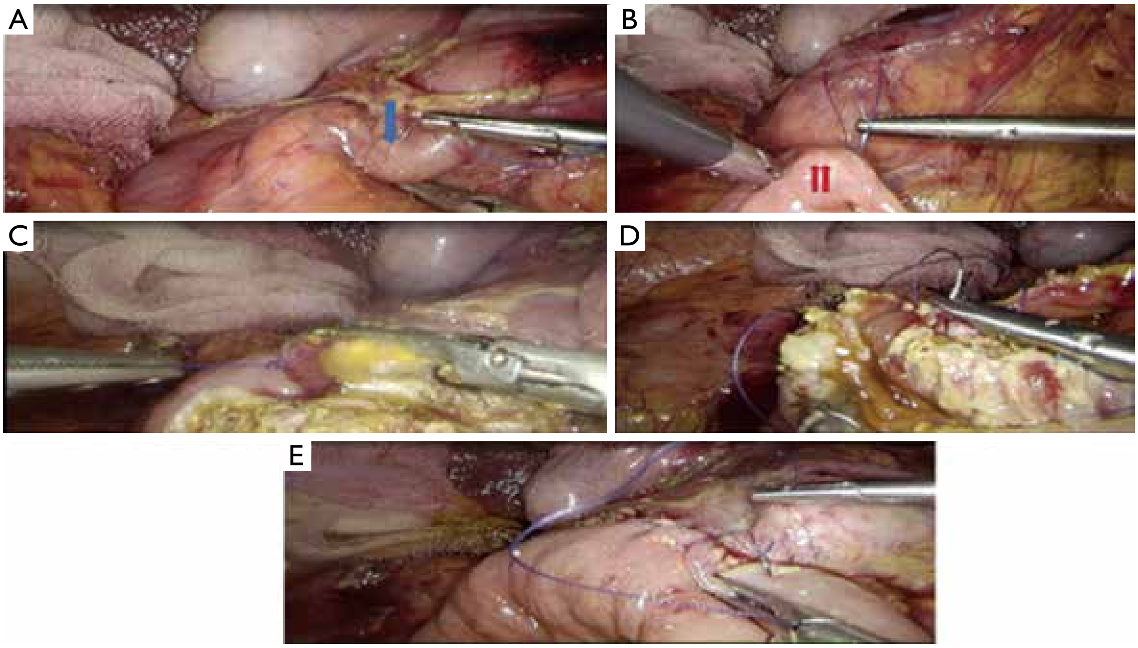

Figure 4 Duodenojejunostomy. (A) Single arrowhead: duodenum (B) double arrowheads: proximal jejunum; (C) open the jejunum; (D) suture intestinal openings; (E) sutures the second layer.

Table 1 Laparoscopic treatment for annular pancreas

Authors' name	Year	Cases	Treatment	Follow-up
De Ugarte (23)	2006	2	Laparoscopic gastrojejunostomy	Not mentioned
Chinnappan (24)	2008	1	Robotic duodenoduodenostomy	2 years
Zilberstein (25)	2011	1	Laparoscopic duodenojejunostomy	2 years
Noh (21)	2012	1	Laparoscopic gastrojejunostomy	1 year
Badiola (11)	2014	1	Laparoscopic duodenojejunostomy	2 years

without containing a duct (3). Duodenoduodenostomy or duodenojejunostomy are the procedures of choice which is better for younger patients and gastrojejunostomy is an alternative option for elder, but choice should be tailored to the patient at hand (2,9,14). In case of grossly fibrotic duodenal C-loop, gastrojejunostomy may be better choice but require an additional vagotomy as it caused more anastomotic site ulcers than duodenoduodenostomy or duodenojejunostomy (23). Laparotomy was the most widely used methods in the most published cases and less by laparoscope. Although there are no studies in which compared the two methods, we believe that laparoscopy can be safely and effectively conducted in the treatment of this disease, with the benefit of minimally invasive surgery which means less trauma and fast recovery, as were seen in cases described literature (*Table 1*). Despite all of them recovery well, none used a Roux-en-Y side to side duodenojejunostomy. In our case, we have a follow-up of more than 2 years, the patient is feeling well and gains weight without any symptoms.

In summary, we think that laparoscopic duodenal bypass is a minimally invasive choice for annular pancreas in adults with less pain and fast recovery meanwhile giving the surgeon enhanced visualization but more complex suturing. It can be argued that this study had limitations, case report, data from only a single center, and a not very long follow-up. Thus, more control studies from multiple centers are needed to support our conclusions.

Acknowledgements

Funding: This work was supported by the National Institutes of Health of China [grant number W2017ZWS07].

Footnote

Conflict of Interest: The authors have no conflicts of interest to declare.

Informed Consent: Informed consent was obtained from the patient and her husband included in the study.

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Cite this article as: Cai H, Wang X, Cai YQ, Li YB, Meng LW, Peng B. Laparoscopic Roux-en-Y duodenojejunostomy for annular pancreas in adults: case report and literature review. Ann Transl Med 2018;6(11):211. doi: 10.21037/atm.2018.05.13

It is feasible to perform laparoscopic pancreaticoduodenectomy for patients with prior abdominal operation

Yunqiang Cai[1,2], Junfeng Wang[3], Xin Wang[1], Yongbin Li[2], Pan Gao[2], Bing Peng[1]

[1]Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, China; [2]Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, China; [3]Department of Hepatobiliary Surgery, The First People's Hospital of Yunnan Province, Kunhua Hospital Affiliated to Kunming University of Science and Technology, Kunming 650032, China

Contributions: (I) Conception and design: Y Cai, J Wang, B Peng; (II) Administrative support: B Peng; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: Y Cai, J Wang, B Peng; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Bing Peng. No 37, Guo Xue Alley, Chengdu, Sichuan, 610041, China. Email: liu745588@163.com.

Background: A history of intra-abdominal surgery is a relative contraindication for laparoscopic surgery. The safety and feasibility of laparoscopic pancreaticoduodenectomy (LPD) in patients with previous upper abdominal operation (PUAO) are uncertain.

Methods: We performed 282 LPD cases from November 2010 to May 2017. A cohort of 84 patients was matched in terms of age, gender, body mass index, American Society of Anesthesiology, tumor size, tumor location, and histopathologic diagnosis (group 1 consisting of 42 cases with PUAO and group 2 comprising 42 cases without PUAO). Data were collected and analyzed retrospectively in terms of demographic characteristics, intraoperative variables, and postoperative variables.

Results: Only one patient in group 1 required to convert to hand-assisted surgery due to massive adhesion. No 30-day mortality was reported in both groups. The mean time for adhesiolysis in group 1 was 16 min, but the total operative time (392±41 *vs.* 385±33 min, P=0.217) and the estimated blood loss (147±32 *vs.* 162±43 mL, P=0.142) was comparable between the two groups. No statistical difference was observed between the groups in terms of complications and postoperative hospital stay.

Conclusions: LPD can be safely performed in patients with PUAO. PUAO should not be regarded as a contraindication for LPD.

Keywords: Laparoscopic; pancreatectomy; pancreaticoduodenectomy; previous abdominal operation; adhesion

Submitted May 04, 2018. Accepted for publication May 16, 2018.
doi: 10.21037/tcr.2018.05.27
View this article at: http://dx.doi.org/10.21037/tcr.2018.05.27

Introduction

Intra-abdominal surgeries may induce scarring and bowel adhesions to the abdominal wall. Approximately 30–50% of severe complications associated with laparoscopic surgery may occur during surgical access, and a major risk factor is previous upper abdominal operation (PUAO) (1). A history of intra-abdominal surgery has been reported to be a relative contraindication for laparoscopic surgery (2). However, rapid developments in technological innovations, improvements in surgical skills, and accumulated operative experience have expanded the indications for laparoscopic surgeries. Some surgeons began to perform laparoscopic surgeries in patients who previously underwent abdominal operations (2-6). Performing laparoscopic surgery in these patients is safe, although this procedure is associated with an increased risk of operative complications, a high conversion rate, and a prolonged operating time (5,6).

Pancreatectomy is a kind of highly specialized operation, and laparoscopic pancreaticoduodenectomy (LPD) is one of the most challenging laparoscopic pancreatic operations (7). Adhesion caused by previous abdominal surgery causes complications during surgical access and considerably increases the difficulty in performing dissections and reconstructions during LPD. To our knowledge, this is the first study to comparatively assess the feasibility of LPD in patients who underwent PUAO.

Methods

We performed 282 LPD cases, including 42 cases with PUAO (group 1), from November 2010 to May 2017. A cohort of 84 patients was matched in terms of age, gender, body mass index, American Society of Anesthesiology, and histopathologic diagnosis [42 cases without PUAO (group 2)]. All of the surgeries were performed by a single surgeon, and data were collected and analyzed retrospectively in terms of demographic characteristics, intraoperative variables (operation time, estimated blood loss, and conversion rate), postoperative variables (postoperative hospital stay and complications). Written consent was obtained from the patients enrolled in this study, and this work was permitted by the Ethics Committee of Sichuan University.

Operative procedures

All of the patients were given general anesthesia and placed in a supine position with legs apart and a 20° head-up tilt. Generally, five trocars were used. A 12 mm trocar was placed at the lower umbilicus for a 10 mm 30° camera. Two 12 mm main manipulating trocars were placed at the bilateral medioclavicular line 1–2 cm above the umbilical level. Two 5 mm trocars were placed at the bilateral anterior axillary line subcostally. At the beginning of all operations, a full laparoscopic abdominal exploration was performed to exclude liver metastases and abdominal dissemination. A window in the gastrocolic ligament was created and enlarged to reveal the entire pancreas by using a harmonic scalpel (Ethicon Endo-surgery, Cincinnati, OH, USA). An extended mobilization of the hepatic flexure of the colon was carried out, and an extended Kocher maneuver was performed to expose the inferior vena cava and the aorta. The right gastroepiploic vein and artery were then dissected and transected. The superior mesenteric vein (SMV) was identified at the lower edge of the pancreas, and a tunnel was created between the posterior wall of the pancreas and the SMV/portal vein. After the vessels of the smaller curvature of the stomach were dissected, the distal one-third of the stomach or the duodenum [in the case of laparoscopic pylorus-preserving pancreaticoduodenectomy (LPPPD)] was transected by using a 60 mm endoscopic linear cutting stapler (Ethicon Endo-Surgery). Cholecystectomy was performed, and the common bile duct at the confluence of the hepatic ducts and the pancreas neck were transected with an ultrasonic scalpel. The jejunum was transected approximately 15 cm to Treitz's ligament by utilizing an endoscopic linear cutting stapler. The mesentery of the uncinate process was completely dissected, and standard lymphadenectomy was carried out. The specimen was placed in a retrieval bag and retrieved from a 4 cm incision around the umbilicus. The proximal jejunal stump was delivered through a window in the transverse mesocolon. The digestive tract was reconstructed in the following order: pancreaticojejunostomy, hepaticojejunostomy, and gastrojejunostomy. Pancreaticojejunostomy was conducted with an end-to-side and duct-to-mucosa running suture with an internal intent. An end-to-side hepaticojejunostomy was carried out with a 4-0 monofilament absorbable running suture. Side-to-side gastrojejunostomy was conducted with an endoscopic linear cutting stapler. In LPPPD cases, the end-to-side duodenojejunostomy was performed with 3-0 monofilament absorbable suture lines. Three prophylactic drainages were placed near pancreatic anastomosis and hepaticojejunostomy.

We adopted the policy of attempting laparoscopic surgery for all of the patients with PUAOs. The initial access to the abdominal cavity was around the umbilicus in all of the cases either by a blind or open technique. For patients with previous supraumbilical intraperitoneal operations, the first trocar was placed at least 3 cm away from the previous incision to avoid organ injury. The distributions of the trocars were slightly adjusted on the basis of the adhesions between the intestinal tracts and the abdominal wall. Once the surgeon reached the peritoneal cavity, adhesiolysis was adequately carried out to expose the operative field and establish the accurate definition of the anatomy. The remaining operative procedures were the same as those for patients without PUAOs.

Definitions

Operative time was defined as the time from the first skin incision to the skin closure. Overall morbidity was described as any complication associated with the operation within 30 days of surgery. Pancreatic fistula was graded A–C as defined by the International Study Group on Pancreatic Fistula (8). Delayed gastric emptying after

Table 1 Demographic characteristics of patients

Variables	Group 1	Group 2	P value
Cases	42	42	–
Age (years)	61.2±6.3	62.5±5.8	NS
Sex (male/female)	18/24	18/24	NS
Body mass index (kg/m^2)	21.4±1.7	22.3±1.5	NS
Histopathologic diagnosis			NS
Ampullary adenocarcinoma	14	14	
Cholangiocarcinoma	9	9	
Pancreatic ductal adenocarcinoma	5	5	
Duodenal adenoma	3	3	
Cystadenoma	4	4	
P-NET	5	5	
SPT	2	2	
Prior upper abdominal operation			
Open cholecystectomy	11	–	
Laparoscopic cholecystectomy	14	–	
Common bile duct exploration	7	–	
Laparotomy and enterolisis	3	–	
Repair of gastric perforation	3	–	
Subtotal gastrectomy	1	–	
Cholangiojejunostomy	2	–	
Drainage of abdominal abscess	1	–	

P-NET, pancreatic neuroendocrine tumor; SPT, solid pseudopapillary tumor; NS, not significant; group 1, with PUAO; group 2 ,without PUAO.

pancreatic surgery was defined by the International Study Group of Pancreatic Surgery (9). Length of hospital stay was calculated from the day of surgery through the day of discharge.

Statistical analysis

Numerical data were expressed as mean ± standard deviation. Statistical analyses were performed using SPSS 16.0 for Windows. Differences between variables were compared using Student's *t*-test, chi-square test, or Fisher's exact test. Data were considered significant at P<0.05.

Results

Table 1 shows the demographic characteristics of the patients included in this study. The mean age of the patients in the group 1 was 61.2±6.3 years. The most frequent indication for surgery was ampullary adenocarcinoma, followed by cholangiocarcinoma and pancreatic ductal adenocarcinoma. The most common type of PUAO was laparoscopic cholecystectomy (14 cases) followed by open cholecystectomy (11 cases) and common bile duct exploration (7 cases). Three patients with previous abdominal surgery suffered from the adhesive ileus and underwent open enterolisis. Three patients who suffered from gastric perforation received an open repair of gastric perforation. One patient with refractory duodenal ulcer was treated with open subtotal gastrectomy. Two patients were subjected to cholangiojejunostomy for choledochal cyst and common bile duct stones, respectively. One patient with abdominal abscess was performed with open

Table 2 Operative outcomes and post-operative details

Variables	Group 1	Group 2	P value
Cases	42	42	–
Total operative times (min)	392±41	385±33	NS
Time for adhesiolysis (min)	16±5	–	
Estimated blood loss (mL)	147±32	162±43	NS
Conversion	1 (2.4%)	0	NS
Transfusion	0	0	NS
Time to passage of flatus (days)	2.8±1.1	2.7±1.1	NS
Post-operative hospital stay (days)	9.8±1.8	9.5±1.1	NS
30-days mortality	0	0	NS
Complications			
Complications associated with trocar placement	0	0	NS
Intestinal injury during adhesiolysis	1 (2.4%)	0	NS
Pancreatic fistula			NS
Grade A	6 (14.3%)	6 (14.3%)	
Grade B	1 (2.4%)	1 (2.4%)	
Grade C	0	1 (2.4%)	
Biliary leakage	1 (2.4%)	0	NS
Post-operative bleeding	0	0	–
Delayed gastric emptying	3 (7.1%)	4 (9.5%)	NS
Abdominal fluid collection	1 (2.4%)	0	NS

NS, not significant; group 1, with PUAO; group 2 ,without PUAO.

drainage of abscess. Overall, 16 patients underwent previous laparoscopic surgery, and 26 patients received previous open surgery. Furthermore, 34 patients underwent previous abdominal surgery once, 6 patients received prior abdominal surgeries twice, and 2 patients underwent prior abdominal surgery thrice. The patients in the two groups were well matched in terms of age, gender, body mass index, tumor size, tumor location, and histopathologic diagnosis.

The operative outcomes and postoperative details are shown in *Table 2*. One patient in the group 1 was converted to hand-assisted surgery because of extensive adhesion between the patient's small intestines caused by abdominal abscess. The mean time for adhesiolysis in the group 1 was 16 min, but the total operative time was comparable between the two groups (392±41 *vs.* 385±33 min, P=0.217). The estimated blood loss was also comparable between the two groups (147±32 *vs.* 162±43 mL, P=0.142). No patient in both groups required blood transfusion. No statistical difference was observed between the two groups in terms of mean time to the first passage of flatus and postoperative hospital stay. Moreover, no 30-day mortality was reported in both groups. We used an open technique to insert the first trocar in the high-risk patients who were suspected to suffer from extensive adhesion. No complication occurred during the first trocar placement in our series. One patient was injured in the small intestine during adhesiolysis, and the injury needed repair. This patient was discharged on the ninth postoperative day uneventfully. Seven patients in group 1 suffered from pancreatic fistula. Of these patients, six cases of grade A and one case of grade B pancreatic fistula were included. One patient suffered from biliary fistula and three patients experienced delayed gastric emptying. These patients were cured with conservative treatment. One patient suffered from abdominal fluid collection, which required percutaneous drainage. The overall complications were comparable between the two groups.

Discussion

Laparoscopic surgery is associated with less invasiveness, short recovery time, reduced morbidity, and enhanced cosmetic results. This procedure has been widely accepted as an alternative to conventional open surgery in many gastrointestinal fields, including left-sided pancreatic resections. In 1994, Gagner *et al.* (10) reported that LPD is associated with long operative time, lack of apparent advantages, and advanced laparoscopic skills. With the development of operative instruments and the accumulation of operative experience, many studies have reported that LPD is safe and feasible compared to open surgery.

PUAO is associated with difficulty in inserting the first trocar and obtaining adequate exposure of the operating field. Moreover, PUAO increases the risk of injury of organs adherent to the abdominal wall during trocar insertion and adhesiolysis. Few retrospective studies have explored the safety and feasibility of laparoscopic surgery in patients with PUAO. Diez *et al.* (11) performed 411 cases of laparoscopic cholecystectomy in patients with previous infraumbilical intraperitoneal surgery. No morbidity caused by trocars or adhesiolysis was reported in their study. They concluded that previous abdominal operations are not contraindications for laparoscopic cholecystectomy. Karayiannakis *et al.* (2) also performed 473 cases of laparoscopic cholecystectomy to patients with previous abdominal surgery and concluded that previous upper abdominal surgery is associated with the need for adhesiolysis, increased open conversion rate, and prolonged operating time. Tsunoda *et al.* (12) performed 22 cases of laparoscopic gastrectomy to patients who underwent upper abdominal surgery and concluded that this procedure is safe and feasible and that PUAO should not be regarded as a contraindication for laparoscopic gastrectomy. In comparison with these laparoscopic surgeries, LPD is associated with considerably complex organ dissections, necessity for rigorous adhesiolysis for explicit anatomy, and complicated alimentary tract reconstructions, resulting in a prolonged operative time and increased operative morbidity. However, the safety and feasibility of LPD for patients who have undergone PUAO remain unclear. In this study, the average duration for adhesiolysis was 16 min, but the average operative time was comparable between the two groups. No significant difference was observed between the two groups in terms of estimated blood loss, transfusion rate, conversion rate, and complications.

Of note, the first trocar should be placed safely. Intestinal injury could happen during the placement of the first trocar. We found that blindly placing the Veress needle and the first trocar 3 cm away from the abdominal scar could be safe. However, we implemented an open technique to insert the first trocar in high-risk patients who were suspected to suffer from extensive adhesion. No complications associated with the insertion of the Veress needle or any of the trocars were reported in our series. Once the surgeon reached the peritoneal cavity, adhesiolysis was performed carefully by using an ultrasonic dissector or electrocautery scissors. Technically, adhesiolysis can be performed easily after the creation of a pneumoperitoneum, which elevates the abdominal wall to provide an enhanced dissection plane for laparoscopy (12).

With the lack of tactile sensation, further attention should be given to the aberrant hepatic artery. We performed computed tomography angiography for each patient to identify vessel variation. For patients who underwent a previous surgery associated with the hepatoduodenal ligament, we should avoid causing hepatic artery injury during adhesiolysis, especially in patients with aberrant hepatic artery. We conducted electrocautery to reveal the anatomy of hepatic artery and its branches. With three anastomoses, rigorous adhesiolysis is required for the explicit anatomy of the small intestine. In our series, we performed two cases of LPD with previous Roux-en-Y cholangiojejunostomy. We dismantled the previous anastomosis and dissected the jejunum between bilioenteric anastomosis and jejunal anastomosis. However, identifying the right anatomy was technically challenging. In such cases, Treitz's ligament is a hallmark used to find previous jejunal anastomosis and distal jejunum. One patient was required to convert to hand-assisted surgery because of extensive adhesion between the small intestines caused by abdominal abscess.

Our study had several important limitations. First, our study was retrospective. Potential selection bias in matched pair analysis could not be easily ruled out. Second, our study reported short-term outcomes, and long-term outcomes are unavailable.

Conclusions

LPD can be safely and feasibly applied to patients with

PUAO. PUAO should not be regarded as a contraindication for LPD. We recommend that a policy to attempt laparoscopic surgery should be adopted for all patients, including those who underwent previous complicated upper abdominal operations.

Acknowledgements

Funding: This study was funding by National Institutes of Health of China (W2017ZWS07).

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: Written consent was obtained from the patients enrolled in this study, and this work was permitted by the Ethics Committee of Sichuan University.

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Cite this article as: Cai Y, Wang J, Wang X, Li Y, Gao P, Peng B. It is feasible to perform laparoscopic pancreaticoduodenectomy for patients with prior abdominal operation. Transl Cancer Res 2018;7(3):645-650. doi: 10.21037/tcr.2018.05.27

Laparoscopic pancreaticoduodenectomy with major venous resection and reconstruction with repassed round ligament: a case report

Yunqiang Cai[1,2], Yongbin Li[2], Pan Gao[2], Xin Wang[1], Bing Peng[1]

[1]Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, China; [2]Department of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, China

Correspondence to: Bing Peng, MD. No. 37, Guo Xue Alley, Chengdu 610041, China. Email: liu745588@163.com.

Abstract: It is technical challenging to perform laparoscopic pancreaticoduodenectomy (LPD) with major venous resection. Herein, we reported the first case of LPD with major venous resection and reconstruction with repassed round ligament. Between November 2015 and January 2018, a total of 35 LPD with major venous resection were performed in our department; however, only one patient underwent LPD with major venous resection and reconstruction with repassed round ligament. The patient suffered from pancreatic ductal adenocarcinoma with superior mesenteric vein and portal vein (SMV/PV) involvement. The operative time was 450 min and intra-operative blood loss was 200 mL. The duration of blood occlusion time was 48 min. No blood transfusion was required. The post-operative pathological examination showed that the pancreatic mass was pancreatic duct adenocarcinoma, and all the margins were negative. The post-operative period was uneventful. The patient was discharged on postoperative day 15. It is safe and feasible to perform LPD with major venous resection and reconstruction with repassed round ligament. However, long-term patency of repassed round ligament for venous reconstruction required further investigation.

Keywords: Minimally invasive surgery; pancreaticoduodenectomy; venous resection; round ligament

Submitted Apr 30, 2018. Accepted for publication May 10, 2018.
doi: 10.21037/atm.2018.05.33
View this article at: http://dx.doi.org/10.21037/atm.2018.05.33

Introduction

Open pancreaticoduodenectomy (OPD) with major vascular resection and reconstruction has been shown in many studies to have short-term and long-term outcomes that are similar to those of patients undergoing a pure pancreaticoduodenectomy without venous resection (1,2). However, it is technical challenging to perform laparoscopic pancreaticoduodenectomy (LPD) with major venous resection, especially in cases with long segment vascular resection. Several small series have shown that LPD with major venous resection is safe and feasible in high-specialized minimal invasive pancreatic centers (3,4). Herein, we reported a case of LPD with major venous resection and reconstruction with repassed round ligament.

Case presentation

A 62-year-old female patient complaining of upper abdominal pain for one month admitted in our institution. She had no comorbid illness or cholangitis. Her BMI was 23.1 kg/m^2, total serum bilirubin was 19.8 umol/L, and direct bilirubin was 6.3 mg/dL. The carbohydrate antigen 19-9 was 9.07 U/mL, and carcinoembryonic antigen was 4.18 ng/mL. The contrast-enhanced computed tomography showed a 2.8 cm × 3.0 cm low-density mass in the head of the pancreas with superior mesenteric vein/portal vein (SMV/PV) involvement and without artery involvement (*Figure 1A*). Computed tomography angiography (CTA) showed that the length of venous involvement was 4 cm (*Figure 1B*).

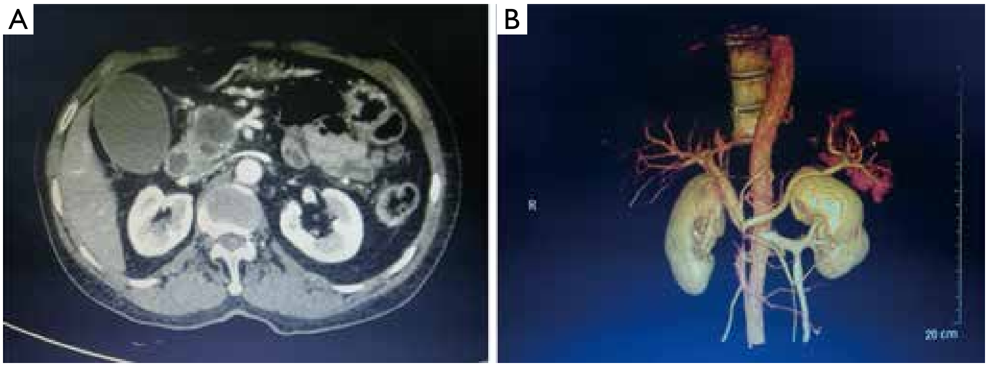

Figure 1 Preoperative CT images of patients. (A) Contrast-enhanced CT showing the mass in the pancreatic head involved the superior mesenteric vein. (B) CT angiography showing the length of venous involving was approximate 4 cm.

Figure 2 A suction tube was inserted into the round ligament confirm its patency.

Operative procedure

The patient was placed in the supine position with legs apart. Pneumoperitoneum was created using a Veress needle and maintained in 13 mmHg during the operation. Five trocars were used. One 10-mm umbilical trocar for the laparoscope port, two 12-mm trocars located at the right and left flank of rectus abdominis, and one 12-mm trocar and one 5-mm trocar distributed at the left and right midclavicular. The operation began with full exploration of the whole abdominal cavity. The great omentum was dissected with ultrasonic scalpel. Then we fully took down the hepatic flexure of the colon and the mesentery of the transverse colon to expose the head of pancreas and the horizontal part of the duodenum. A wide Kocher maneuver was performed to ensure that the tumor did not involve the inferior cava, left renal vein, celiac trunk, aorta, and superior mesenteric artery (SMA). SMV was recognized at the lower edge of the pancreas and hanged with a rubber band. As the anterior wall of SMV was involved by the tumor, we did not create the post-pancreatic tunnel. We removed the No. 8a lymph node and showed the common hepatic artery, gastroduodenal artery and hepatic artery. The gastroduodenal artery was double clipped with hem-o-lock and transected with scissors. We transected the duodenum approximate 2 cm away from pylorus with endoscopic liner stapler. Then we dissected the gallbladder and transected the common hepatic duct. The proximal stump of the common hepatic duct was clipped by an endoscopic bull-dog clips to prevent bile juice pollution. The PV was identified and hanged with rubber band. The jejunum was transected using the endoscopic stapler at a site 15 cm from the Treitz ligament. We transected the pancreas approximate 1 cm away from pancreatic neck and the main pancreatic duct was identified and transected with scissors. The splenic vein was transected with endoscopic stapler. We retracted the SMV/PV axis along with the pancreatic head to the right and obtained a favorable exposure of the SMA/celiac trunk axis. The right semicircular dissection of all soft connective tissues surrounding the SMA was performed.

After the uncinate process was completely dissected and the lymphadenectomy was performed, we dissected the round ligament as long of a segment as possible. The round ligament was put into a petri dish containing normal saline with the addition of a small amount of heparin. The surrounding fat tissue of round ligament was roughly separated. A long mosquito clamp was gently inserted via a route with less resistance to repass the round ligament. The patency of repassed round ligament was confirmed by a suction tube (*Figure 2*).

Figure 3 The completion of the venous reconstruction.

Figure 4 The gross specimen showing the tumor involved the SMV/PV. SMV/PV, superior mesenteric vein/portal vein.

Figure 5 Postoperative CTA showed the patency of reconstructed vein. CTA, computed tomography angiography.

The SMV and PV were occluded using laparoscopic bulldog clips and transected with scissor. Vascular reconstruction was performed with 5-0 prolene. We firstly performed anastomosis of SMV with round ligament. The anastomosis started from posterior wall and followed by anterior wall in a continuous suturing. Then we performed anastomosis of PV with round ligament in the same fashion (*Figure 3*). Blood flow patency was ascertained by intra-operative laparoscopic color Doppler.

Then we performed duct-to-mucosa pancreaticojejunostomy, end-to-side hepaticojejunostomy and end-to-side duodenojejunostomy laparoscopically.

Intra-operative and post-operative outcomes

The Operative time was 450 min and intra-operative blood loss was 200 mL. The duration of blood occlusion time was 48 min. No blood transfusion was required. The number of lymph node harvested was 17. The specimen was shown in *Figure 4*. The post-operative pathological examination showed that the pancreatic mass was pancreatic duct adenocarcinoma, and all the margins were negative. The tumor involved the whole layer of the SMV/PV. Post-operatively, the patient received low-molecular heparin therapy (2,500 IU/day for 7 days). We performed CTA for the patient on the post-operative day 5 (*Figure 5*). The CTA confirmed the patency of the anastomosis of blood vessels. The post-operative period was uneventful. The patient was discharged on postoperative day 15.

Discussion

In OPD, venous reconstruction has been performed with end-to-end anastomosis or using various grafts including artificial grafts, autologous veins, and the parietal peritoneum (5). However, the most common graft used in LPD was artificial graft (4,6). LPD was firstly reported by Gagner and Pomp in 1994 (7). Compared with OPD, LPD could provide several advantages, such as lower blood loss, shorter lengths of stay in the intensive care unit or hospital, and fewer complications (8). However, it is technical challenging to perform LPD with major venous resection and reconstruction. Only a few retrospective small series and several case reports were available in the literature. Kendrick *et al.* reported a case of LPD with venous reconstructed using autologous left renal vein (3). Dokmak reported a case of LPD with venous reconstructed using with the parietal peritoneum (9).

We have performed 35 cases of LPD with major venous resection and reconstruction in our institution. To date, we reported the first case of LPD with major venous resection and reconstruction with repassed round ligament. Takahashi *et al.* reported eleven patients who underwent venous wedge resection and patch repair using the repermeabilized umbilical vein of the round ligament (10). Compared with autologous veins, a round ligament could be obtained without any further exploration or any greater risk for the patient. Furthermore, a round ligament could be harvested rapidly with no limitation in length. The diameter of repassed round ligament is approximately 1 cm, which is perfect to perform anastomosis with SMV and PV. Compared with artificial graft, long-term therapeutic anticoagulation is not essential and the theoretical risk of infection is very low. The peri-operative and short-term outcomes of this patient were favorable. However, the long-term patency of repassed round ligament required further investigation.

Conclusions

It is safe and feasible to perform LPD with major venous resection and reconstruction with repassed round ligament. Compared with other grafts, round ligament can be harvested rapidly with no limitation in length, and could be obtained without any further exploration or any greater risk for the patient. Long-term therapeutic anticoagulation is not essential for the patients. However, long-term patency of repassed round ligament for venous reconstruction required further investigation.

Acknowledgements

Funding: This study was funding by National Institutes of Health of China (W2017ZWS07).

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Informed Consent: Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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Cite this article as: Cai Y, Li Y, Gao P, Wang X, Peng B. Laparoscopic pancreaticoduodenectomy with major venous resection and reconstruction with repassed round ligament: a case report. Ann Transl Med 2018;6(11):213. doi: 10.21037/atm.2018.05.33

Robotic biotissue curriculum for teaching the robotic pancreatoduodenectomy

Amr I. Al Abbas, Melissa E. Hogg

Division of Surgical Oncology, Department of Surgery, University of Pittsburgh, Pittsburgh, PA, USA

Contribution: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: None; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Melissa E. Hogg, MD, MS. Division of Surgical Oncology, Department of Surgery, University of Pittsburgh, 3550 Terrace Street, 497 Scaife Hall, Pittsburgh, PA 15261, USA. Email: HOGGME@upmc.edu.

Abstract: Minimally invasive surgery has revolutionized the face of surgical practice. Use of the robot in pancreas surgery is emerging as a feasible and effective technique. Its wide-spread implementation remains hindered by the significant learning curve. We describe how the biotissue curriculum at the University of Pittsburgh can decrease the learning curve and lead to systematic implementation of the technique. The Biotissue Curriculum is the second step of the proficiency-based robotic surgery curriculum at the University of Pittsburgh. It is comprised of suture drills and four biotissue drills: the running hepaticojejunostomy (RHJ), interrupted hepaticojejunostomy (IHJ), gastrojejunostomy (GJ) and pancreatojejunostomy (PJ). The purpose is the deliberate practice of the operative steps with frequent objective feedback for trainees toward a designated standard of proficiency. The role of the biotissue curriculum, in the context of the robotic curriculum, in mitigating the learning curve is also explored. The implementation of a training curricula that includes inanimate or biotissue practice is important for future surgical practice when adopting the robotic pancreatoduodenectomy (RPD) considering a low number of cases per trainee and the need for safe implementation of new techniques. Outcomes on robotic gastrointestinal and specifically pancreas surgery have shown feasibility and non-inferiority compared to the open approach. The biotissue curriculum in the context of the proficiency based robotic curriculum serves to help trainees achieve proficiency while mitigating the learning curve.

Keywords: Biotissue; robotic curriculum; pancreas surgery; proficiency-based training; deliberate practice

Received: 14 November 2017; Accepted: 14 January 2018; Published: 01 February 2018.
doi: 10.21037/apc.2018.01.06
View this article at: http://dx.doi.org/10.21037/apc.2018.01.06

Introduction

Minimally invasive techniques have revolutionized surgical practice ever since the first laparoscopic appendectomy in 1980 (1) and laparoscopic cholecystectomy in 1985 (2). It has been shown to have decreased short and long-term morbidity and mortality across a wide array of surgical procedures (3-7). Despite the advantages of laparoscopic procedures, their adoption in complex gastrointestinal surgeries such as pancreatoduodenectomy (PD) has been limited to a few centers owing to the advanced technical expertise required (8-11). This left an opening for robotic PD (12-14). Robotic pancreatoduodenectomy (RPD) offers improved three-dimensional imaging, 540° movement of surgical instruments, improved dexterity, and precision in complex tasks like vascular dissection and intracorporeal suturing (15-17).

However, wide-spread adoption of RPD is hindered by a significant learning curve (18-20) and the low volume of surgeries relative to the trainees. Tseng *et al.* analyzed the learning curve of high volume pancreatic surgeons for open PD and found that perioperative morbidity and

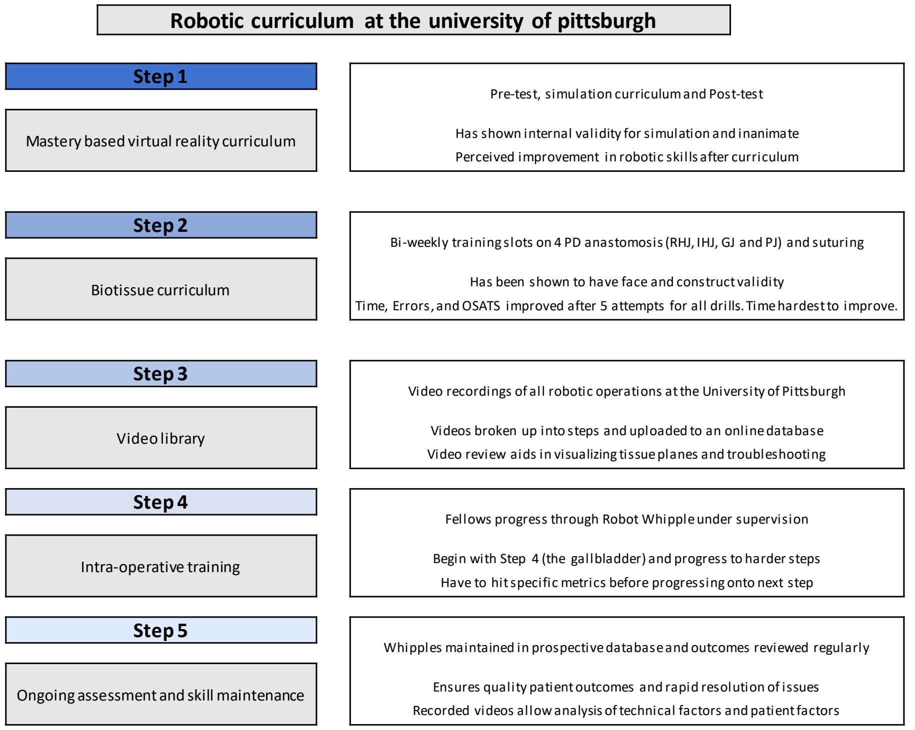

Figure 1 Summary of the robotic surgery curriculum at the University of Pittsburgh. PD, pancreatoduodenectomy; RHJ, running hepaticojejunostomy; IHJ, interrupted hepaticojejunostomy; GJ, gastrojejunostomy; PJ, pancreatojejunostomy.

mortality improved after 60 cases (21). In a similar study, it was shown than perioperative morbidity and mortality was higher for surgeons who had done less than 50 PDs (22). Compounding the issue further is the lack of standardized programs for safe adoption of this new technique, marking it as a potential safety blind spot for patients (19,23).

Therefore, it is imperative that a comprehensive and mastery based curriculum be implemented both to shorten the learning curve in RPD and to establish common quality metrics and credentialing systems that help hospitals better gauge the surgical experience of trainees and practicing surgeons. At the University of Pittsburgh, we have developed an innovative comprehensive five step curriculum for RPD that includes a simulation curriculum, a biotissue curriculum, a video library, an operative curriculum and a credentialing system for Society of Surgical Oncology (SSO) and hepato-pancreato-biliary (HPB) fellows (*Figure 1*).

Mastery-based simulation curriculum

Surgical simulation has advanced significantly over the past two decades with the development of simulators for both laparoscopic and robotic platforms. These have been shown to be valid tools for training and assessment of surgical skill and, more importantly, they have been shown to improve a surgeon's performance in the operating room (24-27). At the University of Pittsburgh, we have two simulation platforms that are used for trainees. The first is the Intuitive Surgical Backpack Simulator and the second is the Mimic Technologies da Vinci Trainer. On one of these platforms, trainees complete a pre-test which includes four virtual reality exercises and a box-test on the robot with three exercises. Simulated drills were scored by the simulator interface. Inanimate drills on the robot were scored by two trained graders independently according to modified Objective Structured Assessment of Technical Skills (OSATS) (*Figure 2*) (28,29). Upon completion of these exercises, trainees go through a simulation curriculum on the trainers encompassing 24 virtual reality exercises (*Figure 3*). This is followed by a post-test at completion which includes the same exercises as a pre-test.

In a previous study published by the group at the University of Pittsburgh, a total of 17 surgical oncology fellows were enrolled in the curriculum and 16 (90%)

Modified objective structured assessment of technical skills (OSATS)		
Gentleness Minimizing tissue injury	1 2 3 4 5	Rough, tears tissue and poor control Minor trauma with occasional breaks Appropriate tension with negligible injury
Time and motion Efficiency in movement	1 2 3 4 5	Uncertain, inefficient and lack of progress Slow, reasonable and organized Confident, efficient and fluid
Instrument handling Fluid use of instruments	1 2 3 4 5	Overshoots target, slow to correct Some overshooting, but quick to correct Accurate direction, correct plane, minimal readjustments
Flow of operation Smooth transitions between steps	1 2 3 4 5	Uncertain, constantly changing focus Slow, but planned and reasonably organized Safe, confident, maintains focus until time to move on
Tissue exposure Tissue retraction and camera visualization	1 2 3 4 5	Use of one hand and poor coordination Use of both hands, but with sub-optimal dexterity Expertly utilized both hands complementarily
Summary score Overall assessment of trainee's technical skill	1 2 3 4 5	Deficient Average Masterful

Figure 2 Modified Objective Structured Assessment of Technical Skills (OSATS) used to train video graders.

Mastery based simulation robotic curriculum

Pre-test	Mastery based curriculum	Post-test
Virtual reality	Pick and place	**Virtual reality**
Match Board 3	Peg board 1	Match Board 3
Ring Rail 2	Peg board 2	Ring Rail 2
Tubes	Match board 1	Tubes
Continuous Suture	Match board 2	Continuous Suture
Inanimate reality	Ring and rail 1	**Inanimate reality**
Ring Rollercoaster 4	Camera targeting 1	Ring Rollercoaster 4
Around the World	Camera targeting 2	Around the World
Interrupted Suture	Scaling	Interrupted Suture
	Ring walk 1	
	Ring walk 2	
	Ring walk 3	
	Energy switching 1	
	Energy switching 2	
	Energy dissection 1	
	Energy dissection 2	
	Energy dissection 3	
	Needle targeting	
	Threading the rings	
	Suture sponge 1	
	Suture sponge 2	
	Suture sponge 3	
	Dots and needles 1	
	Dots and needles 2	

Figure 3 Master based robotic simulation curriculum at the University of Pittsburgh: pre-test, curriculum and post-test.

completed it (30). Of 16 fellows who completed the curriculum, 4 fellows (25%) achieved mastery on all 24 modules with fellows mastering 84% of the modules on average. Individual test scores improved significantly after curriculum completion (P<0.0001) and an average of 2.4 attempts was necessary to master each module. The median time spent completing the curriculum was 4.2 hours across the cohort and, overall, 15 (94%) fellows perceived improvement in robotic skills after completing the curriculum. This showed that a mastery-based simulation curriculum had internal validity with regards to improvement in scores while simultaneously constituting minimal time commitment on the part of the surgical trainee. Having touched on the 1st step of the curriculum, this work will focus on the second step; the biotissue curriculum.

Goals of the biotissue curriculum

Studies have shown equivalence of virtual reality and box simulation for laparoscopic skills (31), our biotissue curriculum addresses the gap in virtual reality training by offering visual feedback on 3-dimensional objects which is especially critical owing to the loss of haptic feedback in the robotic platform (32). In a randomized controlled trial of medical students to compare different methods of learning basic laparoscopic skills using a box trainer, virtual reality simulator and mental training, not all the skills learned in virtual reality were transferable to the box trainer (33). In fact, practice on both the box trainer and the virtual reality simulator has been shown to be important for improvement in laparoscopic skills (34).

Other similar curricula have been reported for additional procedures, though most are short-term and not designed to be proficiency-based with defined metrics and assessment to show improvement over time. Maricic *et al.* has developed a low-cost inanimate model for minimally invasive repair of esophageal atresia and tracheoesophageal fistula (35). They used different materials to simulate ribs, intercostal spaces, the trachea in addition to different tubular latex balloons to simulate the esophagus. Surgeons of different levels of experience were tasked with testing the model and then answered several questionnaires. In relation to the anatomical characteristics of the model, 94.48% (n=37) of respondents considered that the model has a high degree of similarity; in relation to surgical anatomy 88.2% (n=34) respondents considered that the model has a high degree of similarity; 87.17% (n=34) respondents considered that the model can generate a good amount of skills. Assessment of errors and technical performance showed that there was a significant correlation between surgeon experience and their performance in the model considering operating time (P<0.0001), quality of the anastomosis (P=0.04) and errors (P<0.0001). In another study by Goh *et al.* evaluated face, content and construct validity of FIRST (Fundamental Inanimate Robotic Skills Tasks), which is a series of four inanimate robotic skills tasks in a large multi-institutional cohort of expert surgeons and trainees (36). Here again, experts appeared to outperform trainees across all skill tasks (P<0.001). Kiely *et al.* have also developed a low-cost inanimate model of robotic pelvic lymphadenectomy and rated highly for face and content validity (37). Most of these previous studies have validated training models and did not necessarily validate an ongoing curriculum.

It is our group's assertion that the virtual reality simulator teaches the instrument (clutching, energy switching, using the master controllers and handling the camera), while the biotissue curriculum instills gentle tissue handling and recognition of visual cues and, most importantly, makes the operative steps second nature to the trainee (38). The box trainer is deficient when compared to biotissue owing to the lack of realism in anatomical set up and tissue fidelity (39). Therefore, the steps of our curriculum were designed to progress from one step to another. Simulation is first and this teaches the instrument console, the box trainer is second and this allows trainee to work in an inanimate environment to get a sense of loss of haptics and spatial relations; however, the key component is the deliberate practice biotissue models which mimic the exact step of the corresponding surgical procedure with designated metrics to achieve.

Proving face and construct validity is critical when establishing any new curriculum's assessment metrics. The biotissue curriculum has been shown to have construct validity because of its ability to distinguish between high and low performance based on measured OSATS, errors and time (35). It also was shown to have face validity when three SSO trained surgeons, who did the drills, rated them as having high levels of likeliness in terms of mechanical set up, tissue fidelity, anatomical angles and needle or suture choice (38).

Methodology of the biotissue curriculum

The bioartificial tissue is created by Lifelike BioTissue Inc. (Ontario, Canada) and the models were designed and assembled by the research team. Fellows are supplied with

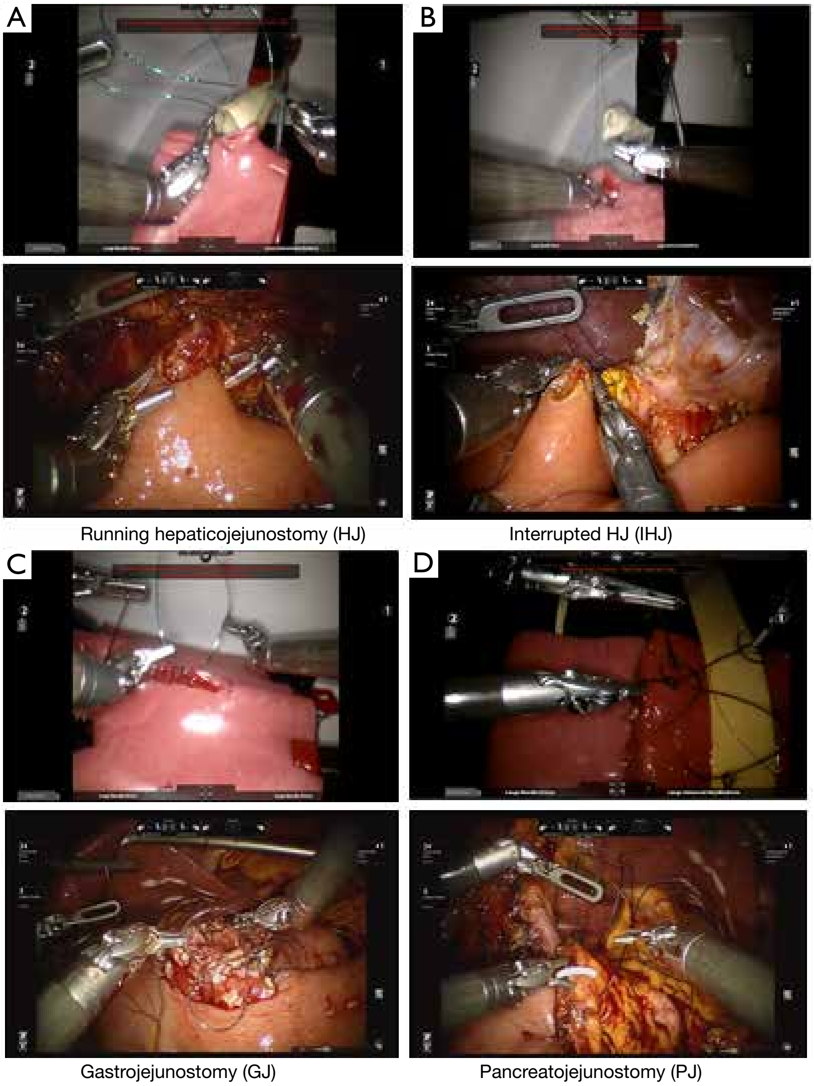

Figure 4 Side-by-side stills of biotissue drills and corresponding operative steps: (A) running hepaticojejunostomy (RHJ), (B) interrupted hepaticojejunostomy (IHJ), (C) gastrojejunostomy (GJ), and (D) pancreatojejunostomy (PJ).

videos of attending surgeons performing the drills and PowerPoint instructions. Drills are set up on a bi-weekly basis on an Si da Vinci training robot (Intuitive Surgical Inc., Sunnyvale, CA, USA). Fellows are encouraged to sign up, but not mandated.

Our biotissue includes two kinds of HJs. The first is a running HJ consisting of one bowel segment cut to 4 cm (acting as jejunum) and a 1 cm wide femoral artery biotissue cut to about 5 cm (acting as a bile duct). The trainee pre-cuts a small hole in the bowel just large enough to anastomose to the "bile duct". For the running HJ, we supply two running 4-0 vloc stitches (*Figure 4A*). The interrupted HJ is similar in terms of set up, but uses saphenous vein biotissue instead of the femoral artery biotissue (thinner walled and with smaller diameter). For this drill, we supply the trainees with five 5-0 Maxon stitches cut to 5" (*Figure 4B*). In the GJ, we use two segments of bowel representing jejunum and stomach cut to around 8 cm. The trainee pre-cuts both bowel segments and then performs a two-layered anastomosis. The trainee is supplied with five 3-0 silk stitches cut to 8" as lambert stitches and two 3-0 vloc as the running and Connell stitches (*Figure 4C*). And finally, the PJ consists of the same bowel biotissue, but cut to 5-cm long and pancreas biotissue cut to 8-cm wide and 4 cm long. The

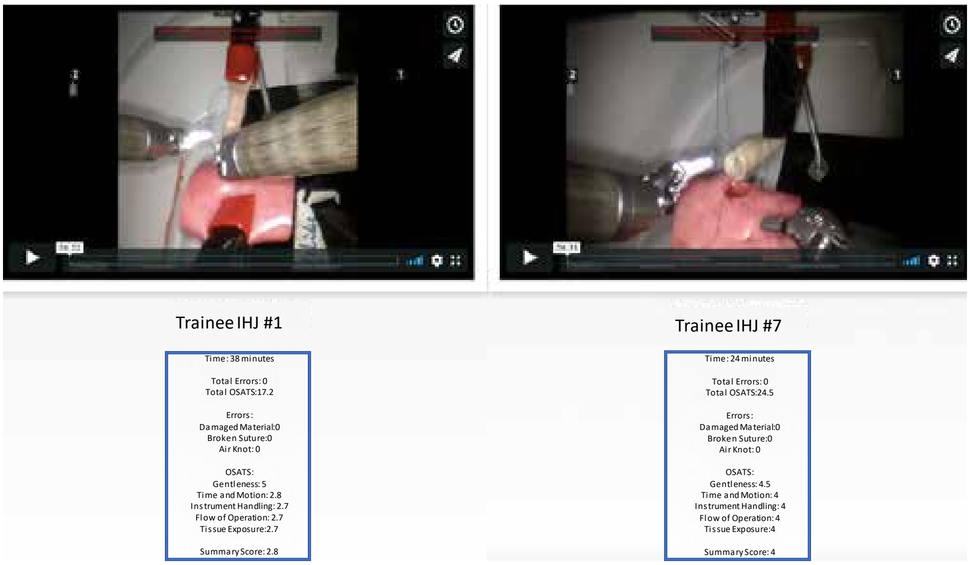

Figure 5 Vimeo interface for trainee drill evaluation. OSATS, objective structured assessment of technical skills; IHJ, interrupted hepaticojejunostomy.

pancreas biotissue consists of a polymer designed to mimic the actual pancreas, including a pancreatic duct within. The anastomosis performed is a modified Blumgart with five 5-0 Maxon cut to 5" duct-to-mucosa stitches and three 2-0 silk stitches cut to 8" as the outer mattress (*Figure 4D*).

All anastomotic drills are recorded using AIDA video capture system by KARL STORZ GmbH & Co. KG (Tuttlingen, Germany) and then retrieved by research staff who edit the videos. The research staffs upload the edited video segments to the Vimeo website, developed by Vimeo, Inc. (New York City, New York). The links are sent to crowdsource graders on a weekly basis. These undergraduate hourly employees who are hired at the beginning of each year after passing through training by our research staff. Their training includes having them watch drills completed by experts, novices and moderately proficient surgeons. They are taught to recognize these different skill levels and to grade them according to modified OSATS (*Figure 2*). The grades are returned a week later and both the video of the drill and these grades are uploaded to a separate Vimeo account and grouped by fellow. The errors and OSATS for the drill are displayed below each video for the fellow to review (*Figure 5*). Once each fellow has completed a minimum of 5 drills, they begin to receive more detailed report cards on their performance relative to the group.

Tam *et al.* showed that modified OSATS, time and errors improve in fellows who have undergone the biotissue curriculum. On the RHJ and the GJ drills, there was statistically significant decrease in time, errors and OSATS after the fifth attempt (*Table 1*). On the other hand, while there was a significant improvement in errors and OSATS in the PJ drill after the fifth attempt, there was no significant improvement in time after the fifth attempt. This is likely owing to the difficulty of the PJ anastomosis. The interrupted HJ is a newer drill which has not undergone analysis, yet, but we expect it to mirror the results above.

The metrics of time, errors, and OSATS for the attending surgeons serve as "mastery" or the expected threshold to achieve for optimal operating room performance. As a group, the trainees were not able to achieve the level of mastery set forth by the attendings for any metric on the running HJ and for time on the other drills. Differentiating individual skill level and performance quartiles to determine factors predictive of better performance is the next step of analysis.

Biotissue curriculum and patient outcomes

The link between technical skill and patient outcomes is well established (28,40). In Birkmeyer *et al.* the bottom quartile of technical skill, as compared to the top quartile, was associated with higher rates of surgical site infections (4.60% *vs.* 1.04%; P=0.001), reoperation (3.4% *vs.* 1.6%; P=0.01), readmission within 30 days (6.3% *vs.* 2.7%; P<0.001) and higher overall

Table 1 Outcomes of fellow training in robotic pancreatoduodenectomy biotissue curriculum

Biotissue drill	1st drill	5th drill	P value
Running hepaticojejunostomy			
Time	32	21	0.001*
Errors	6	3	0.007*
OSATS	19	23.8	0.004*
Gastrojejunostomy			
Time	69	58.5	0.002*
Errors	15	3.5	<0.001*
OSATS	18	23.5	0.001*
Pancreatojejunostomy			
Time	53.5	48.5	0.08
Errors	8	5	0.002*
OSATS	19.5	23.5	0.001*

*, found to be statistically significant. Comparison of first and fifth attempt by SSO fellows on the running hepaticojejunostomy (RHJ), gastrojejunostomy (GJ) and pancreatojejunostomy drills (PJ) as in Tam *et al.* 2016. OSATS, Objective Structured Assessment of Technical Skills.

complication rates (14.5% *vs.* 5.2%; P<0.001). Similarly, the group at the University of Pittsburgh has shown that surgeon operative performance can predict the incidence of post-operative pancreatic fistula (40).

Training using virtual reality simulators and inanimate materials can help improve operative performance. In a recent study by Palter *et al.*, a randomized single-blinded prospective trial allocated 20 surgical trainees to a structured training and assessment curriculum (STAC) group versus conventional residency training. The STAC consisted of case-based learning, proficiency-based virtual reality training, laparoscopic box training, and OR participation. After completion of the intervention, all participants performed 5 sequential laparoscopic cholecystectomies in the OR (41). Residents in the STAC group significantly outperformed residents in the conventional group in the first (P=0.004), second (P=0.036), third (P=0.021), and fourth (P=0.023) surgery. In another study, trainees underwent a validated 16-session advanced laparoscopy simulation training program (42). They were then compared to general surgeons with no simulation training and expert bariatric surgeons in performing a stapled jejunojejunostomy in the OR. They assessed the participants according to the Global rating scale and specific rating scale scores, operative time and the distance traveled by both hands measured with a tracking device. Ten junior trainees, 12 general surgeons and 5 bariatric surgeons were assessed performing a stapled jejunojejunostomy in the OR. All trainees completed the entire anastomosis in the OR without any takeovers by the bariatric surgeons whereas six (50%) bariatric surgeon takeovers took place in the general surgeon group. Trainees had significantly better results in all measured outcomes when compared to general surgeons with considerable higher global rating scale median [19.5 (18.8–23.5) *vs.* 12 (9–13.8) P<0.001] and lower operative time.

OSATS are reliable and have been repeatedly validated as tools for assessing surgeon technical skill (28,29). Our deliberate biotissue curriculum, in the context of the larger robotics training curriculum at the University of Pittsburgh, improves the technical performance of surgical oncology fellows (38). We are currently in the process of collecting data from the past four years of the curriculum. Our goal is to link trainee participation in the curriculum to increased involvement in operative cases and ultimately better operative performance and improved patient outcomes.

Conclusions

In conclusion, robotic assisted pancreatic surgery improves outcomes and is non-inferior to traditional pancreatic surgery. The lengthy learning curve is the primary barrier against wide-spread implementation of this technique. Utilizing a mastery based robotic curriculum including deliberate practice of the operative steps in the biotissue curriculum can mitigate this learning curve, improve trainee operative involvement and their operative performance. Our group has shown that trainee technical performance improves in terms of time, OSATS and errors. Data directly linking trainee operative performance and practice in the curriculum is currently lacking, but will be detailed in later publications.

Acknowledgements

None.

Footnote

Conflicts of Interest: ME Hogg receives funding from Veteran's Affairs in way of salary support. AI Al Abbas has no conflicts of interest to declare.

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doi: 10.21037/apc.2018.01.06
Cite this article as: Al Abbas AI, Hogg ME. Robotic biotissue curriculum for teaching the robotic pancreatoduodenectomy. Ann Pancreat Cancer 2018;1:9.

Robotic distal pancreatectomy and splenectomy: rationale and technical considerations

Nelson A. Royall, R. Matthew Walsh

Department of General Surgery, Digestive Disease Institute, Cleveland Clinic Foundation, Cleveland, Ohio, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Dr. R. Matthew Walsh, MD, FACS. Professor and Chairman, Rich Family Chair of Digestive Diseases, Chairman. A100, 9500 Euclid Ave, Cleveland, OH 44195, USA. Email: walshm@ccf.org.

Abstract: Minimally invasive distal pancreatectomy has had significant adoption in the United States over the past decade. Robotic distal pancreatectomy is a type of minimally invasive technique which affords greater dexterity and visualization compared to traditional laparoscopy. In addition to standard distal pancreatectomy procedures with or without splenectomy, the use of robotic surgical systems has been efficacious in performing more complex techniques such as radical antegrade modular pancreatosplenectomy (RAMPS) or spleen-preservation. There are important technical considerations to performing robotic distal pancreatectomy procedures which differ from other minimally invasive approaches. The purpose of this report is to describe the rationale and technical considerations for implementation of robotic distal pancreatectomy procedures in clinical practice.

Keywords: Pancreatectomy; pancreatic diseases; robotic surgical procedures; robotics; minimally invasive surgical procedures

Received: 22 April 2017; Accepted: 27 July 2017; Published: 30 September 2017.
doi: 10.21037/jovs.2017.08.01
View this article at: http://dx.doi.org/10.21037/jovs.2017.08.01

Introduction

Minimally invasive distal pancreatectomy has become the most commonly performed technique for distal pancreatectomy in the United States (1). A majority of surgeons had utilized laparoscopic techniques for minimally invasive distal pancreatectomy prior to the advent of modern robotic surgical systems. In contrast to traditional laparoscopy, robotic distal pancreatectomy has been shown to be feasible in performing both standard and more complex resections with greater technical demands (2-4).

To date, there is no standardized approach to minimally invasive distal pancreatectomy to guide surgeons in selecting the most appropriate technique for an individual patient. Cost considerations and surgeon-specific experience or competency level are oftentimes used as the main determinants for performing a specific technique (1,5). With increased availability and a potentially shorter learning curve, robotic distal pancreatectomy may be a useful modality in increasing the successful adoption and application of minimally invasive distal pancreatectomy. The purpose of this report is to describe the rationale and technical approach for the implementation of robotic distal pancreatectomy.

Rationale

Robotic surgical systems provide more instrument range of motion and control compared to traditional laparoscopic instruments. Hand movement in standard laparoscopy leads to exponentially increased instrument movement which makes dissection around sensitive structures challenging. In contrast, robotic surgical systems allow manipulation of the

Table 1 A relative comparison of applications of laparoscopy and robot-assisted minimally invasive distal pancreatectomy

Technique	Psychomotor level		Ergonomic comfort	Open conversion	Procedural cost
	Primary surgeon	First assistant			
Standard distal pancreatectomy with total splenectomy					
Laparoscopy	–	–	–	–	↓
Robotic	–	–	–	–	↑
Distal pancreatectomy with total splenectomy and enterectomy and/or adrenalectomy					
Laparoscopy	↑↑↑	↑↑↑	↓	↑↑↑	–
Robotic	↑	–	–	↑	↑
Distal pancreatectomy with total splenectomy and celiac axis resection (modified Appleby procedure)					
Laparoscopy	↑↑↑↑	↑↑↑	↓	↑↑↑	↓
Robotic	↑↑	–	–	↑	↑
RAMPS					
Laparoscopy	↑↑↑	↑↑	↓	↑↑	–
Robotic	↑	–	–	–	↑
Distal pancreatectomy with spleen-preservation (vessel-preservation technique)					
Laparoscopy	↑↑↑	↑↑	↓	↑↑	–
Robotic	↑	–	–	↑	↑
Distal pancreatectomy with spleen-preservation (Warshaw technique)					
Laparoscopy	↑	↑	↓	↑	–
Robotic	↑	–	–	↑	↑

RAMPS, radical antegrade modular pancreatosplenectomy.

hand to instrument movement ratio, which allows for safe dissection of delicate structures which otherwise require high psychomotor ability. In the situation of a standard distal pancreatectomy, there is limited need to manipulate the hand to instrument movement ratio and does not require significant instrument articulation. Standard port placement and in-line laparoscopic instruments, such as a Maryland dissector and right-angle dissector, are generally adequate for dissection of the splenic vein and artery or other structures in a standard distal pancreatectomy with total splenectomy. In contrast, the use of articulating instruments and manipulating the hand to instrument movement ratio may change the ability to complete a minimally invasive distal pancreatectomy without open conversion in those patients with significant peripancreatic fibrosis, enlarged tumors, or other challenging anatomy. *Table 1* provides a relative comparison of traditional laparoscopy and robotic techniques for distal pancreatectomy procedures.

For patients with locally advanced pancreatic tumors or those warranting a more thorough lymphadenectomy [i.e., radical antegrade modular pancreatosplenectomy (RAMPS)] the use of the robotic system has particular appeal (6). In locally advanced pancreatic body and tail tumors the use of the robotic systems can aid the surgeon in performing en bloc resections of the involved structures such as the duodenum or adrenal gland. Additionally, the robotic system is decidedly more straightforward for the surgeon to perform hand-sewn anastomoses should they be necessary in the case of a bowel anastomosis or oversewing of vessels. The full wrist articulation mimicking the surgeon's hand can make performing these anastomoses more straightforward, particularly in the case of a surgeon less comfortable with advanced intracorporal suturing skills.

Further, robotic surgical systems are advantageous in RAMPS procedures where the gastroduodenal and infra-pancreatic lymph node basins must be resected to complete the N1 dissection. Clearance of nodal tissue along the right gastroepiploic vein, gastroduodenal artery, and common hepatic artery is believed to be a critical component for the survival advantage noted in RAMPS (6). Although a pure laparoscopic approach may be feasible, many pancreatic surgeons are unlikely to feel comfortable with this dissection given the limited dexterity of current laparoscopic instruments. In minimally invasive RAMPS, careful dissection and mobilization of perivascular lymphatic tissue is greatly facilitated using fully articulating instruments which can also be adjusted to decrease the hand to instrument movement (4).

A final technical modification of the distal pancreatectomy which can be facilitated using the robotic system is spleen-preservation (2,3,7). In spleen preserving techniques where pancreatic branches from the splenic vein and artery are individually ligated and sutured (splenic vessel preservation), robotic surgical systems increase the likelihood of successful splenic preservation compared to traditional laparoscopy (2,3). This effect can be explained by the impact of the robotic instrument articulation providing greater needle dexterity which is critical in ligating small venous or arterial branches along the relatively thin-walled splenic vein. Given the number of sutures required, surgeon comfort also becomes a greater consideration during these types of technically demanding procedures and the improved ergonomics seen with robotic surgical systems can help prevent surgeon discomfort and fatigue throughout the procedure. In comparison, the Warshaw technique (non-splenic vessel preserving) where the splenic vein and artery are divided, the ability to carefully dissect the splenic vein tributaries seen in the diffuse splenic vein anatomy is challenging in pure laparoscopy. Robotic instrumentation with articulation and modification of the hand to instrument movement ratio appears to aid in minimizing blood loss and completing the procedure with a minimally invasive approach.

Considerations

Robotic surgical systems require institutional credentialing prior to use (8). Furthermore, mentorship to develop competency in robotic instrumentation is critical to avoid life-threatening injuries which can be seen with any surgical instrument (8). Although robotic surgical systems are certainly more generalizable to the traditional surgeon compared to laparoscopic techniques, training in safe trochar and robot-specific instrument use must be obtained prior to implementing the technology in clinical practice.

With respect to robotic distal pancreatectomy, trochar placement is similar to those used in laparoscopic distal pancreatectomy. Depending on the robotic surgical system used and preferred instrumentation, the trochars are a combination of either 5, 8, or 12 mm in diameter. The patient should be deemed a safe candidate for pneumoperitoneum and if intraperitoneal adhesions exist then trochar placement may need to be staged with adhesiolysis performed until all trochars can be placed under direct visualization.

Most minimally invasive distal pancreatectomy procedures utilize endoscopic stapling devices to transect the pancreatic parenchyma. Both robotic stapling devices, depending on the surgical system used, and laparoscopic stapling devices can be used. Parenchymal suturing at the transection margin can be performed depending on surgeon preference and does increase the degree of technical challenge encountered compared to open techniques. If a RAMPS procedure is performed, additional trochars are used to aid in performing the hepatoduodenal ligament and infra-pancreatic lymph node dissections. The assistant port in RAMPS procedures is of greater importance to retract or hold structures during the dissection. In the setting of a locally advanced tumor requiring duodenal resection, table manipulation may be needed during the procedure while mobilizing the ligament of Treitz. Although commercially available operative tables are available which coordinate table movement with the robotic system, if not available the robotic system will need to be undocked from the patient to manipulate the operative table during this portion of the procedure.

Technique

The peritoneal cavity can be entered in a variety of methods including traditional laparoscopic techniques or a robot-assisted method. Utilizing the robotic camera with an optical view trochar in the left aspect of the epigastrium is a cost-effective method we utilize to avoid use of laparoscopic equipment. Additional trochars are then placed in the right anterior axillary line, right para-median, supraumbilical, left para-median, and left anterior axillary line. The size of the trochars depends on the robotic device utilized. Examples of port placement are demonstrated for the Intuitive Da Vinci Si and Xi systems for distal pancreatectomy in *Figures 1,2*. The potential use of smaller trochars such as robotic 5 mm trochars has the advantage of a potentially lower risk for incisional hernia, although the instruments at this time are more limited in the existing robotic systems and not ideal

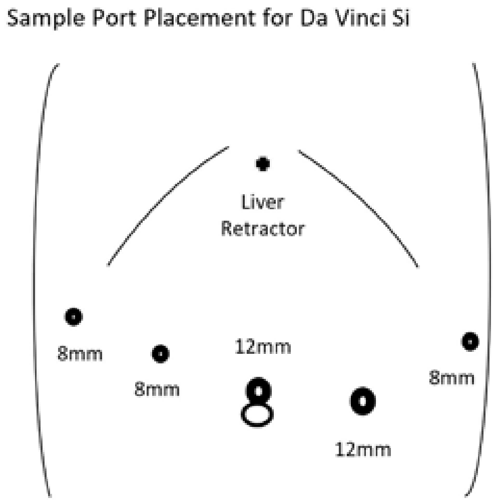

Figure 1 Sample port placement for robotic distal pancreatectomy with an Intuitive Da Vanci Si system. Eight mm trochars are utilized for instrument arms and the supra-umbilical trochar is used for the camera and eventual specimen removal. The 12 mm left para-median trochar is used for the assistant port in addition to the site for a stapling device if used.

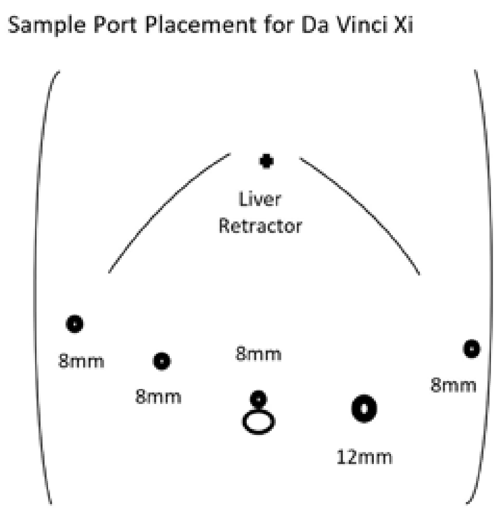

Figure 2 Sample port placement for robotic distal pancreatectomy with an Intuitive Da Vanci Xi system. Eight mm trochars are utilized for instrument arms and the supra-umbilical trochar is used for the camera and eventual specimen removal. The 12 mm left para-median trochar is used for the assistant port in addition to the site for a stapling device if used.

Figure 3 Technique for robotic-assisted distal pancreatectomy and splenectomy (9).
Available online: http://www.asvide.com/articles/1719

for robotic distal pancreatectomy.

After placement of the robotic trochars, the epigastric trochar is removed and the camera repositioned to the supraumbilical trochar site. A liver retractor such as the Nathanson retractor is placed through the epigastric port site. The robotic surgical system is then docked from either above the head or obliquely depending on the surgical system used. The first assistant is positioned on the patient's left side and will utilize the left para-median trochar for suctioning and potentially stapled transection of the pancreas. The surgeon at this point moves to the robotic console after ensuring correct placement of the desired instruments. An example of an instrument orientation would be an atraumatic grasping device in the right anterior axillary and left anterior axillary trochars with an ultrasonic dissector or bipolar dissector in the right para-median trochar.

The operation proceeds similar to previous descriptions of distal pancreatectomy depending on the extent of lymphadenectomy or performance of splenic preservation. *Figure 3* demonstrates the standard technique for a robot-assisted distal pancreatectomy with splenectomy. For a standard distal pancreatomy with total splenectomy, the gastrosplenic ligament and short gastric vessels are serially divided using the dissecting device up to the level of the left phrenoesophageal ligament. The stomach is grasped and retracted lateral and caudal using the right anterior axillary grasping device while the left anterior axillary grasping device retracts the greater omentum caudal. The right anterior axillary grasping device serially regrasps the posterior aspect of the stomach and rotates the stomach counter-clockwise to better expose the gastric fundus and cardia while dividing the gastrosplenic ligament. The superomedial aspect of the splenodiaphragmatic ligament can be divided at this point as well given the excellent exposure. The liver retractor is re-positioned to retract the stomach and liver anteriorly. Similarly a Penrose drain can be placed to similarly retract the stomach anteriorly.

The gastrocolic ligament is divided in conjunction with the gastrosplenic ligament up to the level of the right gastroepiploic vein depending on the extent of pancreatectomy and lymphadenectomy desired. If a distal pancreatectomy at the level of the superior mesenteric vein is necessary then the right gastroepiploic vein is followed distally to the junction with the superior mesenteric vein while retracting the stomach anteriorly with the left anterior axillary grasping device. The peritoneum overlying the superior mesenteric vein and caudal aspect of the pancreatic neck or body is divided using an electrosurgical device or dissector. The peritoneum along the caudal aspect of the pancreatic body and tail is similarly divided to allow for caudal retraction of the colon and transverse mesocolon to prevent an iatrogenic mesocolic defect.

A retro-pancreatic tunnel is created using blunt dissection with the right and left anterior axillary grasping at the level of the superior mesenteric vein. The dissection ends at the cephalad aspect of the pancreas beyond the level of the splenic vein. The dissection proceeds anteriorly at the cephalad aspect of the pancreas to isolate the splenic artery. The splenic artery should be followed proximally to the celiac trunk and all lymphatic tissue dissected from the splenic artery and celiac trunk to be included with the specimen. A laparoscopic or robotic ultrasound probe should be routinely employed to evaluate the pancreatic parenchyma, identify the pancreatic lesion, and main pancreatic duct. The ultrasound exam is additionally used to guide the level of pancreatic parenchyma transection ensuring an adequate margin is achieved.

Except in the case of splenic vessel preservation, the splenic artery is divided at the level of the celiac trunk or distally to preserve the dorsal pancreatic artery. The splenic artery can be divided using either surgical clips or a surgical vascular stapler load. The splenic vein is then bluntly dissected from the pancreatic parenchyma circumferentially on the posterior aspect of the pancreatic body at the level of the planned parenchymal transection. The splenic vein is divided using either surgical clips or a surgical vascular stapler load. The pancreatic parenchyma can be divided at this step using a variety of transection techniques including a surgical stapling device, electrosurgical dissector, ultrasonic dissector, or sharp transection. If desired the pancreatic transection stump and main pancreatic duct can be over sewn using robotic needle drivers placed through the left anterior axillary trochar.

The pancreatic body and tail are then elevated anteriorly using the right anterior axillary trochar while the transverse colon is retracted caudal. The splenocolic ligament is divided using either a monopolar or a surgical dissecting device to mobilize the splenic flexure of the colon. The splenorenal ligament can be divided at this point with adequate caudal retraction of the transverse colon. The retro-pancreatic lymphatic tissue is then divided using either an ultrasonic or bipolar dissector to complete the retro-pancreatic lymphadenectomy. The remaining splenodiaphragmatic and splenorenal ligaments are divided as well to complete the resection.

There are two predominant methods for specimen removal in minimally invasive distal pancreatectomy with splenectomy. The specimen can be left intact or the distal pancreas can be divided from the spleen and the specimens removed separately. There has been no evidence suggesting a benefit of maintain the specimen intact at the time of removal assuming the lesion is not violated by performing this maneuver. The most commonly utilized extraction site for the specimen is the supra-umbilical trochar site which requires replacement of the robotic camera to the right para-median or left para-median trochar depending on the surgical system utilized. Prior to removal of the specimens a surgical drain can be placed through the left anterior axillary trochar site with removal of the trochar. The specimens are placed within a protective bag to avoid trochar site seeding or contamination. The extraction trochar often requires enlargement for specimen removal. Trochar fascial defects can be closed using either a transfascial or anterior approach.

Conclusions

Robotic distal pancreatectomy is a valuable technique for performing minimally invasive distal pancreatectomy. The increased dexterity afforded by the robotic surgical systems can aid the surgeon, particularly during lymph node dissections such as those in a RAMPS procedure or vascular dissection such as spleen-preserving techniques. Further investigations which will attempt to expand the body of evidence on the role of robotic distal pancreatectomy may be important to clarifying how to best implement the technology.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.08.01

Cite this article as: Royall NA, Walsh RM. Robotic distal pancreatectomy and splenectomy: rationale and technical considerations. J Vis Surg 2017;3:135.

Robotic central pancreatectomy and pancreatogastrostomy: surgical technique and review of literature

Ammar A. Javed [1,2], Alina Hasanain[1,2], Matthew J. Weiss[1,2]

[1]Department of Surgery, [2]The John L. Cameron Division of Hepatobiliary and Pancreatic Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Matthew J. Weiss, MD, FACS. Assistant Professor of Surgery and Oncology; Surgical Director, Pancreas Cancer Multidisciplinary Clinic; Program Director, Complex Surgical Oncology Fellowship; Department of Surgery, Johns Hopkins Hospital, 600 N. Wolfe Street, Halsted 608, Baltimore, MD 21287, USA. Email: mweiss5@jhmi.edu.

Abstract: Improved imaging techniques, coupled with more frequent cross-sectional imaging, have led to a recent rise in the detection of low-grade pancreatic lesions, including intraductal papillary mucinous neoplasms (IPMN), mucinous cystic neoplasms (MCN), pancreatic neuroendocrine tumors (PNET) and solid pseudopapillary tumors (SPEN). Consequently, in addition to more routine procedures to treat resectable pancreatic lesions such as the pancreaticoduodenectomy (PD) and distal pancreatectomy (DP), the use of central pancreatectomy (CP) to resect low-grade, mid-pancreatic tumors has increased. The aim of a CP is the removal of disease while maintaining optimal preservation of the surrounding pancreatic parenchyma. It has been demonstrated that open CP is safe and efficacious, but literature on robotic CP is limited. The aim of this manuscript was to describe the technique of robotic CP and review the current literature. PubMed, Embase and Google Scholar were reviewed to identify literature on robotic CP. Twelve articles reporting 116 patients were identified and data were collected. The overall morbidity and mortality was 64.7%, and 0.0% respectively. Reoperation was required in 1.7% patients, and 56.9%, and 0.9% developed postoperative pancreatic fistula (POPF) and diabetes mellitus (DM) respectively. No postoperative exocrine insufficiency. These outcomes were comparable to those reported for open and laparoscopic CP. Robotic CP is a safe procedure when performed by trained surgeons at high-volume centers.

Keywords: Middle pancreatectomy; central pancreatectomy (CP); robotic surgery; pancreatogastrostomy

Received: 07 November 2017; Accepted: 15 January 2018; Published: 01 February 2018.
doi: 10.21037/apc.2018.01.02
View this article at: http://dx.doi.org/10.21037/apc.2018.01.02

Introduction

Ehrhardt reported the first segmental neck resection (SNR) in 1908, followed by Finney in 1910 (1,2). In 1982, Dagradi and Serio performed and reported the first central pancreatectomy (CP) (3-5). Improvements in operative techniques and advancements in surgical instruments resulted in minimally invasive (MIS) approach being utilized to perform various surgical procedures. Baca and Bokan were the first to report laparoscopic CP in 2003, followed by Giulianotti *et al.*, who reported the first robotic CP in 2004 (1,6).

Centrally located pancreatic lesions present a significant challenge, as the surgeon tries to achieve a balance between preserving maximum endocrine and exocrine function of the pancreas while maintaining oncological efficacy (7). There is a variety of options available for surgical resection, including pancreaticoduodenectomy (PD), distal pancreatectomy (DP) or CP. The decision to select a particular approach is dependent upon the size, location and type of pancreatic lesion (3). In cases of main-duct IPMN with an invasive component or transformation to pancreatic ductal adenocarcinoma (PDAC), extended PD or near-total

DP are preferred over CP for complete extirpation of the tumor and its surrounding lymph nodes (7,8). A DP or PD performed for centrally located low-grade lesions would entail the removal of a larger volume of the pancreas. These patients would thus be at a higher risk of post-operative diabetes and exocrine insufficiency without therapeutic benefit (7-9). Small benign lesions can be treated with enucleation, but this procedure is not optimal for malignant tumors or ones next to the main pancreatic duct (10). For patients with centrally located, low-grade malignant or benign disease, CP is a favorable option (10).

Studies have reported that CP can be complicated by the relatively high (20–50%) incidence of post-operative pancreatic fistula (POPF) and incomplete resection of malignant lesions (7). In most cases, however, the POPF is clinically insignificant (9). Additionally, these cases are often in patients with soft glands or small ducts, both being independent, well-established risk factors for POPF (9). Unlike DP, CP allows for splenic preservation, while compared to PD, CP has a lower mortality with duodenal and bile duct preservation (3,7,11). While multiple anastomoses to preserve the functionality of the hepatic and pancreatic ducts and the intestinal tract are necessary in PD, CP requires a single anastomosis for reconstruction (3,11).

MIS is now the standard of care in DP as outcomes are more favorable than in open DP (12,13). A recent meta-analysis demonstrated that laparoscopic DP is associated with less blood loss, shorter hospital length of stay, fewer surgical site infections and lower morbidity compared to open DP (14). The MIS approach to PD has garnered attention for showing comparable morbidity, mortality and oncologic outcomes to open PD in select patient populations (13,15-18). Though both laparoscopic and robotic approaches to CP are being utilized, the smaller operative workspace and complexity of the procedure restrict the utility of laparoscopic CP; robotic surgery can potentially overcome a number of these limitations (10,19-21).

Surgical technique and technical aspects of MIS CP

Appropriate evaluation of patients is performed using a pancreas protocol CT or MRI and serum CA19-9 levels. If the lesion is amenable to resection via robotic CP, an assessment by an anesthesiologist is performed.

The patient is placed in a supine position with both arms extended to 90°. A nasogastric tube, intravenous access, monitoring lines, and Foley catheter are placed. The abdomen is prepped and draped and is entered using the Hassan technique. The abdomen is then insufflated and a camera port is placed in the periumbilical position. A port is placed in the right anterior axillary line for the liver retractor, followed by two right-sided and two left-sided abdominal robotic ports. Furthermore, an assistant port is placed in the left lower quadrant. The robot is then docked.

Upon entering the abdomen, the abdominal cavity is examined thoroughly. Using a vessel-sealing device, the lesser sac is entered by dissecting the gastrocolic omentum free from the stomach. Of note, the gastroepiploic vessels should be preserved. An ultrasound can be employed to assist in finding the lesion and assess the extent of the tumor invasion and the anatomy of the splenic vessels. The inferior border of the pancreas is mobilized and the superior mesenteric vein (SMV) is identified. The superior border of the pancreas is also mobilized, and the common hepatic artery (CHA), gastroduodenal artery (GDA) and portal vein (PV) are identified. A tunnel is created between the posterior aspect of the neck of the pancreas and the PV. The undersurface of the pancreas is then dissected to free the pancreas from the splenic vessels. The splenic artery can be tortuous and, therefore, meticulous dissection is necessary to avoid vessel injury. As the pancreatic neck is freed from the splenic artery, the overlying coronary vein (left gastric vein) should be identified. It serves as an important anatomic landmark of the celiac trunk, and can be ligated if necessary. Once dissection has been performed to the left of the tumor, a transection plane is identified and marked for pathological examination. The transverse pancreatic arteries are suture ligated, and pancreatic neck is divided using a GIA stapler. The pancreatic parenchyma to the left of the tumor is then transected with cautery scissors or a thermal device while making sure that the pancreatic duct can be identified. The specimen is then placed into an Endo Catch™ (Covidien, New Haven, CT, USA) bag, and removed through the accessory port. Once pathology is confirmed as a benign tumor or a low-grade neoplasm and margins are assessed as being negative, the reconstruction is performed. In case the pathology is found to be malignant or high-grade neoplasm, a formal PD or DP should be performed.

There are two types of reconstruction that can be performed: pancreaticogastrostomy (PG) or Roux-en-y pancreaticojejunostomy. PG is the more commonly used technique. This could be owing to formation of a single anastomosis in comparison to Roux-en-y pancreaticojejunostomy (7). The transected surface of the pancreas at pancreatic head is oversewn using a running V-Loc™ (Medtronic, Minneapolis, MN, USA) suture to ensure hemostasis.

Subsequently, the stomach is allowed to lie flat in the retroperitoneum and an optimal location for the anastomosis is marked. The mobility of the pancreatic tail is assessed to ensure a tension free anastomosis. The cranial and caudal aspects of the pancreas are anchored to the stomach using Corner sutures. The anterior surface of the pancreas is then sutured to the posterior surface of the stomach to create the 'back row' of the PG. A gastrostomy is created to perform a duct-to-mucosa anastomosis using interrupted 5-0 absorbable monofilament sutures over a pediatric feeding tube as a stent. The posterior surface of the pancreas is then sutured to the stomach in a running manner. In cases where the main pancreatic duct is too small to be visualized, an invagination PG can be performed.

Once the anastomosis is complete, the abdomen is examined to ensure adequate hemostasis. Two drains are placed: one in close proximity to transection surface at the pancreatic head and the other in close proximity to the PG anastomosis. The ports are removed and the skin is closed.

Outcomes of MIS CP

The recent increase in patients undergoing CPs can be attributed to more frequent use of cross-sectional imaging resulting in diagnosis of centrally located low-grade and benign pancreatic lesions (22). Despite an overall increase in the number of CPs performed, MIS-CPs are performed less commonly as compared to open CPs; robotic CP is rarer still compared to laparoscopic CP (23). The study identified and reviewed 12 articles reporting outcomes of robotic-CP (6,10,21,22,24-31). One hundred and sixteen cases were reported and patient demographics and characteristics are detailed in *Table 1*. The overall morbidity was 64.7% (N=75), while 2 (1.7%) patients required reoperation and no mortality was observed. Postoperatively, 66 (56.9%), 1 (0.9%) patients developed POPF, and DM respectively and no patients developed exocrine insufficiency. In a majority of studies, the pancreatic enteric anastomosis was performed via pancreatogastrostomy (10,19,22,23).

The largest series of robotic CP (N=50) was reported by Chen *et al.*, in a randomized control trial that randomized patients between open and robotic CP. They reported a significant reduction in the length of stay (P=0.002), median operative time (P=0.002), and median blood loss (P<0.001) in patients undergoing robotic CP. Furthermore, the rate of clinically relevant POPF was also reduced in the robotic CP group (P<0.001) (20).

Recently, Ronnekleiv-Kelly *et al.* reported literature available on open CP in which 15 articles reporting 586 patients were identified (3,7-9,11,33-42). Furthermore, they also reported four studies on 17 patients undergoing laparoscopic CP (19,20,43,44). The mean morbidity reported for open and laparoscopic CP was 50.3% (range, 13.0–72.0%) and 35.3% (range, 0.0–44.0%) respectively. The mean morbidity reported for robotic CP in the articles reported in the study was higher than that reported for open and laparoscopic CP: 64.7% (range, 20.0–100.0%). Contrastingly, the mortality reported for open, laparoscopic and robotic CP was 0.7%, 0.0%, and 0.0%, respectively. Reoperation was required in 3.9%, 5.9% and 1.7% of patients undergoing open, laparoscopic and robotic CP. In terms of complications, the rate of POPF was 34.1%, 23.5%, and 56.9% in patients undergoing open, laparoscopic and robotic CP. Interestingly, when Chen *et al.* compared the rate of clinically relevant POPF in the setting of a randomized control trial comparing open and robotic CP, a significant reduction in rates of POPF in the robotic CP group was observed (P<0.001). While the overall rate of POPF in robotic CP remains high, there is a significant reduction in the rates of clinically relevant POPF. The rate of postoperative DM in patients undergoing open, laparoscopic and robotic CP was 3.2%, 0.0%, and 0.9% respectively. Postoperative exocrine insufficiency was only reported in patients undergoing open CP (6.5%). Pancreatogastrostomy was used for pancreatic enteric anastomosis in 66.0%, 37.5%, and 94.9% of open, laparoscopic and robotic CP.

Compared to open CP, there were improved outcomes for mortality, a lower rate of re-operations, and fewer incidences of postoperative endocrine and exocrine dysfunction observed for robotic CP in this review. Outcomes of robotic CP are thus similar to and in some instances more favorable than those observed for open and laparoscopic CP. Despite the relatively limited number of cases available for review, these outcomes suggest that robotic CP is a feasible procedure for certain centrally located pancreatic lesions when performed at high-volume centers by appropriately trained surgeons.

Conclusions

In select patients, robotic CP is a safe and effective procedure when performed by trained surgeons, with

Table 1 Outcomes following robotic central pancreatectomy

Author	Year	N	Morbidity (%)	Mortality (%)	Reoperation (%)	POPF (%)	DM (%)	EI (%)	Recon PG/PJ	OR time, min (mean)	Mean LOS (days)
Giulianotti *et al*. (6)	2010	3	1 (33.0)	0	0	1 (33.3)	0	0	3/–	320	15
Kang *et al*. (22)	2011	5	1 (20.0)	0	0	1 (20.0)	0	NR	5/–	360	12
Addeo *et al*. (24)	2011	1	1 (100.0)	0	0	1 (100.0)	NR	NR	1/–	450	15
Zureikat *et al*. (31)	2011	4	4 (100.0)	0	0	3 (75.0)	NR	NR	NR	NR	NR
Boggi *et al*. (26)	2012	3	2 (66.7)	0	0	2 (66.7)	0	0	–/3	390	14
Cheng *et al*. (28)	2013	7	6 (85.7)	0	0	5 (71.4)	0	0	7/–	150	21
Zhan *et al*. (29)	2013	10	8 (80.0)	NR	0	7 (70.0)	NR	NR	10/–	219	26
Abood *et al*. (10)	2013	9	8 (88.9)	0	0	7 (77.8)	0	0	7/2	425	10
Zureikat *et al*. (21)	2013	13	13 (100.0)	0	1 (7.7)	12 (92.3)	NR	NR	NR	394	8
Zhang *et al*. (30)	2015	10	8 (80.0)	0	0	5 (50.0)	1 (10.0)	0	10/–	120	20
Addeo *et al*. (25)	2016	1	0	0	0	0	NR	NR	1/–	290	10
Chen *et al*. (32)	2017	50	23 (46.0)	0	1 (2.0)	22 (44.0)	NR	NR	50/–	120	16
All studies	–	116	75 (64.7)	0	2 (1.7)	66 (56.9)	1 (0.9)	0	94/5	294	16

OR, operating room; POPF, postoperative pancreatic fistula; DM, diabetes Mellitus; EI, exocrine insufficiency; LOS, length of stay; NR, not recorded.

outcomes comparable to those of the open or laparoscopic approach. It may potentially become an acceptable and even favored approach for these patients given potential benefits of greater preservation of normal pancreatic parenchyma and spleen preservation.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/apc.2018.01.02
Cite this article as: Javed AA, Hasanain A, Weiss MJ. Robotic central pancreatectomy and pancreatogastrostomy: surgical technique and review of literature. Ann Pancreat Cancer 2018;1:8.

Robotic vascular resections during Whipple procedure

Bassan J. Allan, Stephanie M. Novak, Melissa E. Hogg, Herbert J. Zeh

Division of Surgical Oncology, Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Contributions: (I) Conception and design: BJ Allan, ME Hogg, HJ Zeh; Administrative support: BJ Allan, SM Novak; (III) Provision of study materials or patients: SM Novak; (IV): Collection and assembly of data: BJ Allan, SM Novak; (V) Data analysis and interpretation: BJ Allan, ME Hogg, HJ Zeh; (VI) Manuscript approval: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Herbert J. Zeh, MD. Division of Surgical Oncology, Department of Surgery, University of Pittsburgh Medical Center, 5150 Centre Avenue, Suite 413, Pittsburgh, PA 15232, USA. Email: zehxhx@upmc.edu.

Abstract: Indications for resection of pancreatic cancers have evolved to include selected patients with involvement of peri-pancreatic vascular structures. Open Whipple procedures have been the standard approach for patients requiring reconstruction of the portal vein (PV) or superior mesenteric vein (SMV). Recently, high-volume centers are performing minimally invasive Whipple procedures with portovenous resections. Our institution has performed seventy robotic Whipple procedures with concomitant vascular resections. This report outlines our technique.

Keywords: Robotic-assisted; pancreaticoduodenectomy; Whipple; portovenous reconstruction; vein resection

Received: 12 May 2017; Accepted: 13 December 2017; Published: 17 January 2018.
doi: 10.21037/jovs.2017.12.15
View this article at: http://dx.doi.org/10.21037/jovs.2017.12.15

Introduction

Pancreatic cancer is the fourth leading cause of cancer-related death in the United States. Surgical resection with negative margins is the only curative chance for patients with no evidence of metastasis at diagnosis. Several studies have shown similar outcomes for patients with loco-regional disease as compared to patients with resectable pancreatic cancer, if R0 resections are attained at the time of surgery (1-3). These outcomes are generally seen with the addition of neoadjuvant therapies to the treatment algorithm (4-6).

Pancreatic surgery with major venous resection remains a topic of controversy. However, more institutions are offering this surgery to carefully selected patients. Given the added complexity of pancreatic resection with venous reconstruction, the initial surgical approach was open surgery. However, minimally invasive approaches have recently been applied as selected centers have gained experience in robotic or laparoscopic pancreatic resections (7,8). Various institutional reviews have shown that minimally invasive surgery for pancreatic resections that treat borderline resectable or locally advanced pancreatic tumors is both safe and feasible (9-14). This article focuses on the technique of robotic Whipple procedure with concomitant vascular resection used at our institution.

Preoperative workup

A triphasic, contrast-enhanced computed-tomography scan of the abdomen and pelvis is attained to rule out metastatic disease and evaluate the pancreatic tumor and its relationship to the peri-pancreatic vessels. Next, an endoscopic evaluation is performed with ERCP +/− stenting and brushings, and endoscopic ultrasound (EUS) to delineate the extent of vascular involvement and to attain a biopsy for tissue diagnosis. Chemotherapy is recommended for all patients with preoperative evidence of abutment/encasement of peri-pancreatic vessels. We measure CA 19-9 levels before (once patients have normal total bilirubin) and after neoadjuvant therapy. CA 19-9 reduction after neoadjuvant therapies has been associated with increased rates of R0 resection, histopathological response and survival (15). CA 19-9 response, in the absence of radiographic response to neoadjuvant therapy, may at times help decide if a patient is a candidate for surgical exploration, as long as the venous involvement

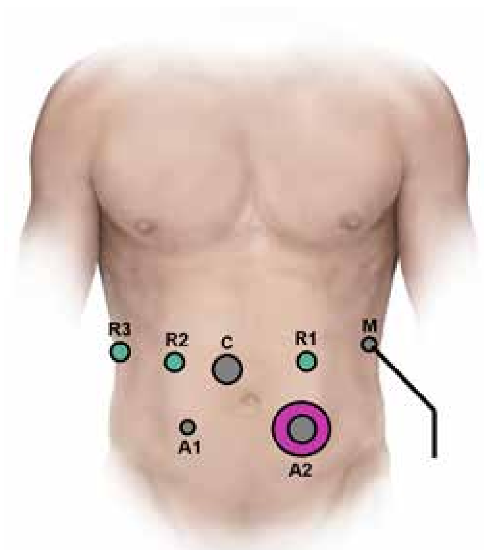

Figure 1 Port placement for robotic Whipple procedure. (R1–3, 8 mm robot ports; C, 12 mm lap port for camera; A1, 5 mm port for assistant; A2, gel mini port for assistant; M, 5 mm port for Mediflex liver retractor).

appears amenable to reconstruction. Specifically, a good inflow and outflow target with a relatively short segment are required. All cases are considered individually and discussed in a multidisciplinary tumor board. Patients are not excluded from being offered minimally invasive resection based on age, body mass index (BMI), or comorbidities; however, prior extensive abdominal surgery, particularly prior pancreatic or liver resection, is considered a relative contraindication. The only absolute contraindication to robotic PD at our institution is vascular encasement of a long segment of the portal vein (PV) or superior mesenteric vein (SMV), which would likely require an interposition graft. We typically use the internal jugular vein as our conduit for interposition grafts. The ergonomics of the robot docked over the patient's head can make this harvest potentially challenging.

Procedure

Anesthesia preparation

Prior to surgery, patients take a bowel prep and are encouraged to carbohydrate-load. Additionally, they are allowed to have clear liquids until two hours prior to surgery. All patients are considered for our institutional enhanced recovery pathway after surgery (ERAS) protocol using multimodal analgesia, minimizing IV opioids and intra-operative goal-directed fluid management. Like other major abdominal procedures, patients receive a dose of prophylactic subcutaneous heparin prior to induction and wear pneumatic mechanical compression boots. Preoperative antibiotics are administered within one hour of incision and re-dosed as indicated. Hemodynamics are monitored with an arterial line, +/- central venous catheter, and Foley. An oral gastric tube is placed after intubation and removed during surgery.

Port placement

Over time several minor modifications have been made to our standard robotic PD (16-18). A split leg table is utilized to allow access to the abdomen for an assistant surgeon. Entry into the abdominal cavity is achieved via a one cm incision in the left upper quadrant using an optical separator trocar and a 0-degree 5-mm scope. The abdominal cavity is then insufflated with CO_2 gas. The abdomen is inspected for evidence of carcinomatosis or metastatic disease. The remaining ports are then placed. A 12-mm port is placed two fingerbreadths above and to the right of the umbilicus, two robotic 8-mm ports are placed in the right upper quadrant, a 5-mm port is placed in the right lower quadrant, a 12-mm port in the left lower quadrant and a 5-mm port in the anterior axillary line on the left side of the abdomen. Typical port placement is depicted in *Figure 1*. A liver retractor is then placed through that anterior axillary line port with a Mediflex.

Laparoscopic preparation

The ligament of Treitz is identified and the bowel is then traced about 80 cm distal to it. This segment of the small bowel is then tacked down to the stomach in an antecolic, isoperistaltic fashion using an EndoStitch. This will be the site for the gastrojejunostomy later on during the reconstruction. The 12-mm ports are closed with a figure of "8" stitch. The patient is then placed in steep reverse Trendelenburg with right side up and the robot is then docked.

The resection

The dissection begins by accessing the lesser sac through the greater omentum below the gastroepiploic pedicle. The distal half of the greater curvature omentum is mobilized.

Then the avascular plane between the colon and the duodenum is separated, allowing for mobilization of the hepatic flexure followed by a Cattell–Braasch maneuver. The colonic mesentery is dissected off Gerota's fascia and rolled over as well, until the duodenum is identified. A Kocher maneuver is then performed all the way from the foramen of Winslow to the Ligament of Treitz, taking down all the fibers until the Inferior Vena Cava and the left renal vein are identified. All the fibers of the Ligament of Treitz are dissected until the jejunum can be delivered through to the right upper quadrant.

For cases where venous resection is anticipated, an extensive colonic mobilization is performed such that the root of the mesentery can be mobilized after transection of the SMV. An outline of the superior mesenteric artery (SMA) from the aorta can also be appreciated at the conclusion of this maneuver. The jejunum is transected approximately ten cm distal to the Ligament of Treitz using a stapler. The bowel mesentery is then taken with an energy device until the uncinate process is reached.

Next, the lesser sac is opened up through the pars flaccida, the right gastric and gastroepiploic arteries are ligated and the stomach is divided with a stapler. The oral gastric tube is removed prior to stomach transection. The dissection continues along the superior pancreas and into the porta hepatis. The common hepatic artery is exposed following removal of the common hepatic lymph node. The gastroduodenal artery (GDA) is then identified and test clamped to confirm blood flow in the common hepatic artery. Flow is assessed visually or with color flow Doppler with robotic ultrasound probe. Once flow is verified, the GDA is stapled and marked with a metal clip. Dissection continues until the common bile duct (CBD) and portal vein are exposed. The CBD is then divided with a stapler. Next, the SMV is dissected off the inferior pancreas and a tunnel is created. Finally, the pancreas is transected with the hot scissors halfway through the gland and the duct is cut with the cold scissors technique.

Vascular dissection

For cases where a vein resection is anticipated an "artery-first" approach is used, staying lateral to the porto-mesenteric venous junction, dissecting inferiorly to superiorly. We often accomplish this through a "hanging maneuver", whereby the SMV above the first jejunal branch, splenic and portal vein are isolated and looped. The third robotic hand can then grasp all three of the vessel loops mobilizing the SMV and PV to the right, allowing for dissection of the SMA. This maneuver helps free the peripancreatic tissues near the SMA allowing for full assessment of the extent of venous resection required. If venous involvement is marginal, we may transect using a microCutter stapler in a tangential fashion or resection with re-approximation by primary venorrhaphy. If abutment is moderate (45–180 degrees of involvement), our preference is to transect and reconstruct using a pericardial bovine patch, as shown on the attached video. Patients with encasement greater than 180 degrees for an extended segment are scheduled for open procedures and reconstructed using Internal Jugular Vein grafts. While there is no technical reason preventing these procedures from being performed with the robotic platform, the logistics and timing of the conduit harvest, concurrent with the steep reverse Trendelenburg positioning are a few challenges that have kept this approach from gaining traction.

Once ready to resect, the patient is heparinized (usually single IV bolus of 3,000 units of heparin) with an unfractionated bolus. The portal vein, splenic vein and SMV are all circumferentially dissected and encircled with vessel loops. Small branches, including the coronary or inferior mesenteric vein, are potentially ligated if within our clamps. Laparoscopic bulldog clamps are placed across the three venous tributaries by the bedside assistant. Next, tangential resection or partial venectomy is performed according to the extent of involvement as described above. Typically we use a 5-0 prolene suture for primary repair or for vascular patches. In the case of a patch, it is sewn in a "diamond" formation and infused with heparinized saline prior to unclamping as demonstrated in video (*Figure 2*). A cholecystectomy is then performed and the specimens extracted via the left lower quadrant.

Reconstruction

The reconstruction then begins with a two-layer, end-to-side, duct-to-mucosa modified Blumgart pancreaticojejunostomy. First, 2-0 silk transpancreatic horizontal mattress sutures are placed to secure the pancreatic parenchyma to the jejunum. Following an enterotomy, interrupted 5-0 PDS sutures are used to approximate jejunal mucosa to the pancreatic duct. A small stent is placed after the posterior duct-to-mucosa stitches and before the anterior ones. A final anterior layer of 2-0 silk buttress sutures completes the anastomosis.

Figure 2 Intraoperative video of robotic pancreatic resection with tumor involvement of the SMV-PV junction. Isolation and control of all major venous vasculature. "Artery-first" approach implemented to isolate tumor to its point of vascular involvement. Transection of involved venous segment with Bovine patch reconstruction in a diamond configuration (19). PV, portal vein; SMV, superior mesenteric vein.
Available online: http://asvidett.amegroups.com/article/view/22378

Attention is next turned to the hepaticojejunostomy, which is performed using two 4-0 V-loc sutures in a running fashion. Finally, an antecolic end to side hand-sewn gastrojejunostomy is performed by using 2-0 silk to place interrupted mattress stitches in the outer layer. The inner layer is performed 3-0 V-loc suture in a running Connell fashion. A Jackson-Pratt drains is left anterior to the pancreaticojejunostomy at the conclusion of the procedure. The instruments are removed and the robot is undocked. The abdominal cavity is suctioned and irrigated out. All incisions are closed in layers.

Video clinical vignette

Our video shows a 58-year-old female who presented with painless jaundice and was diagnosed with cancer of the head of the pancreas. At diagnosis, the tumor measured 38×32 mm^2 by EUS and abutted the SMA and SMV. Her CA 19-9 level was 56. She was started on neoadjuvant chemotherapy, (completed 4 cycles of FOLFORINOX and 2 cycles of gemcitabine/Abraxane) demonstrating a partial radiographic response with tumor regression to a size of 21×8 mm^2 and no longer abutting the SMA. Her post-chemo CA 19-9 level was 15. The patient underwent a robotic pancreaticoduodenectomy with partial venous resection of a 5-cm segment of the lateral wall of the Portal vein/SMV junction and bovine patch reconstruction. Total vascular clamp time was 55 minutes. There were no intra-operative complications. The final pathology showed a 0.8 cm moderately differentiated pancreatic ductal adenocarcinoma invading the peripancreatic tissues, with minimal-to-moderate treatment response, no lymphovascular or perineural invasion, carcinoma involving 2 of 23 nodes and negative margins of resection with a final pathological stage IIB (ypT3 N1 M0). The patient had no post-operative complications, the peripancreatic drain was removed on post-op day 3 and the patient was discharged home on post-op day 7.

Post-operative management

The post-operative management of patients after pancreatic resections with vascular reconstructions is similar to that of our standard robotic pancreaticoduodenectomies. Postoperatively, patients are taken to the surgical floor and the ICU is reserved for patients with significant co-morbidities or per the discretion of the attending surgeon (20). Patients ambulate as early as the evening of the surgery. Nasogastric tubes are not routinely used post-operatively. Patients are kept nothing per os (NPO) the night of surgery, and sips of clear liquids are started on post-operative day (POD) 1. Diets are advanced as tolerated. After vascular reconstructions, patients are given regular strength Aspirin daily starting in the recovery room, initially rectally and subsequently in an oral formulation once they are tolerating a diet. All patients receive chemical deep venous thrombosis (DVT) prophylaxis with subcutaneous heparin prior to surgery, and it is continued post-operatively starting the night of surgery. Patients are closely monitored for any evidence of mesenteric venous hypertension. One of the earliest signs of this is abrupt increase in the volume of the surgical drain with clear non-amylase, non-bilious, non-chylous fluid. A duplex ultrasound can be attained to assess flow of the meso-portal system. If there is any evidence of mesenteric venous hypertension or PV/SMV thrombosis, patients are started on a heparin drip. In our experience, early PV/SMV thrombosis is best treated with systemic anticoagulation and we avoid operative re-exploration as it rarely is able to re-establish a patent graft.

The most common complication affecting patients following pancreatic surgery is a pancreatic fistula. Our standard approach is to leave one drain anterior to the pancreatic anastomosis following completion of surgery. Drain amylase is checked on POD 1 and 3. The drain is removed on POD 3 if: (I) drain amylase is less than 5,000 IU on POD 1 and decreasing by POD 3; (II) the volume of the drain output is less than 500 cc/day; (III) the fluid appearance is non-bilious, non-chylous. The second most common complication is delayed gastric emptying (DGE). DGE results from a functional impairment of gastric motility, resulting in delay to oral intake, prolongation of hospital-stay and poor quality of life. Development of pancreatic leak, post-operative sepsis and need for reoperation are independent risk factors for DGE following pancreaticoduodenectomy (21). Our median length of stay for a patient on the ERAS pathway is 6 days. Patients follow up in the office 2 to 3 weeks after surgery to assess resolution of pancreatic fistulas, discuss final histopathology and to outline a plan for adjuvant therapy as indicated.

Conclusions

The role of minimally invasive pancreatic surgery for pancreas cancer with vascular involvement at the time of surgery is likely to expand as surgeons become more comfortable with Minimally Invasive Surgery (MIS) platforms. Available data stems from high-volume institutional retrospective reviews (22-24), that demonstrate similar operative and oncologic outcomes for MIS compared to standard open pancreatic surgery.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.12.15
Cite this article as: Allan BJ, Novak SM, Hogg ME, Zeh HJ. Robotic vascular resections during Whipple procedure. J Vis Surg 2018;4:13.

Robotic distal pancreatectomy combined with celiac axis resection

Jonathan Greer, Amer H. Zureikat

Division of Surgical Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: AH Zureikat; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Amer H. Zureikat, MD, FACS. Assistant Professor of Surgery, Division of Surgical Oncology, UPMC Pancreatic Cancer Center, University of Pittsburgh Medical Center, 5150 Center Ave., Suite 421, Pittsburgh, PA 15232, USA. Email: zureikatah@upmc.edu.

Abstract: A subset of pancreatic body and tail cancers present with locally advanced disease due to involvement of the celiac axis. Previously considered unresectable, these T4 tumors may be extirpated with a distal pancreatectomy and *en bloc* resection of the celiac trunk in carefully selected patients. In the setting of multimodality treatment, these resections can yield survival similar to resectable and borderline resectable lesions. Robotic surgery has been shown to be safe and feasible in complex pancreatic resections. This article summarizes our patient selection criteria and operative approach to robotic distal pancreatectomy with celiac axis resection (DP-CAR) for locally advanced body and tail tumors of the pancreas.

Keywords: Distal pancreatectomy (DP); celiac axis resection (CAR); robotic pancreatectomy; pancreatic cancer

Received: 12 May 2017; Accepted: 14 August 2017; Published: 18 October 2017.
doi: 10.21037/jovs.2017.08.18
View this article at: http://dx.doi.org/10.21037/jovs.2017.08.18

Introduction

Modern management of pancreatic adenocarcinoma requires multimodality therapy to enhance overall survival, but complete surgical resection remains the most important component. Unfortunately, nearly 80% of patients present with unresectable disease, either due to metastasis or—less commonly—locally advanced disease in which the tumor abuts or encases regional vasculature. The National Comprehensive Cancer Network (NCCN) guidelines define locally advanced pancreatic body and tail tumors as those with involvement of the celiac axis with relative sparing the gastroduodenal artery (GDA) (1). Historically considered unresectable, this cohort of T4 tumors were not offered resection due to concerns of increased operative morbidity and mortality in the face of aggressive disease biology. A recent autopsy study however, demonstrated that a subset of patients with locally advanced pancreatic cancer will succumb to local disease without evidence of metastasis (2). Such data provide a rationale for attempting aggressive local surgical resection in carefully selected T4 tumors.

Lyon H. Appleby initially described his now eponymous procedure in 1952 for locally advanced gastric cancer. The procedure consisted of an *en bloc* gastrectomy, distal pancreatectomy, splenectomy, and celiac axis resection (3). A modified version of this procedure (omitting the gastrectomy) has been adopted for locally advanced pancreatic body and tail cancer, now termed the modified Appleby or distal pancreatectomy with celiac axis resection (DP-CAR). A number of single institutional studies have shown this procedure to be feasible (4-9), however concerns remain regarding the additional morbidity compared to a standard distal pancreatectomy and splenectomy. A recent NSQIP study for example reported that DP-CAR was associated with higher mortality comparted to standard distal pancreatectomy, however the analysis was limited by relatively low numbers of procedures performed at each participating institution and the inclusion of low volume centers and surgeons (10). In contrast, two studies from high volume pancreatic centers recently demonstrated that DP-CAR is safe and feasible if performed by experienced pancreatic surgeons, reporting oncologic outcomes that rival resectable and borderline resectable disease (11,12).

At the University of Pittsburgh, we have attempted to curtail some of the morbidity of pancreatic resections by applying minimally invasive—in particular robotic—platforms to complex gastrointestinal (GI) procedures such as the DP-CAR. Recently, we summarized our 30-case experience and compared 19 open to 11 robotic DP-CARs performed between 2008–2015; morbidity was acceptable in both groups while a decrease in operative time, blood loss, blood transfusion was observed in the robotic cohort (12). Notably, no robotic cases were converted to open DP-CAR and median survival in both groups was nearly 3 years. Based on our experience, we herein highlight our robotic DP-CAR case selection criteria and technique.

Patient selection and preoperative workup

In order to be considered for a DP-CAR at our institution, patients must meet the following criteria: (I) biopsy proven pancreatic body/tail tumor with involvement of any of the branches of the celiac axis, without affecting the trunk itself; (II) the GDA must be present and free of disease; (III) all patients must be eligible for, and have received neoadjuvant therapy in the form of chemotherapy (with or without radiation) and (IV) the patient must have a reasonable performance status.

Patients are imaged preoperatively using a triple phase contrast-enhanced CT scan of the chest, abdomen, and pelvis to delineate vascular anatomy and rule out metastatic disease. Endoscopic ultrasound with fine needle aspiration (FNA) is used for biopsy confirmation of the tumor, which is required for administration of neoadjuvant therapy. A cancer antigen 19-9 (CA19-9) level is also checked and used to monitor response to neoadjuvant therapy. Case discussion at a multidisciplinary conference, involving medical oncology, surgical oncology, radiation oncology, pathology, and radiology, is crucial to proper patient selection.

The patient typically receives one of two neoadjuvant chemotherapy regimens, FOLFIRINOX or gemcitabine-nab paclitaxel. Duration of neoadjuvant therapy is variable but we generally favor a 3–6-month course. Regular interval restaging with physical examination, CA19-9 and CT is performed at 2 monthly intervals. A rise in the CA19-9 during neoadjuvant therapy is a poor prognostic marker, and an indication to switch chemotherapy regimens and delay surgery. In a recent analysis of neoadjuvant therapy for borderline resectable and locally advanced tumors at our institution, no patient with a rising CA19-9 during neoadjuvant therapy was able to achieve an R0 resection (13). Radiation therapy is favored at some institutions in the neoadjuvant setting, however currently its role remains unclear

Surgery is typically undertaken within 4 weeks of completion of neoadjuvant therapy. The decision to pursue robotic versus open surgery is primarily dictated by surgeon preference and level of expertise with the robotic platform. In preparation for surgery, an ERAS protocol may be employed.

Equipment preference card

Two laparoscopic 5-mm ports; three robotic 8-mm portal; one 12-mm laparoscopic port for the camera; one 12-mm laparoscopic working port; da Vinci Si Surgical System (Intuitive surgical); 3.0–4.0-mm tissue (purple) Tri-Staple Endo GIA 60-mm cartridge (Covidien, St. Louis, MO, USA) for pancreatic neck transection; 2.0–3.0-mm vascular (gold) Tri-Staple Endo GIA 45-mm cartridge (Covidien, St. Louis, MO, USA) [for common hepatic artery (CHA), splenic vein, left gastric pedicle]; laparoscopic suction; laparoscopic liver retractor; LigaSure (Covidien, St. Louis, MO, USA); 15-mm Endo Catch bag; robotic Doppler ultrasound; 19-mm fluted Blake drain; #1 Vicryl for fascial closure of 12-mm port site and utility extraction site; 4-0 Monocryl for subcuticular closure.

Patient positioning and role of team members

The patient is placed supine on a split leg table to allow the laparoscopic/bedside assistant easy access to all ports. The table is placed in steep Trendelenburg position and the left arm is tucked. All pressure points are padded. Central venous and arterial lines are placed for hemodynamic monitoring. The operating room bed is placed at 45 degrees angle from the anesthesia machine to allow the robot to be docked over the head. Extra-long endotracheal and intravenous (IV) tubing may be needed, since the patient's head is now further away from the anesthesia cart. The operating team consists of an operating surgeon at the robotic console, a surgical assistant at the bedside, the anesthesiologist, the surgical technician, and the circulating nurse. All members of the operating room staff must be familiar with robotic surgery, particularly patient positioning and robot-specific instrumentation. Additionally, the operative team should be familiar with the processes and procedures needed to safely and efficiently

Figure 1 Robotic distal pancreatectomy with celiac axis resection (14). Available online: http://www.asvide.com/articles/1757

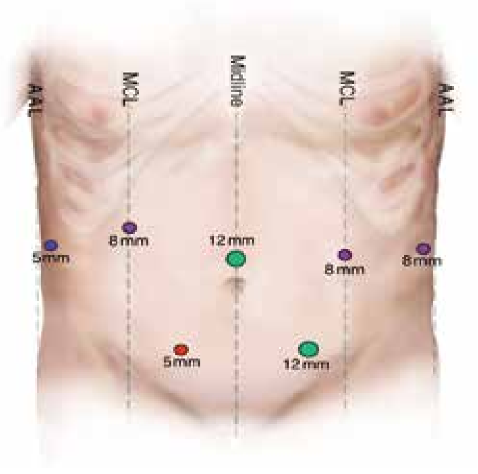

Figure 2 Port sites for robotic distal pancreatectomy and celiac axis resection. Upper ports: 8 mm (purple), robotic arms; 12 mm (green), robotic camera; 5 mm (blue), laparoscopic port for liver/stomach retractor; lower ports: 5 mm (red), laparoscopic assistant port; 12 mm(green): laparoscopic assistant port for stapler/suture/ultrasound probe insertion and specimen extraction. AAL, anterior axillary line; MCL, mid clavicular line.

convert a case to laparotomy.

Procedure

Here, we provide a video of the procedure (*Figure 1*). Laparoscopic and robotic port placement is shown in *Figure 2*. We begin by performing a diagnostic laparoscopy to evaluate for peritoneal spread. In the absence of metastasis, the robot is docked over the head of the patient. The lesser sac is opened and borders of the pancreas are defined. The short gastric vessels are divided with the LigaSure taking care to preserve the right gastroepiploic vessel. The stomach is then retracted to put the left gastric artery and vein under stretch, thereby exposing the neck and body of the pancreas. We then proceed to the medial dissection. Here, the CHA is traced along the superior border of the pancreas distally to locate the takeoff of the GDA. The CHA is test clamped and ultrasound is used to assess the adequacy of collateral flow within the proper hepatic and right and left hepatic arteries. If there is insufficient triphasic flow in these vessels, the robotic DP-CAR should be aborted and consideration given to perform an open DP-CAR with a jump graft from the aorta to the proper hepatic artery.

In the presence of sufficient flow, the pancreatic neck is encircled and transected using a 3.0–4.0-mm Tri-Staple Endo GIA (Covidien, St. Louis, MO, USA) to the left of the GDA. The splenic vein is dissected at its confluence with the superior mesenteric vein (SMV) and transected with a stapler. We then trace the inferior border of the pancreas laterally, with care to identify and ligate the inferior mesenteric vein using a vascular stapler or the ligaSure. The splenic flexure is lowered and the splenorenal and splenocolic ligaments are divided.

The superior dissection is then performed. The CHA is transected using a 2.0–3.0-mm curved-tip vascular Tri-Staple Endo GIA (Covidien, St. Louis, MO, USA), with care taken to preserve the origin of the GDA. The CHA is followed proximally to the celiac axis, where the left gastric artery and vein are transected using a 2.0–3.0-mm curved-tip vascular stapler. The aorta is exposed superior to the celiac trunk and is traced inferiorly until the celiac trunk is located.

Attention is then turned to the inferior dissection. The superior mesenteric artery (SMA) is identified posterior to the pancreas and dissected proximally to its origin from the aorta. At this level, decussating crural fibers are transected exposing the celiac trunk. Using the robotic hook, all lymphatic and perineural tissue surrounding the aorta and celiac trunk is cleared. Confirmation of the location of the SMA and celiac trunk is aided by the use of the robotic ultrasound. Ultrasound is again used to document adequacy of flow through the proper hepatic artery and the porta hepatis prior to transection. The celiac axis is then transected using a 2.0–3.0-mm curved-tip vascular. A 15-mm Endo Catch bag is used to remove the specimens, which is exteriorized after enlarging the left lower quadrant port site. A 19-mm fluted Blake drain is placed in the resection bed and left to bulb suction

Post-operative management

We employ a pancreas-specific ERAS protocol for DP-CAR and other pancreatic resections. Patients are managed post-operatively on a surgical rather than the ICU. The nasogastric tube is removed upon extubation. Multimodal analgesia is employed utilizing a combination of intrathecal morphine or subcutaneous nerve blocks, ketamine or lidocaine for the initial 48 hours, non-steroidal anti-inflammatory drugs (NSAIDS) and acetaminophen. Narcotics are minimized. Venous thrombophylaxis is started on the evening of the operative day, in addition to aspirin if a concomitant portal vein resection is performed. The patient is allowed clear liquids in the recovery room and diet is advanced as tolerated on postoperative day 1. The Foley catheter is removed the morning after surgery. A drain amylase is checked on the first and third postoperative days and—in the absence of leak (ISGPF definition)—is removed on postoperative day 3 or 4. Intravenous fluid rates are kept to a minimum. In addition to known complications observed after distal pancreatectomy, liver abscess and gastric ischemia are unique complications following DP-CAR. The latter complication is suspected in the presence of delayed gastric emptying in conjunction with a leukocytosis and fever. It is best managed with nil per os (NPO), fluid resuscitation and antibiotics. Occasionally prolonged parenteral nutrition is needed.

Tips, tricks, and pitfalls

Judicious patient selection is critical to reducing the morbidity and mortality of this procedure. We advocate that all patients receive neoadjuvant therapy. While on neoadjuvant therapy, serial CA19-9 levels and CT's should be used to guide chemo-responsiveness, identify disease progression, and select patients that may benefit from DP-CAR. If preoperative radiation is used, surgery should be ideally performed within 4 weeks of completion of radiation. Familiarity with the anatomic landmarks including the crura, the SMA and the neuro-lymphoid plexus surrounding the celiac trunk is important. Furthermore, familiarity and experience with the robotic platform prior to attempting a robotic DP-CAR is strongly advised; our group only attempted robotic DP-CARs after accumulating sufficient experience with robotic distal pancreatectomy and pancreaticoduodenectomy.

Careful assessment of preoperative imaging is essential. The use of intra-operative ultrasound to confirm the location of the SMA and celiac trunk, and the adequacy of collateral flow in the setting of temporary (test clamp) CHA occlusion cannot be overemphasized. Lastly, attempting this procedure in a center unfamiliar with the post-operative care of pancreatic surgery patients is unsafe, as even in the most experienced hands, more than half of all patients will experience a complication.

Conclusions

The robotic DP-CAR is a safe and technically feasible approach for highly selected locally advanced body and tail pancreatic adenocarcinomas after neoadjuvant therapy. As neoadjuvant therapies and minimally invasive pancreatic surgery techniques evolve, an increasing subset of patients with locally advanced disease will be candidates for this aggressive surgical approach.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.08.18
Cite this article as: Greer J, Zureikat AH. Robotic distal pancreatectomy combined with celiac axis resection. J Vis Surg 2017;3:145.

Robotic enucleation of benign pancreatic tumors

Ana Sofia Ore, Courtney E. Barrows, Monica Solis-Velasco, Jessica Shaker, A. James Moser

The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA

Contributions: (I) Conception and design: AJ Moser, AS Ore, CE Barrows; (II) Administrative support: AJ Moser; (III) Provision of study materials or patients: AS Ore, CE Barrows, M Solis-Velasco, J Shaker; (IV) Collection and assembly of data: AS Ore, CE Barrows, M Solis-Velasco, J Shaker; (V) Data analysis and interpretation: AS Ore, CE Barrows; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: A. James Moser, MD, FACS. The Pancreas and Liver Institute, Beth Israel Deaconess Medical Center, Harvard Medical School, 185 Pilgrim Avenue, Palmer 6, Boston, MA 02215, USA. Email: ajmoser@bidmc.harvard.edu.

Abstract: Robot-assisted enucleation provides the dual benefits of a minimally-invasive technique and pancreatic parenchymal conservation to selected patients with functional pancreatic neuroendocrine tumors (F-pNETs) and serous cystadenomas. Insulinomas, the most common F-pNETs, are ideal candidates for enucleation when <2 cm given the 80% probability of being benign. Current evidence suggests enucleation for the following: benign, isolated lesions with a distance between tumor and main pancreatic duct ≥3 mm (no focal stricture or dilation), insulinomas, gastrinomas <2 cm, and nonfunctional pancreatic neuroendocrine tumors (NF-pNETs) <1–2 cm and low Ki67 mitotic index. Minimally-invasive enucleation is an imaging-dependent procedure that requires recognizable anatomic landmarks for successful completion, including tumor proximity to the pancreatic duct as well as localization relative to major structures such as the gastroduodenal artery, bile duct, and portal vein. Tumor localization often mandates intraoperative ultrasound aided by duplex studies of intratumoral blood flow and frozen section confirmation. Five patients have undergone robot-assisted enucleation at Beth Israel Deaconess Medical Center between January 2014 and January 2017 with median tumor diameter of 1.3 cm (0.9–1.7 cm) located in the pancreatic head [2] and tail [3]. Surgical indications included insulinoma [2] and NF-pNETs [3]. Median operative time was 204 min (range, 137–347 min) and estimated blood loss of 50 mL. There were no conversions to open or transfusions. Robotic enucleation is a safe and feasible technique that allows parenchymal conservation in a minimally-invasive setting, reducing operative time and length of stay with equivalent pathological outcomes compared to open surgery.

Keywords: Robotic surgical procedure; pancreatic neoplasms; pancreatic adenoma

Received: 26 July 2017; Accepted: 08 August 2017; Published: 28 October 2017.
doi: 10.21037/jovs.2017.08.15
View this article at: http://dx.doi.org/10.21037/jovs.2017.08.15

Introduction

Surgical resection is the only potentially curative treatment for benign and borderline neoplasms of the pancreas. Robot-assisted enucleation provides the dual benefits of a minimally-invasive technique and pancreatic parenchymal conservation to selected patients with functional neuroendocrine tumors (pNETs) and serous cystadenomas. This review describes the technique of robot-assisted enucleation with an up to date description of indications, patient selection, pre-operative evaluation, and post-operative outcomes.

Patient selection

The 2017 NCCN guidelines (1) for functional pancreatic neuroendocrine tumors (F-pNETs) recommend enucleation for superficial insulinomas, gastrinomas, and VIPomas and peripancreatic lymphadenectomy reserved for gastrin and VIP-secreting lesions (2). Enucleation is usually reserved for solitary pancreatic lesions <2 cm in diameter given the link between tumor size and risk for malignancy and metastasis, but has been reported for benign tumors greater than 4 cm, suggesting that tumor type and distance to the main pancreatic duct are more important than

Table 1 Indications for enucleation of pancreatic lesions

(I) Benign tumors (no evidence of malignant disease)
(II) Isolated lesions
(III) Distance between tumor and main PD ≥3 mm (no focal stricture or dilation)
(IV) Insulinomas and gastrinomas <2 cm in size
(V) NF-pNETs when <1–2 cm and low Ki67 mitotic index

NF-pNETs, nonfunctional pancreatic neuroendocrine tumors.

tumor size alone (3,4). Insulinoma is the most common functional neuroendocrine tumor of the pancreas and are ideal candidates for enucleation when <2 cm given 80% probability that such lesions are benign (5,6).

Whereas most insulinomas are benign, other functional pancreatic neuroendocrine tumors such as gastrinomas, VIPomas, glucagonomas, and somatostatinomas have a higher incidence of malignancy and are more controversial targets for enucleation. Preoperative staging is necessary to rule out local invasion or metastasis. Contrast-enhanced CT and MRI detect liver metastasis with 94% sensitivity and demonstrate tumor number and location as well as distance to the main pancreatic duct. Sensitivity ranges between 55–78% for smaller lesions like insulinomas and gastrinomas (4,7,8). Although endoscopic ultrasound (EUS) detects small lesions with a sensitivity of approximately 90% and permits cytological confirmation, the radial detector provides less useful anatomic localization for operative planning (9). Somatostatin receptor-based PET scan can be used to detect metastatic insulinoma and guide medical treatment with somatostatin analogues (2). Specialized studies including arterial calcium stimulation and hepatic venous sampling are now used only sporadically to localize lesions that cannot be identified on imaging studies (10).

Enucleation of nonfunctional pancreatic neuroendocrine tumors (NF-pNETs) should be approached with greater caution (11). Triponez *et al.* reported a correlation between the size of NF-pNETs and the risk of distant metastases, rising from 4% for lesions ≤1 cm, 10% between 1.1–2 cm, and 43% when the tumor was >3 cm (6). Current guidelines do not recommend enucleation for NF-pNETs >1–2 cm or for lesions <1 cm with significant growth in the prior 3–6 months (4).

Currently, pNETs share the same TNM/AJCC staging system with pancreatic exocrine tumors albeit with significantly better survival outcomes. The World Health Organization (WHO) recommends histological grading of gastroenteropancreatic neuroendocrine tumors according to mitotic rate and Ki-67 index (2). Current evidence reserves enucleation for lesions meeting specific characteristics (*Table 1*).

Evaluation for hormonal activity

Approximately 30–80% of patients with MEN1 syndrome harbor functional pNETs (4), which may be multifocal. Distinguishing sporadic pNET from MEN1 is critical since MEN1 patients may harbor multifocal disease for which medical management is initially indicated (2). Clinical suspicion for MEN1 requires assessment for multi-gland parathyroid hyperplasia and pituitary tumors (2).

The preoperative biochemical evaluation should be guided by the suspected clinical syndrome. Insulin and gastrin (Zollinger-Ellison syndrome, ZES) are the most common hormones produced by F-pNETs. Insulinomas typically present with symptoms of neuroglycopenia associated with high insulin (>3 mcIU/mL) levels, elevated C-peptide (>0.6 ng/mL) and proinsulin concentrations (>5 pmol/L) (6) during fasting hypoglycemia (<55 mg/dL). Insulinomas are potentially dangerous tumors, and hypoglycemia must be addressed with diet or diazoxide so that localization may be safely obtained (12). Gastrinomas may present with recurrent peptic ulcers, diarrhea, and steatorrhea and manifest as elevated fasting serum gastrin concentration (>10 times elevated) with abnormal basal gastric acid secretion (pH <2) (6). Symptoms may be controlled preoperatively with high-dose proton pump inhibitors (13) and octreotide as required (14).

Technique of robot-assisted enucleation

Suggested equipment

(I) A 5-mm optical separator for peritoneal entry;
(II) A 12-mm Versaport trocar for the robotic camera;
(III) A 5-mm Maryland Ligasure energy device;
(IV) A 5-mm suction irrigator;
(V) Intraoperative ultrasound;
(VI) Da Vinci Robotic Surgery System with fenestrated bipolar; Prograsp; cautery hook; and possibly large needle drivers (robotic instruments).

Patient positioning

The patient is placed on the operating table in a well-padded split leg supine position with a gel-padded foot board. The arm corresponding to the side of the lesion is tucked, and the other arm remains exposed for anesthesia access.

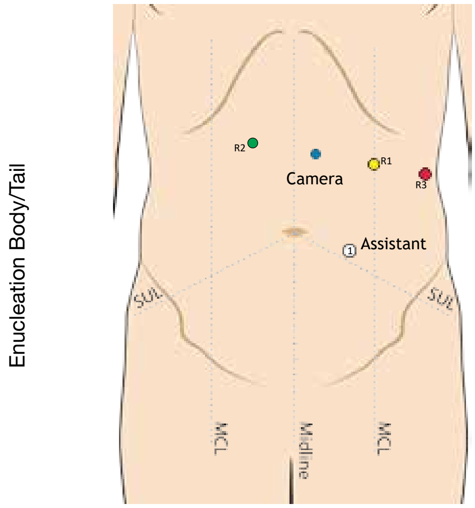

Figure 1 Ports for robotic enucleation of pancreatic lesions located in the body or tail of the pancreas. R1, 8-mm robotic port, R2, 8-mm robotic port, R3, 8-mm robotic port. Liver retractor through a 5-mm port. Camera, 12-mm port; Assistant 1, 12-mm port.

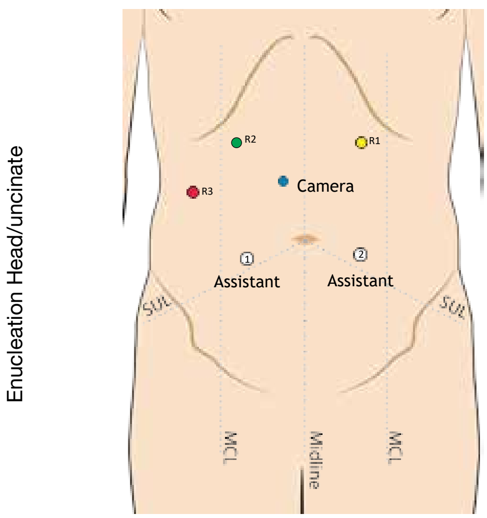

Figure 2 Ports for robotic enucleation of pancreatic lesions located in the head or uncinate process. R1, 8-mm robotic port, R2, 8-mm robotic port, R3, 8-mm robotic port. Liver retractor through a 5-mm port. Camera, 12-mm port; Assistant 1-2, 12-mm port.

Operative technique

Step 1: port placement

We enter the peritoneal cavity in the left midclavicular line approximately three fingerbreadths below the costal margin using a 5-mm optical separator. Six-Seven ports are required: a 5 mm port in the right anterior axillary line to secure the liver retractor; a 12 mm port in the right lower quadrant for ultrasound access and needle passage; a 12 mm camera port located in proximity to the tumor, and three 8 mm robotic ports across the upper abdomen, with the two robot arms on the side of the tumor (*Figures 1,2*).

Step 2: exposure

For lesions of the pancreatic head and uncinate process, the lesser sac is divided and a generous Kocher maneuver is performed to expose the pancreatic head and root of the mesentery. The right gastroepiploic vascular pedicle may be divided to expose the medial border of the pancreatic head and uncinate process. Exposure of the superior mesenteric vein may be required to protect it during enucleation of uncinate process lesions and those over the pancreatic neck.

For tumors of the pancreatic body/tail, the greater omentum is divided as far to the left as required to gain adequate exposure, which may require dividing the short gastric vessels as well as splenic flexure omentum along the inferior border of the pancreas.

Step 3: localizing the lesion

With the anterior surface of the pancreas in view and the stomach retracted, we dock the robot prior to intraoperative ultrasound. Minimally-invasive enucleation is an imaging-dependent procedure that requires recognizable anatomic landmarks for successful completion. Critical information includes tumor proximity to the pancreatic duct as well as localization relative to major structures such as the gastroduodenal artery or bile duct, as well as the portal vein behind the pancreatic neck. Intraoperative palpation is not feasible. Localization often mandates intraoperative ultrasound aided by duplex studies of intratumoral blood flow and frozen section confirmation. We utilize the console's dual visual/ultrasound image platform to localize the lesion and mark the boundaries of enucleation and to confirm proximity to the main pancreatic duct and adjacent major vascular structures (*Figure 3*). The patient cart's bulk effectively precludes intraoperative palpation through a hand access port.

Step 4: enucleating the lesion

The pancreatic parenchyma around the lesion is marked with cautery scissors at the desired margin distance, and

Figure 3 IOUS during robotic benign enucleation (15). Intraoperative robot-assisted ultrasound is often needed in order to identify the limits of the lesion and its relationship to critical anatomic structures. This video is taken from a successful robotic enucleation of a symptomatic pancreatic head insulinoma and shows the intraoperative ultrasound being used to identify the lesion borders, which were scored on the pancreatic parenchymal surface with cautery scissors to guide the enucleation. The lesion measured 1.6 cm in maximum diameter and was 4 mm below the parenchymal surface, with sufficient clearance of the pancreatic duct, gastroduodenal artery, and superior mesenteric vein. IOUS, intra-operative ultrasound.
Available online: http://www.asvide.com/articles/1759

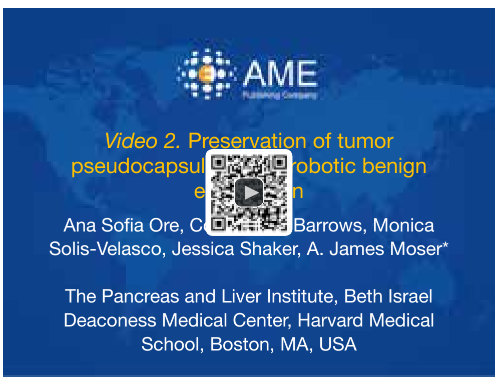

Figure 4 Preservation of tumor pseudocapsule during robotic benign enucleation (16). Successful preservation of the tumor pseudocapsule is critical to achieving a minimal acceptable pathological margin. This often requires a combination of techniques to obtain appropriate traction and counter traction to maintain proper visualization of the pseudocapsule, as shown in this enucleation of a pancreatic body neuroendocrine tumor.
Available online: http://www.asvide.com/articles/1760

a silk suture is used for traction and exposure during dissection. The pancreas is divided sequentially using cautery scissors, with 5-0 Prolene and suction used liberally to maintain visualization of the pseudocapsule which marks the minimal acceptable pathological margin (*Figure 4*).

Step 5: continuity of the pancreatic duct

In the absence of visual evidence that the pancreatic duct has been injured, intraoperative ultrasound is deployed to inspect the deep margin of resection. When in doubt, secretin can be administered while the cavity is observed for signs of a leak. We routinely use a 19 French surgical drain in expectation of a low-output pancreatic fistula.

Post-operative management

An oral diet and pain regimen may be initiated rapidly after minimally-invasive enucleation with expectation of early discharge. Medications, such as diazoxide, used to manage hormone-producing tumors must be adjusted after resection. Surgical drain management is institution-dependent and was not the subject of recent level 1 evidence gathered after pancreaticoduodenectomy or distal pancreatectomy (17).

Postoperative outcomes

The European Association for Endoscopic Surgery Clinical Consensus (13) concluded that minimally-invasive enucleation offered reduced operative time, blood loss and postoperative pain compared to an open approach. Jin *et al.* (18) compared robotic (n=16) to standard open enucleation (n=19) and found shorter operative time (mean 100 min; range, 90–120 min for robotic *vs.* mean 140 min; range, 113–193 min for open; P=0.009) without conversions. Blood loss was reduced, but the difference was not clinically significant (median 30 mL robotic *vs.* 100 mL open; P=0.001). Time to drain removal and discharge were not significantly reduced. Shi *et al.* reported robotic pancreatic enucleation for isolated lesions at least 1–2 mm away from the main pancreatic duct as measured by MRI (3). Mean tumor size was 23 mm, located in the following regions: neck, body, and tail (58%) *vs.* head or uncinate process (42%) (3). Outcomes after robotic enucleation (n=26) demonstrated reduced blood loss and operative time compared to open (n=17) but smaller mean tumor size. No differences in morbidity, post-operative stay, or pancreatic fistula rates were observed. No postoperative diabetes or pancreatic exocrine insufficiency developed in the robotic group. Similar data has been reported after enucleation of ≤ two lesions of 1 cm-diameter or less, in the body or tail (6).

Pancreatic fistula remains the principal concern after enucleation. Univariate analysis of fistula risk by Jin *et al.* (18) reported two important correlations: distance between tumor and the main pancreatic duct as well as operative time. Tian *et al.* conducted a retrospective review of 60 patients who underwent robotic enucleation for benign pNETs <2 cm diameter with a distance >2 mm from the main pancreatic duct (8). Propensity score matching was used to compare 61 robotic enucleations with 187 open procedures and demonstrated no significant difference in pancreatic fistula rates (17% open *vs.* 10% robotic) based on operative approach.

Five patients have undergone robot-assisted enucleation at Beth Israel Deaconess Medical Center between January 2014 and January 2017. Mean age was 56 years (range, 49–66 years) with median tumor diameter of 1.3 cm (0.9–1.7 cm) located in the pancreatic head [2] and tail [3]. Surgical indications included insulinoma [2] and NF-pNETs [3]. Median operative time was 204 min (range, 137–347 min) with 50 mL median estimated blood loss and no conversions or transfusions. One patient developed a post-operative pancreatic fistula. Median time to oral diet was 2 days (1,2). All patients were discharged with a drain. There were no readmissions or deaths at 90 days.

Tips, tricks and pitfalls

(I) Hormonally active neuroendocrine tumors should be evaluated prior to surgery and medicated appropriately to optimize perioperative recovery.

(II) Preoperative cross-sectional imaging and endoscopic intra-operative ultrasound (IOUS) should be used to establish anatomic boundaries for enucleation and estimate proximity to the main pancreatic duct.

(III) Intraoperative ultrasound should be the surgeon's GPS system during enucleation to minimize the risk of margin contamination or pancreatic duct injury.

(IV) Enucleation may require a row of parenchymal sutures to control bleeding during dissection. Bleeding obscures the deep surface of the operative field and may endanger critical structures such as the pancreatic duct, portal or splenic veins, and gastroduodenal or splenic arteries.

(V) The surgical margin should be carefully scrutinized to be certain that tumor is not left behind. This may require frozen section evaluation or specimen ultrasound.

(VI) Post-enucleation ultrasound is mandatory to confirm the integrity of the pancreatic duct. Secretin may be helpful in equivocal cases.

Conclusions

Robotic enucleation is safe and feasible, providing parenchymal conservation in a minimally-invasive setting that reduces operative time and length of stay with equivalent pathological outcomes. Larger studies are needed to confirm these emerging data.

Acknowledgements

Funding: The Alliance of Families Fighting Pancreatic Cancer, the Greg and Cathy Griffith Family Foundation, and the John F. Fortney Charitable Pancreatic Cancer Research Group.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.08.15
Cite this article as: Ore AS, Barrows CE, Solis-Velasco M, Shaker J, Moser AJ. Robotic enucleation of benign pancreatic tumors. J Vis Surg 2017;3:151.

Developing a robotic pancreas program: the Dutch experience

Carolijn L. Nota[1,2], Maurice J. Zwart[3], Yuman Fong[2], Jeroen Hagendoorn[1], Melissa E. Hogg[4], Bas Groot Koerkamp[5], Marc G. Besselink[3*], I. Quintus Molenaar[1*]; for the Dutch Pancreatic Cancer Group

[1]Department of Surgery, University Medical Center Utrecht, CX Utrecht, The Netherlands; [2]Department of Surgery, City of Hope Medical Center, Duarte, California, USA; [3]Department of Surgery, Academic Medical Center Amsterdam, AZ Amsterdam-Zuidoost, The Netherlands; [4]Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, USA; [5]Department of Surgery, Erasmus Medical Center, Rotterdam, CE Rotterdam, The Netherlands

*These authors contributed equally for the senior authorship.

Contributions: (I) Conception and design: CL Nota, IQ Molenaar, MG Besselink; (II) Administrative support: None; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: None; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: I. Quintus Molenaar, MD, PhD. Department of Surgery, University Medical Center Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands. E-mail: I.Q.Molenaar@umcutrecht.nl.

Abstract: Robot-assisted surgery has been developed to overcome limitations of conventional laparoscopy aiming to further optimize minimally invasive surgery. Despite the fact that robotics already have been widely adopted in urology, gynecology, and several gastro-intestinal procedures, like colorectal surgery, pancreatic surgery lags behind. Due to the complex nature of the procedure, surgeons probably have been hesitant to apply minimally invasive techniques in pancreatic surgery. Nevertheless, the past few years pancreatic surgery has been catching up. An increasing number of procedures are being performed laparoscopically and robotically, despite it being a highly complex procedure with high morbidity and mortality rates. Since the complex nature and extensiveness of the procedure, the start of a robotic pancreatic program should be properly prepared and should comply with several conditions within high-volume centers. Robotic training plays a significant role in the preparation. In this review we discuss the different aspects of preparation when working towards the start of a robotic pancreas program against the background of our nationwide experience in the Netherlands.

Keywords: Pancreatic surgery; robotic surgery; training in robotic surgery

Received: 11 June 2017; Accepted: 28 June 2017; Published: 21 August 2017.
doi: 10.21037/jovs.2017.07.02
View this article at: http://dx.doi.org/10.21037/jovs.2017.07.02

Introduction

Minimally invasive pancreatic surgery is gaining popularity worldwide. Although less overwhelming compared with other sub disciplines of gastrointestinal surgery, the portion of pancreatic resections performed minimally invasive is clearly increasing (1). To date only non-randomized studies are available comparing open resection with minimally invasive techniques in pancreatic surgery. These studies suggest several benefits of minimally invasive surgery including less blood loss and shorter hospital stay (2-5). Currently, multicenter randomized controlled trials are being carried out in the Netherlands comparing open resection with a minimally invasive approach, for both distal pancreatectomy and pancreatoduodenectomy (6,7).

Despite its potential benefits, conventional laparoscopy has several technical drawbacks and is, independent of the outcomes of trials, technically more demanding than open surgery. Rigid (i.e., non-articulating) instruments and uncomfortable ergonomics may hinder the broader implementation of minimally invasive pancreatic surgery.

In 2000, the first commercially available robotic system was introduced to overcome these limitations. This robotic system aims to combine the benefits of open and conventional minimally invasive surgery by providing a 3D, magnified view of the operative field with intra-abdominal articulating instruments, thereby increasing surgical dexterity (8). Potentially, the use of the robotic system enables a larger proportion of pancreatic surgeries to be performed minimally invasively, since the technical benefits of the robot may especially be advantageous in reconstructing anastomoses during a Whipple procedure. Moreover, ergonomics are improved and the use of robotics in minimally invasive surgery potentially shortens the learning curve compared to conventional laparoscopy, as previously shown in different procedures (9,10).

Still, pancreatic surgery remains highly complex and is associated with significant morbidity and mortality rates (11-13). Therefore, when starting a robotic program for pancreatic surgery, it should be well prepared and several conditions must be met prior to performing the first procedures. Training of a dedicated multidisciplinary team should play a key-role in the setup. However, specific training programs for teams performing robotic pancreatic surgery are still scarce.

In the Netherlands, surgeons have been performing laparoscopic pancreatic surgery sporadically for over ten years (1). In 2012, the first robot-assisted distal pancreatectomies were performed and last year the first robot-assisted pancreatoduodenectomies were performed in the University Medical Center Utrecht (UMC Utrecht) after following the University of Pittsburgh Medical Center (UPMC) training program. Next, this program made available nationwide by the Dutch Pancreatic Cancer Group, similar as was done previously for laparoscopic pancreatic surgery (1). Other centers, including the Erasmus Medical Center Rotterdam, recently followed the program. In this review we discuss the steps we took on our road to our first successful robot-assisted pancreatoduodenectomy.

The start of the program

With support of the department and hospital leadership, programs should be started only in high-volume centers. A recent study demonstrated that centers with an annual volume less than 22 minimally invasive pancreatoduodenectomies have inferior outcomes (14). A team of dedicated members from several departments should be composed at the start of the project. A complete team should include experienced pancreatic surgeons, operating room nurses, anesthesiologists, and anesthesiology nurses.

Team: experienced HPB surgeons/pancreatic surgeons

Pancreatic resections are complex procedures, with considerable morbidity and mortality. Performing these procedures in a minimally invasive manner makes it even more complex. We are convinced that extensive experience in open hepato-pancreato-biliary (HPB) surgery is essential when setting up a robotic program. All surgeons involved in our project had extensive experience in open pancreatic surgery. Besides that, the surgeons enrolled in the robotic pancreas program had prior experience with conventional laparoscopic pancreatic surgery or had experience with other robotic procedures, like liver resection. The robotic pancreatoduodenectomy is mostly performed by two surgeons. Thus, preferably, the same surgeons should be involved in the setup.

Team: dedicated scrub nurses

All participating scrub nurses were dedicated HPB scrub nurses with extensive experience in open HPB surgery. Besides this, they had extensive experience in high complex robotic surgery (esophagectomies, liver resections, and/or donor nephrectomies). Especially the combination of these two ensures a short learning curve and a rapid buildup of experience.

Team: anesthesiology

Dedicated HPB anesthesiologists and anesthesiology nurses are needed to ensure fast standardization of the procedure. Performing a pancreatoduodenectomy robotically requires several adjustments, also from the anesthesia team. Airway access can be suboptimal with a docked robot (not with the da Vinci *Xi* system), sequential compression devices are necessary since the patient will be lying in anti-Trendelenburg for a significant period of time and extra long IV lines may be necessary to obtain enough space for the robotic system.

Equipment

Alongside the dedicated team, the right equipment should be available. In the Netherlands, most centers started with robotic pancreatic surgery relatively late compared to other robotic procedures; therefore most of the needed equipment and instruments were already available. Intuitive Surgical's da Vinci *S* system, as well as the da Vinci *Si* system and da Vinci *Xi* system are suited for the robotic pancreatoduodenectomy (Intuitive Surgical, Sunnyvale, California, USA). In our experience most of the needed instruments were already available in the hospital. Although not used in open pancreatic resections, instruments like laparoscopic liver retractors, silk sutures, v-loc sutures and beanbags were already available.

Training

Training in minimally invasive surgery has been shown beneficial (1,15,16). However, specific training programs for robotic pancreatic surgery are not widely available yet. When starting up a robotic program for a complex procedure like a pancreatic resection, surgical training should have a significant share in the preparation. Especially reconstructions following a pancreatoduodenectomy require advanced suture skills and therefore should be trained extensively.

In the Netherlands, the nationwide LAELAPS training program for laparoscopic pancreatic surgery was initiated in 2013 (1). In this program, surgeons were trained for laparoscopic distal pancreatectomy. Training consisted of video training, detailed description of the technique/procedure and on-side proctoring by an experienced laparoscopic pancreatic surgeon. In procedures performed after the training program, a significant lower conversion rate (38% to 8%), less blood loss and a shorter hospital stay were observed compared to procedures performed before the training program. This program showed that training is feasible, beneficial and was followed by a 7-fold increase the proportion of distal pancreatectomies performed laparoscopically in the Netherlands (1). In 2016, the LAELAPS-2 program for laparoscopic pancreatoduodenectomy was started.

As a continuation of the successful LAELAPS-1 and -2 programs and after the success of the transatlantic implementation of the UPMC training program, a nationwide program for the safe introduction of the robot-assisted pancreatoduodenectomy in the rest of the Netherlands was developed in 2016: LAELAPS-3. The aim of this program was to introduce robotic pancreatoduodenectomy without a learning curve in complications, but only a learning curve in operating time. This program was set-up in close collaboration with Dr. Herbert Zeh and Dr. Melissa Hogg, initiators of the UPMC robotic pancreas program and the specific training program on robot pancreatic surgery, respectively. Their program was the basis of the LAELAPS-3 program.

Nationwide training program: LAELAPS-3

Training in LAELAPS-3 consists of simulation exercises, suture exercises, practicing anastomoses on artificial organs, watching multiple video recordings of all phases of the procedure and on-site proctoring of the first procedures by a UPMC surgeon. Currently, surgeons in four hospitals have performed their first robotic pancreatoduodenectomy.

Basic robot training course

Prior to starting robotic surgery in general, there are several official courses available one can follow in order to get familiarized with the basic use of the robotic system. Although this is not part of the official LAELAPS-3 training program, every surgeon involved in this program is required to have basic knowledge on the use of the robot, preferably obtained after following one of the official courses, e.g., Intuitive Surgical's the *da Vinci*® Technology Training Pathway (17).

Simulation training

The first steps of the program consist of simulation exercises. These exercises can be done on a training robot (e.g., Mimic®, Mimic technologies, Seattle, Washington, USA) or on a da Vinci robotic system with the use of a da Vinci Skills Simulator, or 'backpack' simulator (Intuitive Surgical, Sunnyvale, California, USA).

In the LAELAPS-3 program simulation is subdivided in three categories: pretest, curriculum and posttest. Pretest and posttest consist of the same exercises: several basic exercises on a Mimic or with help of the backpack simulator and three different box trainer exercises (*Figure 1*). The middle part of the simulation training is the 'curriculum' (18). These are 25 exercises on a Mimic or backpack simulator in which one must obtain a predetermined 90% level of proficiency before passing. Every exercise is taped and scored by the coordinators of the training program using a standardized scoring form.

Advanced suturing and anastomoses training on artificial tissue

In the reconstruction phase of a pancreatoduodenectomy, precise suturing is required for the pancreato-, hepatico- and

Figure 1 The box trainer.

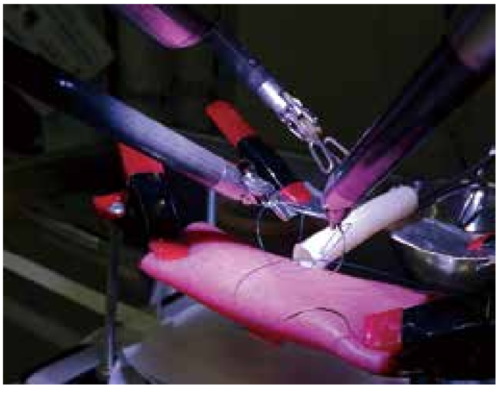

Figure 2 Construction of a hepaticojejunostomy on artificial organs.

gastrojejunostomy anastomoses. Fortunately, the suturing within these anastomoses can be practiced in a simulated situation (19). Hence, simulation plays an important role in this second step of the training program. One will start with basic suture exercises on a piece of artificial human skin. These exercises can be done on a training robot (if available) or in the OR. Next, the anastomoses of the Whipple procedure (e.g., pancreaticojejunostomy and hepaticojejunostomy) are performed on artificial tissue (*Figure 2*). All exercises are recorded and scored by the coordinators of the LAELAPS-3 program. Different aspects of a surgeon's performance are scored using the objective structured assessment of technical skills (OSATS) method, e.g., gentleness, time, flow of the exercise, and instrument handling (20). Currently, these scores are collected in prospective databases for research purposes.

Video training

Although the reconstruction phase of the Whipple procedure can be practiced in a simulated setting easily, this differs for the resection phase of the procedure. The resection phase is trained in our program by a recommended six hours of video observing. These videos are provided on an online platform by UPMC. The platform includes full videos of resections for various pathologies, as well as multiple videos of each phase of the resection and reconstruction. Especially for the resection phase of the procedure, we are convinced that extensive experience in open pancreatic surgery will simplify this part of the operation.

Proctoring of the first procedures

Once the official LAELAPS-3 training program has been successfully completed, the first procedures can be planned. Despite extensive training, the robotic Whipple remains a technically challenging procedure. Hence a more experienced robotic pancreatic surgeon should proctor the first cases. A proctor is more experienced and better aware of the potential obstacles that can be encountered and the possible solutions. Moreover, the direct help of the proctor ensures that the procedure will be finished in a reasonable amount of time.

In our nationwide training program we aim to strategically plan the training sessions for the participating surgeons, so their first procedures can be preferably planned during a single week. In this week, a proctor from UPMC visits the Netherlands to attend the first procedures in different hospitals. The UMC Utrecht has performed over 15 robotic Whipple procedures at this moment and therefore will accompany the proctoring process once the initial learning curve of 20 procedures has been completed.

Patient selection

After finishing training, the most important next step is the initial patient selection. Currently, no guidelines exist for patient selection for minimally invasive pancreatoduodenectomy. In our nationwide experience, patients who underwent pancreatic radiotherapy, extensive upper abdominal surgery, have chronic pancreatitis, who have medical conditions that preclude them from lying in anti-Trendelenburg or who were expected to have problems tolerating pneumoperitoneum, were excluded for undergoing robotic pancreatic resection.

Besides these general exclusion criteria, there are a few other patient and tumor characteristics that should be taken into account. First, body mass index (BMI). There is no consensus currently on ideal BMI for robotic pancreatic surgery. In fact, gaining adequate working space can be difficult when an operating on a patient with a very low BMI. On the other hand, in patients with a significantly higher BMI, it can be troublesome to reach the pancreas with the robotic instruments. When starting up a program, a BMI between 20 and 35 kg/m^2 should be considered for robotic pancreatic surgery. These guidelines can be extended after increased experience. In the ongoing Dutch trials on minimally invasive pancreatic surgery patients with a BMI over 35 are excluded (6,7).

Tumor characteristics should be considered as well, especially in the beginning of one's learning curve. Patients with recurrent acute or chronic pancreatitis, tumors with abutment of the portal vein or SMV that may require vascular reconstruction and large (duodenal) tumors (>6 cm) should not be selected. Although vascular resections have been demonstrated to be safe and feasible in robotic pancreatoduodenectomy, this demands a certain level of expertise and experience (21,22). When selecting patients for a robotic pancreatoduodenectomy, benign lesions (e.g., IPMN or ampullary adenoma) or patients who have a dilated pancreatic duct and/or bile duct, are eminently suited for the first procedures.

Tips, tricks and pitfalls

The vital factor in making a success of your robotic program is team work. Dedication of surgeons, OR staff and the anesthesia team is key. The same team should be involved in, at least, the first ten procedures. Additionally, robotic experts from other departments should be consulted during your startup. Prior to the first procedure, we recommend doing a comprehensive run-through the protocol with the entire team. In this way, the availability of the right instruments is assured and everybody is well aware of one's tasks and attuned to each other.

Second, one should take their time for training and getting the team ready for the first procedure. Although it can be tempting to quickly go through training and start the program, one should not rush into it. This also applies to surgeons who are experienced in pancreatic surgery. Rushing into a procedure like a robotic pancreatic resection can potentially jeopardize patient safety.

Lastly, for the safe setup and expansion of the program an adequate learning curve is essential. Therefore, when starting your program, OR time and robotic availability should be assured for the upcoming months.

Evolution of robots, tools and education

As the Intuitive Robotic systems evolve, and new entries from other companies come into the market, it is likely that complex operations such as pancreatoduodenectomy will get easier, safer, and be accessible to a wider faction of surgeons. With the advent of the Xi robot for example, multi-quadrant surgery no longer requires moving the robot, but simply retargeting the instruments and redocking from the robot in the same location (23). With ever improving stapling and vessel sealing capabilities, the safety of the operation will undoubtedly improve. We will need to be sure educational materials, such as Atlases of robotic surgery are widely available for reference and for ongoing refresh for clinical practice (24). Some professional societies, such as the Society of American Gastrointestinal and Endoscopic Surgery (SAGES), in preparation for widespread adoption of robotic surgery and complex robotic surgery, have begun publication of such atlases.

Conclusions

In conclusion, if well prepared, robotic pancreatoduodenectomy can be safely implemented within high-volume centers. Studies have shown promising results (e.g., reductions in major complications, less blood loss) of the use of a robotic system in pancreatic surgery (2). In order to safely start a robotic program for pancreatic surgery, several components are necessary, including a dedicated team, prior experience with pancreatic surgery and minimally invasive surgery and first and foremost structured training. In our opinion, these factors are essential for the safe and successful implementation. Even though structured training programs for robotic pancreatic surgery are scarce nowadays, it is to be expected that training will be become broader implemented and more important in the future.

Acknowledgements

None.

Footnote

Conflicts of Interest: Dr. Yuman Fong is a scientific advisor to Intuitive Surgical, Medtronic, AVRA Medical Robotics, Inc., Perfint Healthcare Robotics and Johnson & Johnson. The other authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.07.02
Cite this article as: Nota CL, Zwart MJ, Fong Y, Hagendoorn J, Hogg ME, Koerkamp BG, Besselink MG, Molenaar IQ; for the Dutch Pancreatic Cancer Group. Developing a robotic pancreas program: the Dutch experience. J Vis Surg 2017;3:106.

Robotic central pancreatectomy

Ahmad Hamad, Stephanie Novak, Melissa E. Hogg

Division of Surgical Oncology, University of Pittsburgh, Pittsburgh, PA, USA

Contributions: (I) Conception and design: A Hamad, ME Hogg; (II) Administrative support: A Hamad, S Novak; (III) Provision of study materials or patients: A Hamad; (IV) Collection and assembly of data: A Hamad; (V) Data analysis and interpretation: A Hamad, ME Hogg; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Dr. Melissa E. Hogg, MD, MS, FACS. Assistant Professor of Surgery, Division of Surgical Oncology, University of Pittsburgh, Scaife Hall, Suite 497, 3550 Terrace Street, Pittsburgh 15261, USA. Email: hoggme@upmc.edu.

Abstract: Central pancreatectomy (CP) is a parenchyma-sparing procedure that can be utilized in the resection of tumors of the neck or the proximal body of the pancreas. Among 872 open CP reported since 1993, the mean rate of morbidity was 43.2% and mean rate of mortality was 0.24%. The mean pancreatic fistula rate was 28%. The rate of clinically significant pancreatic fistulas with ISGPF Grades B and C was 19%. The rate of development of post-operative diabetes mellitus was at 2% and the average incidence of exocrine insufficiency experienced by patients undergoing open CP was 4.4%. Also, the mean length of hospital stay was around 15 days. In comparison, a total of 100 patients underwent either laparoscopic or robotic CP with a mean rate of morbidity of 37.3% and mean rate of mortality of 0%. Also, the mean rate of development of pancreatic fistula was 36.6%. The rate of clinically significant pancreatic fistulas with ISGPF Grades B and C was 17%. The rate of development of post-operative diabetes mellitus was at 1.5%. None of the patients included in these series developed any postoperative exocrine insufficiency. The mean length of hospital stay was around 13 days. Standard procedures such as DP and PD are associated with lower rates of short-term morbidity such as pancreatic fistula development but are also accompanied with a higher rate of long-term endocrine and exocrine insufficiency due to the significant loss of normal pancreatic parenchyma when compared to CP. It can be inferred, albeit from limited and small retrospective studies and case reports, that conventional and robotic-assisted laparoscopic approaches to CP are safe and feasible in highly specialized centers.

Keywords: Robotic surgery; central pancreatectomy (CP); pancreas; minimally invasive surgery

Received: 15 April 2017; Accepted: 15 May 2017; Published: 26 July 2017.
doi: 10.21037/jovs.2017.05.13
View this article at: http://dx.doi.org/10.21037/jovs.2017.05.13

Introduction

Historically, surgeons have faced a predicament when tackling centrally located pancreatic lesions in the neck or genu. Such lesions pose the problem of needing to resect sufficient parenchyma to minimize the risk of recurrence while simultaneously preserving enough parenchyma to maintain pancreatic endocrine function (1). Central pancreatectomy (CP) is a parenchyma-sparing procedure that can be utilized in the resection of tumors of the neck or the proximal body of the pancreas (2). However, after the operation two transected surfaces of the pancreas remain, which leaves the patient with an increased risk of developing a pancreatic fistula or leak at both ends of the exposed and divided pancreatic duct, a major drawback (3). Other terms used to refer to the CP include: medial, median, segmental, limited conservative, middle segment, intermediate pancreatectomy, and pancreatic isthmusectomy (1).

Oskar Ehrhardt first described the CP in 1908, when he published on segmental pancreatic neck resection (4). Finney, the first president of the American College of Surgeons, followed in 1910 and described the segmental pancreatic neck resection of a cystic tumor (5). Additionally, Takada *et al.* credited the first CP to Honjyo in 1950.

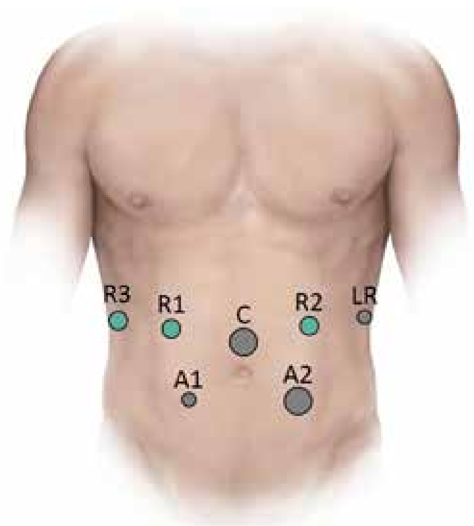

Figure 1 Ports for robotic central pancreatectomy. C, 12-mm camera port; R1, 8-mm robotic port; R2, 8-mm robotic port; R3, 8-mm robotic port; A1, 5-mm laparoscopic assistant port; A2, 12-mm assistant port; LR, 5-mm liver retractor port.

However, Honjyo performed a central resection, and the distal pancreatic stump was not reconstructed (6). Guillemin and Bessot first described the concept of CP followed by reconstruction in 1957 (7). The authors' patient presented with calcific chronic pancreatitis, and by attempting to visualize the main pancreatic duct they inadvertently transected the entire pancreatic neck and thus decided to drain the two pancreatic stumps with an omega jejunal loop. In 1984, Dagradi and Serio performed the first planned CP and reconstruction in order to resect an insulinoma of the pancreatic neck (8). This landmark operation marked the first use of CP (9).

Indications for CP include benign tumors between two and five cm in size, which typically involve the pancreatic duct, benign or low grade lesions at low risk of local regional recurrence, low grade malignant lesions such as neuroendocrine tumors, cystic lesions not suitable for enucleation especially in young patients, cysts that display indeterminate characteristics such as branch-duct-type IPMNs, symptomatic serous or mucinous cystadenomas, pseudopapillary tumors, focal chronic pancreatitis with isolated and short stenosis of Wirsung's duct and solitary metastases in the pancreatic neck. Contraindications to this procedure include malignant tumors such as ductal adenocarcinomas, neoplastic involvement of other adjacent organs such as the stomach or colon, diffuse chronic pancreatitis, large lesions where it is impossible to preserve at least five cm of the left or distal pancreatic stump and distal body-tail atrophy (1,10,11).

Technique

The approach adopted by our experts at the University of Pittsburgh Medical Center (UPMC) is as follows. The patient is placed on a split-leg table in the supine position with the left arm extended at 90° on the arm board. An orogastric tube, a Foley catheter and monitoring lines are inserted. An optical separator is first inserted in the left midclavicular line to access the peritoneal cavity. Next, a 12-mm camera port is placed in the supraumbilical midline, and a 5-mm port is placed in the left anterior axillary line for the liver retractor. Port placement is then continued with the insertion of two robotic 8-mm ports in the right upper quadrant, a 5-mm port in the right lower quadrant and 12-mm assistant port in the left lower quadrant (*Figure 1*). The patient is then placed in reverse Trendelenburg with left side up. The 12-mm ports are closed with a 0-polysorb suture on a Carter-Thompson needle in figure-of-eight fashion.

Subsequently, the robot is docked over the patient's head with two arms on the patient's right side. Of note, two robot arms can also be placed in the left upper quadrant as well. If there is a high chance of performing a distal pancreatectomy (DP) then this is the preference, but both are equally feasible. The standard practice at UPMC is using a Hook monopolar (Intuitive Surgical, Sunnyvale, CA, USA) in console surgeon's right hand and a Fenestrated bipolar in the left hand. The third arm typically has a Cadiere or ProGrasp. The laparoscopic assistant typically has a blunt tipped 5-mm Ligasure (Covidien, Boulder, CO, USA) in the right hand and a suction irrigator in the left hand.

Entry to the lesser sac is achieved through the gastrocolic omentum below the gastroepiploic pedicle. Elevation of the posterior wall of the stomach and exposure of the anterior surface of the pancreas is done using the Mediflex (Mediflex Surgical Products, Islandia, NY, USA) liver retractor. Afterwards, an ultrasound assists in identifying the tumor (*Figure 2A*), determining the lesion's borders and marking the margins of resection. The extent of the right border is the gastroduodenal artery. This can be mobilized 1–2 mm; however, going any more to the right risks injury to the common bile duct. The left has no anatomic border, but the only worth risk is of the pancreatic anastomosis if adequate parenchyma is spared.

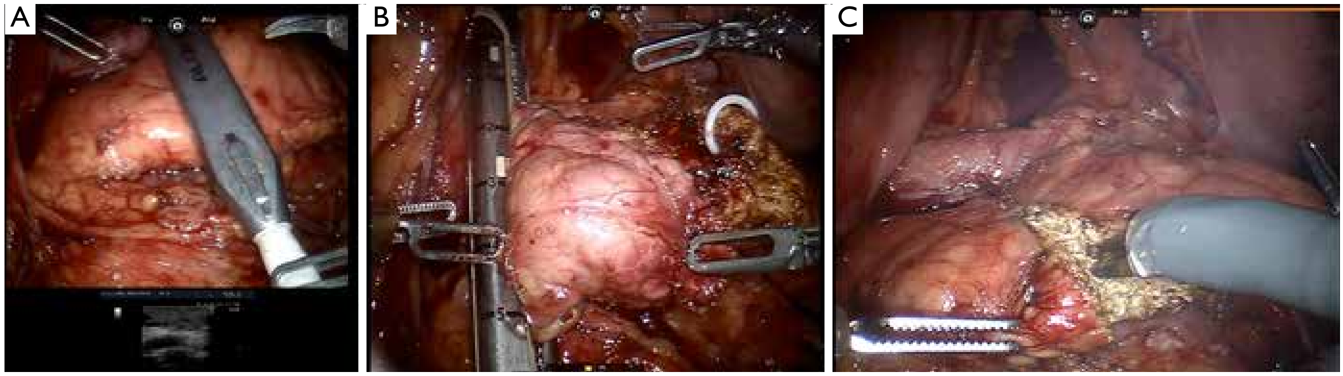

Figure 2 Intraoperative images from robotic-assisted central pancreatectomy. (A) Intraoperative ultrasound is used to identify the tumor, determine the lesion's borders and mark the margins of resection; (B) stapling of pancreatic neck with a vascular stapler. The neck is usually thin allowing for this method of transection. Depending on the thickness and consistency of the pancreas, it may be necessary to use a larger stapler or transect with scissors; (C) transecting distal pancreas with scissors.

After resection, the inferior border of the pancreas is mobilized to elevate the pancreatic neck from the splenic vein-superior mesenteric vein confluence. Exposure to the common hepatic artery, gastroduodenal artery and portal vein at the superior border of the pancreas is easily achieved with removal of the hepatic artery (8A) lymph node. Following removal of this node, the superior pancreatic neck is dissected off the portal vein. A tunnel is created under the neck of the pancreas from the superior mesenteric vein to the portal vain. The pancreatic neck is then divided with a vascular stapler (*Figure 2B*). The neck is usually thin, allowing for this method of transection. Depending on the thickness and consistency of the pancreas, it may be necessary to use a larger stapler or transect with scissors. If the latter is necessary, the pancreatic duct is ligated with a 4-0 polydioxanone suture and the pancreatic parenchyma is oversewn with 3-0 vloc (Covidien, Boulder, CO, USA) horizontal mattress sutures.

Taking precaution to identify and control the left gastric vein as necessary, the central pancreas is then elevated from the splenic vein and artery origin. The dissection between the pancreatic remnant and splenic vein is continued distally using the ultrasound to mark its boundaries in order to ensure adequate tumor surgical margins. Afterwards, the pancreas is transected with monopolar scissors (*Figure 2C*). The transverse pancreatic arteries are easily controlled using the bipolar, as sutures are not necessary along the transverse pancreatic vessels. Using a 12-mm EndoCatch (Covidien, New Haven, CT, USA) bag in the left lower quadrant port, the specimen is removed and frozen section examination of the margins is performed if necessary. If the consistency of the gland is very high risk: soft, friable, tiny duct or if the remnant is small, the CP would be aborted in favor of the DP.

Several options for pancreatic reconstruction exist. In our early experience, we performed a pancreaticogastrostomy (PG). We have subsequently switched to a pancreaticojejunostomy (PJ). Early in the experience the PG was technically easier. However, the downside to a PG is that when a patient leaks, feeding can be problematic, thus necessitating parenteral nutrition. With our more robust experience performing robotic pancreatoduodenectomies, we have transitioned to the PJ.

For the PG, we initially mobilize the greater curvature of the stomach. Next, the anterior surface of the pancreatic remnant is anchored to the posterior wall of the stomach using interrupted horizontal mattress sutures. The pancreatogastrostomy is created using a modified Blumgart technique. First, a small gastrotomy is created using cautery scissors and a pancreatic duct-to-gastric mucosa anastomosis is produced using interrupted 5-0 PDS and bridged with a 7 French Zimmon pancreatic duct stent (Winston-Salem, NC, USA). The posterior surface of the anastomosis is then completed using the transfixion sutures already in place. In the end, two closed-suction drains are placed around the surgical field (1).

Before commencement of the PJ, we first bring up a roux-limb and perform a jejunojejunostomy. We then lift up the transverse mesocolon, identify the ligament of Treitz and measure 40 cm distal. At this point, we make a window in the mesentery and transect the bowel with a linear stapler. Using the Ligasure (Covidien, Boulder, CO,

Figure 3 Technique for robotic-assisted central pancreatectomy (12). Available online: http://www.asvide.com/articles/1591

USA), we take a couple bites in the mesentery, sparing the arcade. We measure another 40–50 cm for the roux-limb and pull this antecolic or retrocolic depending on body habitus, making sure it meets the pancreas without tension. The stapled end of the roux-limb is sutured by the pancreas temporarily to hold it in place. A stitch is then placed by the staple line of the pancreaticobiliary limb and sutured to the bottom portion of the roux-limb. The third hand then pulls this stich cranially. After, using the monopolar, a hole is made in the anti-mesenteric surface of both loops of bowel. A 60-mm stapler is then inserted and fired. The common enterotomy is closed using a 6-inch 4-0 vloc suture in running fashion with lembert stitches.

We perform the PJ using a modified Blumgart technique with three 2-0 silk stitches on a V-20 cut to eight inches and six 5-0 PDS stitches on a CV-23 cut to five inches. We place full-thickness mattress stitches through the pancreas and seromuscular through the bowel. These are tied and the needles left intact. A small enterotomy is made in roux-limb jejunum. Two posterior duct-to-mucosa PDS stitches are placed. A 4 or 5 French Hobbs Stent (Hobbs Medical, Stafford Springs, CT) is placed into duct and bowel. Then four anterior duct-to-mucosa stitches are placed. For these three rows of stitches, our standard practice is to place each row, then tie each row. The last row is a buttress layer using previously placed silk stitches. These are placed seromuscular in bowel and tied as they are placed.

Video clinical vignette

This video depicts a 40-year-old male with a newly discovered well-differentiated pancreatic neuroendocrine tumor (*Figure 3*). He underwent an endoscopic ultrasound that showed a round 12 mm × 11 mm mass in the genu of the pancreas, with well-defined borders. Immunostains were positive for synaptophysin and chromogranin, and weakly positive for CKAE1/AE3. A Ki-67 stain shows a proliferative index of less than 1%. This was initially surveyed with an MRI that demonstrated a stable ovoid mass lesion in the central portion of the pancreas at the junction of the head and neck, measuring 12 mm × 7 mm, consistent with the EUS findings. Given the patient's young age in face of long term surveillance, the patient underwent a robotic CP without any complications. The pathology results demonstrated a well-differentiated pancreatic neuroendocrine tumor, 1.4 cm, WHO grade 1. The Ki-67 index was 1.5%, and zero mitoses per HPF. There was no angiolymphatic or perineural invasion. All margins were negative, and there was no nodal involvement. The patient did well postoperatively and was discharged on post-op day seven with no issues.

CP outcomes

There have been various published series on open CP (*Table 1*). Among 872 open CP reported since 1993, the mean rate of morbidity was 43.2% and mean rate of mortality was 0.24%. The mean pancreatic fistula rate was 28%. The rate of clinically significant pancreatic fistulas with ISGPF Grades B and C was 19%. However, ISGPF nomenclature was not used in all publications. The rate of development of post-operative diabetes mellitus was at 2% and the average incidence of exocrine insufficiency experienced by patients undergoing open CP was 4.4%. Finally, the mean length of hospital stay was around 15 days.

In 2003, Baca and Bokan performed the first laparoscopic CP on a patient with a pancreatic cystadenoma (9). Subsequently, there have been several published case series regarding laparoscopic CP since 2003 (*Table 2*). Recently, the addition of robotic assistance to laparoscopy has redefined minimally invasive surgery by adding the benefits of three dimensional binocular vision, scaling, stabilization of tremor, reduced operative fatigue and improved ergonomics from the console-surgeon interface. In 2004, Giulianotti *et al.* performed the first robot CP (2). In addition to laparoscopic case series, there have been a handful of published case series regarding robotic CP (*Table 2*). In total, 100 patients

Table 1 Published outcomes following open central pancreatectomy

Authors/Year	N	Morbidity (%)	Mortality (%)	Pancreatic fistula (% B/C from total n) (%)	DM (%)	Exocrine insufficiency (%)	Mean LOS (days)
Rotman/1993 (13)	14	29	0	14	0	0	27.6
Ikeda/1995 (14)	24	13	0	13	0	8	NR
Partensky/1998 (15)	10	40	0	0	0	0	NR
Warshaw/1998 (16)	12	25	0	17	0	0	9.6
Iacono/1998 (17)	13	23	0	15	0	0	19
Sperti/2000 (18)	10	40	0	30	0	0	26
Celis/2001 (19)	5	0	0	0	0	0	NR
Sauvanet/2002 (20)	53	41	2	30	2	8	NR
Sugiyama/2004 (21)	5	20	0	0	0	0	NR
Balzano/2003 (22)	32	62	0	50	10	6.2	13.5
Goldstein/2004 (23)	12	25	0	0	17	0	6.5
Efron/2004 (24)	14	50	0	36	0	7	11.1
Shibata/2004 (25)	10	50	0	30	0	0	40
Iacono/2005 (11)	20	35	0	25	0	0	NR
Roggin/2006 (26)	10	60	0	30	10	0	NR
Müller/2006 (27)	40	27.5	2.5	7.5	2.5	45	14
Christein/2006 (28)	8	63	0	63	0	12.5	15
Johnsnon/2006 (29)	8	37.5	0	0	0	0	10.5
Brown/2006 (30)	10	60	0	40	0	0	9
Pratt/2006 (31)	6	83	0	100* [83]	NR	NR	NR
Bassi/2007 (32)	61	51	0	51* [21]	0	0	NR
Crippa/2007 (33)	100	58	0	44* [17]	4	5	13
Allendorf/2007 (34)	26	31	0	7.7	0	0	6.9
Adham/2008 (35)	50	46	0	8	0	22	19.3
Lavu/2008 (36)	34	47.1	0	29.4* [12]	5	0	9.2
Varma/2008 (37)	4	50	0	25	0	0	14.3
Sudo/2010 (38)	19	53	0	47* [47]	0	6	NR
Shikano/2010 (39)	26	38	0	31* [23]	0	4	NR
DiNorcia/2010 (40)	77	39	0	20.5* [16.4]	9.1	6.5	6
LaFemina/2010 (41)	23	70	0	26* [4]	0	0	5
Du/2013 (42)	36	NR	NR	42* [17]	2.8	0	NR
Goudard/2014 (43)	100	72	3	63* [44]	2	6	25
Total	872	43.2	0.24	28 [19]	2.1	4.4	15

*, post-operative pancreatic fistulas were reported using International Study Group of Pancreatic Fistula nomenclature. NR, not recorded.

Table 2 Published outcomes following minimally invasive central pancreatectomies

Authors/Year	Type	N	Morbidity (%)	Mortality (%)	Pancreatic Fistula (% B/C from total n) (%)	DM (%)	Exocrine insufficiency (%)	Mean LOS (days)
Ayav/2005 (44)	Lap	1	NR	NR	NR	NR	NR	NR
Orsenigo/2006 (45)	Lap	1	0	0	0	0	0	10
Sa Cunha/2007 (46)	Lap	6	33	0	33	0	0	18
Rotellar/2008 (47)	Lap	9	33	0	22	0	0	13.5
Sucandy/2010 (48)	Lap	1	100	0	100	0	0	9
Gumbs/2011 (49)	Lap	2	50	0	50	NR	NR	NR
Gonzalez/2013 (50)	Lap	1	0	0	0	NR	NR	6
Dokmak/2014 (51)	Lap	13	77	0	69* [31]	0	0	NR
Machado/2013 (52)	Lap	3	33	0	33* (0)	0	0	7
Zhang/2014 (53)	Lap	1	0	0	0	0	0	8
Chen/2014 (54)	Lap	10	20	0	20* (0)	0	0	13.1
Senthilnathan/2015 (55)	Lap	14	0	0	14* [14]	14	0	8
Giulianotti/2010 (2)	Robotic	3	33	0	33	0	0	15
Kang/2011 (56)	Robotic	5	20	0	20* [20]	0	0	12
Addeo/2011 (57)	Robotic	1	0	0	0* (0)	0	0	15
Boggi/2012 (58)	Robotic	3	66.6	0	66.6* [33.3]	0	0	14.3
Cheng/2013 (59)	Robotic	7	86	0	71* [71]	0	0	21
Abood/2013 (1)	Robotic	9	89	0	78* [22]	0	0	10
Zhang/2015 (60)	Robotic	10	30	0	50* [30]	10	0	19.9
Total	–	100	37.3	0	36.6 [17]	1.5	0	12.5

*, post-operative pancreatic fistulas were reported using International Study Group of Pancreatic Fistula nomenclature. NR, not recorded.

underwent either laparoscopic or robotic CP. Among those, the mean rate of morbidity was 37.3% and the mean rate of mortality was 0%. In addition, the mean rate of development of pancreatic fistula was 36.6%. This relatively high rate compared to the open case series may be due to the much lower sample size in series for minimally invasive surgery for CP. The rate of clinically significant pancreatic fistulas with ISGPF Grades B and C was 17%. However, ISGPF nomenclature was not used in all publications. The rate of development of post-operative diabetes mellitus was at 1.5%. None of the patients included in these series developed any postoperative exocrine insufficiency. The mean length of hospital stay was around 13 days. Ultimately, laparoscopic and robotic-assisted CP can be performed safely with oncologic outcomes comparable to published open series. In conclusion, these multiple series show that laparoscopic and robotic-assisted approaches to CP are safe and feasible and may offer better outcomes for patients.

CP *vs.* DP

In recent times, the diagnosis of incidental pancreatic neoplasms has been on the rise due to the increased use of advanced cross-sectional imaging such as computed tomography (CT) and other imaging modalities to assess nonspecific abdominal symptoms (61). Surgeons may choose to approach such lesions differently by performing either a DP or a CP, among others procedures. Surgeons will weigh up whether to choose a parenchyma-sparing surgery that has a higher risk of postoperative leak and lower risk of long-term endocrine and exocrine insufficiency or a procedure with the opposite outcomes.

Ocuin *et al.* published a study in 2008 comparing 13 patients who underwent CP to 19 patients who underwent an extended left pancreatectomy or DP. It was found that CP patients were significantly more likely to experience complications than those undergoing DP (92% *vs.* 39%, P=0.003) (61). The likelihood of a major complication was only 21% greater in the CP group, but the rate of development of a pancreatic fistula was significantly higher (62% *vs.* 11%, P=0.003). Of those developing a pancreatic fistula, the rate of clinically significant fistulas (ISGPF grade B and C) was 38% in the CP group *vs.* 5.5% in the DP group (P=0.22). However, the DP group had a 17% higher rate of exocrine insufficiency requiring pancreatic enzyme supplementation and had a significantly higher incidence of new-onset diabetes mellitus (57% *vs.* 11%, P=0.04). The only case of new-onset diabetes in the CP group was managed with diet only compared to the patients in the DP group who required medical therapy (61).

Iacono *et al.* performed a meta-analysis of patients who underwent a CP *vs.* patients who underwent a DP. Their study included 359 patients treated by CP and 480 patients treated by DP. Similar to the study performed by Ocuin *et al.*, the overall morbidity was significantly higher after a CP, as was the incidence of pancreatic fistula. However in the Iacono study, CP was found to be associated with a significantly reduced risk of reoperation. The study also found a significant reduction in the incidence of long term endocrine failure after CP, but the reduction in exocrine failure was of only marginal significance (62). Furthermore, Müller *et al.* compared patients undergoing CP to patients undergoing a standard pancreaticoduodenectomy (PD) in addition to patients undergoing a DP. The pancreatic fistula rates for patients undergoing CP, DP and PD were 7.5%, 10% and 2.5%, respectively, although these results were non-significant. However, their study showed a significantly lower rate of endocrine insufficiency in the CP group (15% *vs.* 42% for DP, 29% for PD, P<0.05) (27). This study gave proof to the safety and feasibility of CP in comparison to other procedures for selected patients with benign or low malignant lesions. Finally, Crippa *et al.* compared 100 patients undergoing CP over a 15-year period and found that CP was associated with higher morbidity (51% *vs.* 36%, P=NS) but a lower incidence of long-term endocrine and exocrine insufficiency when compared to patients who underwent DP (33).

Conclusions

In summary, the major motivation behind CP performance is parenchymal conservation. As a result, this procedure should reduce the risk of postoperative diabetes and exocrine insufficiency and allow for the preservation of the spleen and its immunological properties, thus providing good long-term quality of life. Standard procedures such as DP and PD are associated with lower rates of short-term morbidity such as pancreatic fistula development but are also accompanied with a higher rate of long-term endocrine and exocrine insufficiency due to the significant loss of normal pancreatic parenchyma when compared to CP. Minimally invasive surgery such as laparoscopy or robotic-assisted laparoscopy reduces the risk of postoperative morbidity usually encountered with open surgery. The robotic interface offers many technical advantages that overcome the limitations of laparoscopic surgery, such as 2-dimensional imaging, limited range of instrument motion and poor surgeon ergonomics, while permitting a meticulous dissection and reconstruction. It can be inferred, albeit from limited and small retrospective studies and case reports, that conventional and robotic-assisted laparoscopic approaches to CP are safe and feasible in highly specialized centers. However, robotic surgery imposes significant cost and a long learning curve for surgeons training to adopt this new technology. There is a need to further perform comparative studies on the efficacy of minimally invasive approaches with larger population samples.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.05.13
Cite this article as: Hamad A, Novak S, Hogg ME. Robotic central pancreatectomy. J Vis Surg 2017;3:94.

Robotic-assisted spleen preserving distal pancreatectomy: a technical review

Yen-Yi Juo[1,2], Jonathan C. King[2]

[1]Department of Surgery, Center for Advanced Surgical and Interventional Technology (CASIT) at UCLA, Los Angeles, CA, USA; [2]Department of Surgery, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Contributions: (I) Conception and design: YY Juo; (II) Administrative support: JC King; (III) Provision of study materials or patients: JC King; (IV) Collection and assembly of data: YY Juo; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Jonathan C. King, MD, Assistant Professor. Department of Surgery, David Geffen School of Medicine at UCLA, 1304 15th St., Suite 102, Santa Monica, CA 90404, USA. Email: JoKing@mednet.ucla.edu.

Abstract: Minimally-invasive spleen-preserving distal pancreatectomy is indicated for benign or borderline malignant lesions confined to the pancreatic body and tail. With the introduction of the da Vinci robotic system, preliminary case series have suggested an improved spleen preservation rate, higher rate of margin negative resections and improved lymph node yield versus the standard laparoscopic approach. In this article, we described our approach to robotic-assisted distal pancreatectomy with both vessel-conserving (Kimura) and vessel-sacrificing (Warshaw) variations.

Keywords: Minimally-invasive surgery; pancreatectomy; robotic-assisted; laparoscopic

Received: 27 April 2017; Accepted: 07 August 2017; Published: 10 October 2017.
doi: 10.21037/jovs.2017.08.14
View this article at: http://dx.doi.org/10.21037/jovs.2017.08.14

Introduction

Resection of the pancreatic body at any point left of the portal vein is termed distal pancreatectomy (DP) and is traditionally combined with splenectomy. DP with splenic preservation has gained popularity for resection of benign or low-grade malignant lesions of the distal pancreas due to reduced length of postoperative hospital stay and decreased infectious and other severe complications (1,2). Typical indications include: chronic pancreatitis, mucinous cystic neoplasm (MCN), low-grade pancreatic neuroendocrine tumor (PNET), intraductal papillary mucinous neoplasm (IPMN), solid pseudopapillary neoplasm (SPN), and nesidioblastosis (3).

DP is one of the most commonly performed laparoscopic pancreatic surgeries, even considered to be "standard of care" by some authors (4). While laparoscopic DPs still make up the majority of reports in the literature, publication of robotic-assisted DP (RADP) series have steadily increased, confirming the safety and feasibility of the robotic approach (5-10). The da Vinci robotic system provides technical advantages over standard laparoscopy such as stable three-dimensional views, multi-articulated end effectors with seven degrees of freedom, and tremor elimination (11).

While no randomized controlled trial comparing outcomes between laparoscopic DP and RADP has been reported, one retrospective study has suggested that RADP is associated with an increased splenic preservation rate of 95% *vs.* 28% for laparoscopic DP (9). Other perioperative outcomes have been reported by Zureikat *et al.* and show that RADP is associated with comparable or even shorter operative times and conversion to laparotomy (6) and no significant differences in postoperative length of stay, pancreatic fistula, blood transfusion, or readmission rate. RADP is also associated with a higher margin negative resection rate and improved lymph node yield versus laparoscopic DP (8). While the procedural cost is higher with the robotic approach, some argue that this is balanced by shorter overall length of stay making RAPD a cost-effective option (11).

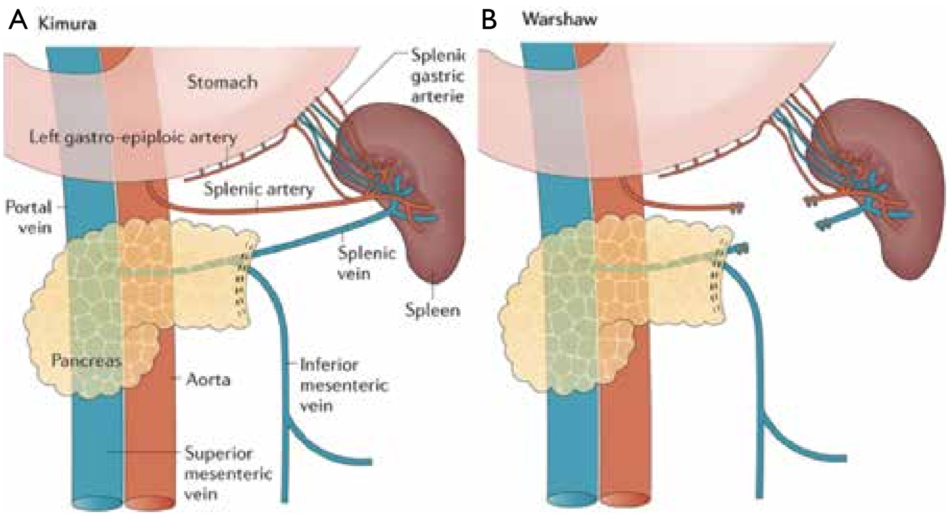

Figure 1 Two different approaches to splenic conservation. (A) Splenic vessel-conserving (kimura) approach and (B) vessel-sacrificing (warshaw) approach to distal pancreatectomy.

There are two approaches to spleen-preserving DP: vessel-preserving and vessel-sacrificing (12) (*Figure 1*). Splenic vessel-preservation (Kimura procedure) (13) allows perfusion of the spleen with its native vasculature. This approach can be technically challenging given it requires dissecting the pancreas from the splenic vein which may be closely adherent. Also, there is some controversy regarding the long-term patency of the splenic vein (1,2). Alternatively, the vessel-sacrificing approach (Warshaw procedure) (14), involves segmental resection of both the splenic artery and vein while the gastroepiploic arcade and short gastric arteries are preserved to provide blood supply and drainage of the spleen. This approach may be associated with splenic infarction, abscess or perigastric varices (15,16). A notable limitation of the Warshaw technique is in patients with splenomegaly where blood flow through the short gastric arteries may not support adequate perfusion.

Spleen-preserving RADP remains a procedure primarily performed in a few large-volume centers. In this technical review, we provide a comprehensive description of our approach.

Patient selection and workup

There are no specific contraindications to spleen-preserving RADP other than confirmed or suspected primary pancreatic malignancy since this requires concurrent splenectomy for lymph node sampling. While adhesions from prior abdominal surgeries and anatomic abnormalities, such as large hiatal hernias, severe scoliosis, and previous bariatric procedures, may pose significant technical challenges for the procedure, these are not absolute contraindications for a surgeon with robotic experience. However, these factors should be considered strongly early in one's experience.

Cross sectional imaging with multi-phase intravenous contrast such as helical computed tomography (CT) should be performed for all potential candidates. Contrast-enhanced magnetic resonance imaging (MRI) with- or without cholangiopancreatography (MRCP) is an acceptable alternative. These studies provide information on the nature of the primary pathology and its anatomic relationship to key surrounding structures such as the splenic vessels and celiac axis (17). Endoscopic ultrasound (EUS) is a useful adjunct to cross-sectional imaging allowing characterization of cystic lesions through aspiration and cyst fluid analysis (18). EUS-guided fine needle aspiration (FNA) may also allow tissue diagnosis, though some have speculated on a potential for seeding the transgastric needle tract (19). In our practice, the diagnostic information provided by trans-gastric FNA outweighs the theoretical risk of tumor seeding. For patients with suspicion of a neuroendocrine tumor octreotide scintigraphy, serum chromogranin A, and assessment of serum hormone concentrations [gastrin, insulin/pro-insulin/C-peptide, glucagon, vasoactive intestinal polypeptide (VIP), pancreatic polypeptide (PP), and 5-HT] may be indicated based on clinical suspicion and patient symptoms.

As with any major operation a thorough cardiopulmonary

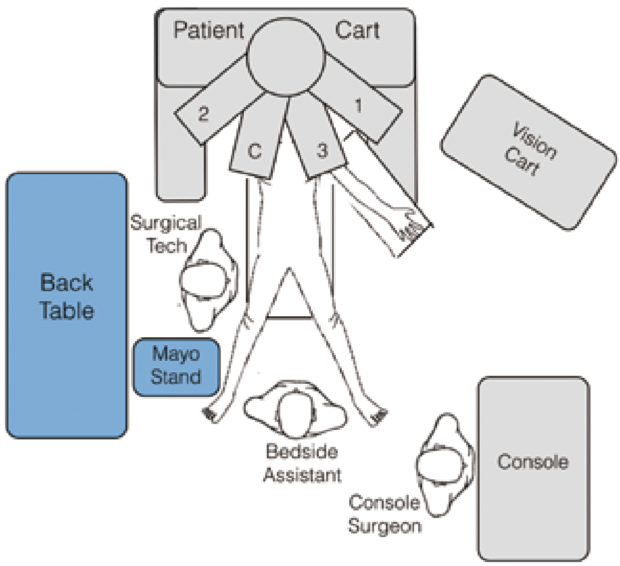

Figure 2 Operation room team member set-up. Despite the clutter introduced by the robotic equipment, each team-member should be allowed an unobstructed view to a monitor at all times.

risk stratification and preoperative optimization is performed. Risk factors for complications following DP include male gender, age, high body mass index (20), soft pancreas (21), chronic pancreatitis (22), malnutrition (hypoalbuminemia), higher American Society of Anesthesiologists score (23), and smoking (24). Among these, smoking and malnutrition are the only modifiable risk factors. Significant weight loss (≥10% pre-morbid body weight), pancreatic insufficiency, biliary obstruction, new-onset or worsening diabetes mellitus, and poor alimentation are of particular importance.

In summary, an individualized and comprehensive approach to patient selection will maximize the chances of operative success while minimizing the chances of perioperative morbidity.

Pre-operative preparation

Bowel preparation is not routinely indicated. Patients adhere to a clear liquid diet for 24 h prior to operation and nil per os starting the midnight prior to surgery. This approach is modified for patients with insulinoma as they generally require admission to the hospital for intravenous 10% dextrose infusion and blood glucose monitoring. A prophylactic, intravenous, broad-spectrum antibiotic is routinely given within an hour of skin incision and re-dosed during operation according to Surgical Care Improvement Project (SCIP) guidelines. Deep vein thrombosis (DVT) prophylaxis with subcutaneous unfractionated or low molecular-weight heparin is also performed routinely. Epidural or para-vertebral regional analgesia is often a useful adjunct for post-operative pain relief.

Equipment preference card

Dissection is carried out with monopolar cautery hook dissector, fenestrated bipolar cautery grasper, and utility grasper forceps (ProGrasp™). A self-retaining liver retractor (Mediflex, Islandia, NY, USA), robotic scissors and Maryland dissectors are used as needed. Standard laparoscopic graspers, scissors, suction-irrigator, and a vessel sealing device such as LigaSure (Covidien-Medtronic, Minneapolis, MN, USA) are important tools for the bedside assistant. In addition, laparotomy trays should be immediately available inside the operation room should indications arise for conversion to open surgery. Commonly used disposables include surgical staplers, laparoscopic clip applier, silastic vessel loops (cut to 4 inches), umbilical tape (cut to 6 inches), and sutures.

Procedure

A typical operating room setup is depicted in *Figure 2*. The patient is positioned supine with the right arm tucked and the left arm extended at the shoulder on a split-leg table. Intravenous access, a nasogastric tube and Foley catheter are placed routinely while an arterial catheter is placed selectively as indicated. All pressure points are padded and we secure the patient to the operative table with straps and foot supports in order to prevent relative movement between patient and the robot (*Figure 3*).

The general order or the operative steps outlined below are not significantly different from laparoscopic DP and they may be modified or re-arranged as clinically indicated.

Port placement/laparoscopy

With the patient in neutral position a 5-mm optical trocar is introduced through the rectus sheath slightly left of midline and 2–3 cm above the level of the umbilicus. Depending on the expected location of adhesions, the method of initial access (i.e., Hasson technique) may be adjusted. Once pneumoperitoneum is established, assess the peritoneum and abdominal organs for evidence of

Figure 3 Patient positioning on the operative table. Patient is placed on a split-leg table, with the right arm tucked and the left arm spread out on an arm board. Care must be taken to ensure all pressure points are padded to decrease risk of skin breakdown.

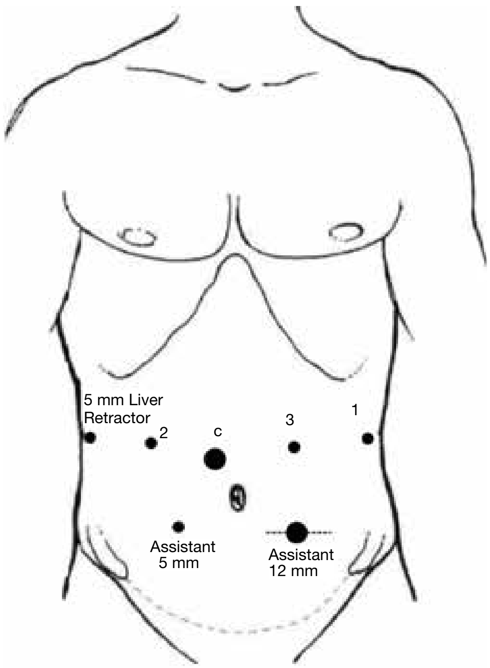

Figure 4 Trocar site positioning. Camera is placed through the umbilical incision (denoted C), robotic instruments are introduced through incisions 1, 2, and 3. Laparoscopic trocars are placed in bilateral lower quadrants for the surgical assistant. Dotted line in the left lower quadrant denotes incision extension for specimen extraction.

metastatic disease or other contraindications to resection. If none are found, additional trocars are placed as shown in *Figure 4*. Approximately 10 cm is required between trocars to minimize conflicts between robotic arms.

The dissection commences by entering the lesser sac through the gastrocolic ligament and opening it widely with a vessel-sealing device, taking care to preserve the gastroepiploic arcade and short gastric vessels (*Figure 5*).

Figure 5 Opening of the lesser sac and exposure of pancreas (25). Available online: http://www.asvide.com/articles/1708

Figure 6 Completed exposure prior to dissection of the pancreas. Note landmarks identifying location of left gastric vessels (blue dotted line) and hepatic artery (red dotted line to anatomic right), splenic artery (red dotted line to anatomic left). Superior border of the pancreas (green solid line).

Laterally, the splenocolic ligament is divided and the splenic flexure of the colon is mobilized inferiorly. At this point the anterior surface of the pancreas is exposed by dissecting adhesions between the stomach and pancreas until the left gastric artery/vein pedicle can be visualized and the liver retractor can be positioned to elevate both the stomach and the left lateral segment of the liver anteriorly, against the abdominal wall (*Figure 6*). Intraoperative ultrasound is used to localize the target pathology, main pancreatic duct, splenic artery, common hepatic artery, superior mesentery artery and superior mesenteric vein.

Patient cart positioning and robot docking

Depending on the robotic system being used, the patient

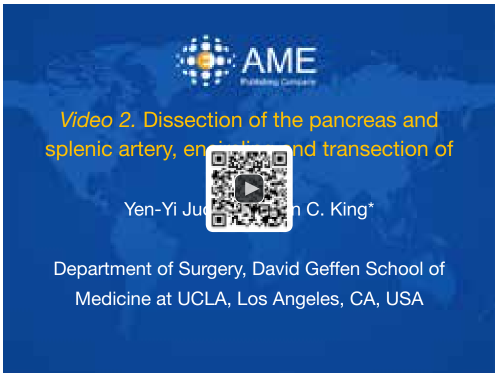

Figure 7 Dissection of the pancreas and splenic artery, encircling and transection of pancreas (26).
Available online: http://www.asvide.com/articles/1709

Figure 8 Dissecting the pancreas from the splenic artery and vein and freeing the specimen (31).
Available online: http://www.asvide.com/articles/1710

cart is positioned over the patient's head (da Vinci S and Si) or from the patient's right side (Xi). Robotic instruments include a ProGrasp™ forceps in arm 1, fenestrated bipolar cautery grasper in arm 2, and monopolar cautery hook dissector in arm 3 (*Figure 4*).

Dissection

The peritoneum along the inferior border of the pancreas is incised with monopolar hook cautery until the pancreatic body can be elevated and the splenic vein identified posteriorly. At the superior border of the pancreas, the splenic artery is identified and dissected circumferentially so that a vessel loop can be placed. Take care to avoid grasping the artery wall directly to prevent trauma or an intimal dissection flap(s) that can predispose to pseudoaneurysm.

The transection point on the pancreatic body is identified (visually or by ultrasound) and marked. A tunnel is created at the planned transection point between the posterior surface of the pancreas and the splenic vein or superior mesenteric vein (SMV) and an umbilical tape is placed to encircle the pancreas (*Figure 7*). Depending on the thickness of the pancreas, a laparoscopic stapler with 3–4-mm (purple load) or 4–5-mm (black load) staples (Endo GIA^{TM}, Medtronic, Minneapolis MN, USA) is used to divide the pancreatic body. A 15-mm trocar is required for black load staplers. Alternatively, the pancreas can be divided with cautery and the stump oversewn with Prolene mattress sutures.

Management of the distal pancreatic stump is controversial. Postoperative pancreatic fistula (POPF) at one week after stapler use was 32% in the multicenter European DISPACT trial, similar to the hand-sewn group (27). Additional staple-line enforcement with seamguard or fibrin glue (28,29) is not associated with decreased POPF rates in retrospective studies. A randomized, controlled trial failed to provide conclusive evidence due to poor accrual (30). With no consensus on the optimal stump closure, the method is determined by surgeon preference and individual patient factors. Our practice is to use surgical staplers without adjunctive measures unless clinical concern for inadequate stump closure is apparent in which case we oversew the stump with a Prolene mattress suture.

If a vessel-sacrificing approach (Warshaw) is chosen, the splenic artery and vein are divided near the pancreatic transection margin using separate vascular staple loads (Endo GIA tan load 2–3-mm staples). The distal pancreas is then mobilized in a medial-to-lateral fashion and the splenic vessels are divided again at the splenic hilum. If a vessel-sparing approach (Kimura procedure) is chosen, the distal portion of the pancreas is dissected from the splenic vein and tributary branches from the pancreas to the splenic vein are sequentially identified, isolated and divided using bipolar cautery, a vessel sealing device, or suture ligation (*Figure 8*). The pancreatic specimen is dissected from the splenic artery with a combination of monopolar cautery and vessel sealing device. Vascular sutures (4-0, 5-0 Prolene cut to 6 inches) should be immediately available throughout this phase of the procedure to manage inadvertent vessel injury.

Specimen extraction/drain placement

Once freed the pancreatic specimen is placed in a retrieval bag and delivered through the left lower quadrant incision which is enlarged transversely as needed. Frozen section analysis is performed to confirm negative margins. In order to re-insufflate the abdomen, we use the GelPOINT-Mini™ (Applied Medical, Rancho Santa Margarita, CA, USA). Alternatively, if one assistant port is sufficient for the remainder of the procedure the incision can be closed.

A 19-French Blake channel drain (Ethicon, Sommerville, NJ, USA) is routinely placed through the left upper quadrant robotic port next to the pancreatic stump. Following removal of all instruments under direct visualization, any fascial incisions greater than 8 mm are closed.

Post-operative management

Care following RADP is similar to laparoscopic DP. Intensive care unit admission is generally not indicated. Regional analgesia with epidural or para-vertebral catheters is continued postoperatively as are chemical and mechanical prophylaxis against DVT. The Foley catheter is removed postoperative day 1 or 2 and nasogastric tubes are usually removed on the day of surgery or postoperative day 1. Oral sips or a clear liquid diet is initiated on postoperative day 1 and advanced as tolerated to a regular diet.

The management of pancreatic drains is standardized and adapted from a protocol published by Molinari *et al.* (32,33). Briefly, serum and drain fluid amylase activity are assayed on the morning of postoperative day 3. If the drain fluid amylase activity is less than or equal to three-times the serum amylase activity and the patient is clinically well, the drain is removed on the following day regardless of the drainage volume.

Tips, tricks and pitfalls

The initial dissection is aimed at widely opening the lesser sac and freeing the posterior body and antrum of the stomach from the anterior surface of the pancreas allowing identification of the pillar of tissue containing the left gastric artery and vein with the caudate lobe to the right and diaphragmatic crus to the left (*Figure 6*). Visualizing this landmark allows identification of the common hepatic and splenic arteries near their origin at the celiac trunk. The splenic artery can be isolated, dissected and divided here (Warshaw technique). Complete mobilization of the splenic flexure of the colon is advisable both to improve visualization of the tail of the gland and to avoid injury to the colon or the tip of the spleen while retracting the colon caudally.

We routinely use intraoperative ultrasound to visualize the primary pathology and plan a transection point with an appropriate margin. Doppler flow ultrasound is also used to confirm pulsatile flow in the hepatic artery while transiently occluding the splenic artery.

Dissecting the pancreas from the splenic vein—if it is to be preserved—is a critical step. Inadvertent tearing of the bridging veins can result in significant blood loss and obscuring of the surgical field making controlled hemostasis difficult or impossible. Initially, direct pressure nearly always controls bleeding and more exact occlusion of the bleeding point can be performed with tissue forceps after clearing the field with suction. Hemostatic suture(s) (4-0 Prolene SH needle, 6 inches in length) can then be placed in a controlled manner. The splenic vein can be divided if bleeding is unable to be controlled with more conservative measures though this may require converting to a spleen-sacrificing procedure. Often this is preferable to converting to an open procedure.

When indicated, we create a vascularized tissue flap with the falciform ligament to protect the splenic artery stump. Anecdotally, this protects against pseudoaneurysm formation and may reduce the incidence of severe post-pancreatectomy hemorrhage.

Splenic infarction and/or abscess, though unusual (<5%) (32), may be a sequela of spleen-preserving DP. Intraoperative visual or Doppler assessment of spleen vascularity at the end of the dissection may help to determine those patients in whom the spleen is not salvageable. Others will present with pain and/or fevers postoperatively. If an undrained abscess is present, antibiotics along with percutaneous image-guided drainage is typically sufficient management. Otherwise, sterile ischemia or necrosis of the spleen may be managed with analgesics and supportive care. Re-operative splenectomy may be required for intractable pain.

Conclusions

The spleen-preserving RADP has demonstrated feasibility and safety in the hands of experienced robotic surgeons. As with all pancreatic surgery, standardization of care and a robust multidisciplinary clinical support team are keys to performing these complex procedures in a safe and efficient manner.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Juo YY, King JC. Robotic-assisted spleen preserving distal pancreatectomy: a technical review. J Vis Surg 2017;3:139. doi: 10.21037/jovs.2017.08.14

Technical considerations for the fully robotic pancreaticoduodenectomy

Daniel Galvez, Rebecca Sorber, Ammar A. Javed, Jin He

Department of Surgery, The Johns Hopkins Hospital Baltimore, MD 21215, USA

Correspondence to: Jin He, MD, PhD. Assistant Professor of Surgery, Department of Surgery, The Johns Hopkins Hospital, 600 N Wolfe Street, Halsted 614, Baltimore, MD 21287, USA. Email: jhe11@jhmi.edu.

Abstract: Minimally invasive surgery, including robotic surgery, has become the standard of care for many abdominal procedures. However, the technical complexity associated with pancreaticoduodenectomy (PD) due to the anatomic location and oncologic characteristics of pancreatic tumors has hindered the widespread application of minimally invasive techniques to this procedure. Recent studies have reported that for experienced surgeons, the application of robotic techniques to PD is associated with equivalent oncologic outcomes and rates of complication when compared to an open operation, and may be associated with accelerated surgical recovery. Despite these encouraging results, robotic PD (RPD) is a procedure attempted by a small group of pancreatic surgeons, leading to the great heterogeneity in the techniques used to perform this operation. Herein we describe our technique for fully RPD and demonstrate its execution with a video supplement.

Keywords: Pancreaticoduodenectomy (PD); robotic surgery; Whipple procedure

Received: 05 April 2017; Accepted: 04 May 2017; Published: 12 June 2017.
doi: 10.21037/jovs.2017.05.08
View this article at: http://dx.doi.org/10.21037/jovs.2017.05.08

Introduction

Pancreaticoduodenectomy (PD), also known as the Whipple, is known to be one of the most challenging and complex abdominal surgical procedures. It remains the only potentially curative procedure for periampullary tumors (1,2). The paramount complexity of this operation can be attributed to the anatomic location of the pancreas within the retroperitoneum, proximity to major visceral vasculature, and the difficult reconstruction required to re-establish gastrointestinal continuity (3-10). In 1994, Gagner and Pomp reported the first successful laparoscopic PD (11-13). Over time, studies have demonstrated the safety and feasibility of laparoscopic pancreatic surgery, as well as reported benefits in terms of postoperative outcomes and equivalent oncologic results when performed by experienced surgeons (14-18). Despite this, only a minority of pancreatic surgeons implemented the laparoscopic approach due to its particular technical challenges, including the difficult nature of the dissection, multiple anastomoses, and steep learning curve.

The development of the robotic surgical platform introduced a three-dimensional view and an extended range of motion, effectively overcoming many of factors limiting a laparoscopic approach to the pancreatic head. In 2003, Giulianotti and colleges reported the first series of robotic PD (RPD) (13). In subsequent years, varied robotic approaches RPD were published, including many hybrid applications of the technology (19). Clearly, despite the technological advantages of the robotic approach, there remains a steep learning curve to the mastery of its technical execution by surgeons. Many institutions remain in the early stages of implementing robotic pancreatic surgery, contributing to the wide variability in how these procedures are performed.

Despite the variation in RPD techniques, data from high volume centers support that RPD equal results in terms of morbidity and mortality, and associated with decreased intraoperative blood loss and length of stay when compared with open approaches (8). Additionally, other studies have demonstrated RPD is associated with equivalent oncologic outcomes in terms of margin positivity

Figure 1 Fully robotic pancreaticoduodenectomy (Whipple procedure) (22).
Available online: http://www.asvide.com/articles/1553

and adequate lymphadenectomy when compared with open techniques (20,21). Although the equivalency of RPD to established open techniques has been demonstrated, the robotic approach associated with extended operative times. Here we describe our technique for RPD, share our tips to facilitate the key steps of the procedure, and demonstrate its operative execution in the accompanying video (*Figure 1*).

Patient selection

Careful patient selection is the critical first step in the successful application of the robotic approach to PD. The potential for conversion to an open approach is relatively high, with an overall conversion rate 17.8% in a recent review (8). While the decision to convert to an open procedure intra-operatively is a reflection of good surgical judgment, there exists a significant expenditure of resources associated with an aborted robotic procedure. This technique should be applied scrupulously with good preoperative as well as intraoperative judgment if it is to benefit outcomes and prove to be cost effective.

The patient's body habitus, prior abdominal surgery, and etiology of the patient's disease should be considered strongly. At experienced centers, RPD can be safely and effectively applied to a wide range of benign and malignant lesions of the pancreatic head and neck with varying degrees of vascular involvement (23-25). However, for those surgeons and institutions in the early stages of incorporating RPD into their practice, it is helpful to apply the technique first to small benign and premalignant pancreatic lesions, as these operations tend to be more anatomically straightforward and with minimal risk of vascular invasion (26). Due to these considerations, high quality imaging in the form of a pancreas protocol CT or MRI is required as part of the preoperative workup to determine resectability, as well as identify any aberrant vasculature.

Clinical summary

The patient in this video was a 68-year-old obese male who presented with several months of indigestion, weight loss and newly diagnosed diabetes mellitus. Subsequent imaging demonstrated a 3.2 cm × 2.3 cm mass in the head of the pancreas with associated dilatation of the main pancreatic duct to 5 mm. The mass was noted to abut the portal vein. Furthermore, the patient was noted to have an accessory right hepatic artery originating from the celiac axis. Endoscopic ultrasound and fine needle biopsy diagnosis of pancreatic ductal adenocarcinoma. Preoperative workup included a high quality abdominal CT scan showing resectable cancer and no evidence of distant metastases. Like other patients presenting with resectable disease at our institution, this patient was enrolled in a clinical trial which he received a combination of cyclophosphamide, nivolumab and a study vaccine in the neoadjuvant setting.

The patient underwent RPD and had an uneventful recovery. On postoperative day (POD) 1, the nasogastric tube was removed and the patient was started on sips of water and ice chips. Deep vein thrombosis prophylaxis was initiated and maintained throughout the hospital course. On POD 2 the Foley catheter was removed and he was able to void spontaneously. By POD 4, he was tolerating a regular diet with pancreatic enzyme supplementation. His JP drains were removed on POD 5 and 6. The average length of stay for a RPD at our institution is 7 days.

Setup

For maximum effectiveness and optimal outcomes after RPD, the importance of a surgical team (i.e., anesthesiologist, bedside assistant, scrub tech and circulator) with robotics experience cannot be overstated. We routinely place a nasogastric tube to decompress the stomach.

After induction of general anesthesia, the patient was placed in a supine and split leg position. A 15 mmHg pneumoperitoneum is established using a Veress needle or a Hasson technique. A 12 mm trocar was placed at the umbilical site and the robotic camera was introduced for abdominal exploration to rule out gross carcinomatosis, liver metastasis and extensive intraabdominal adhesions. If

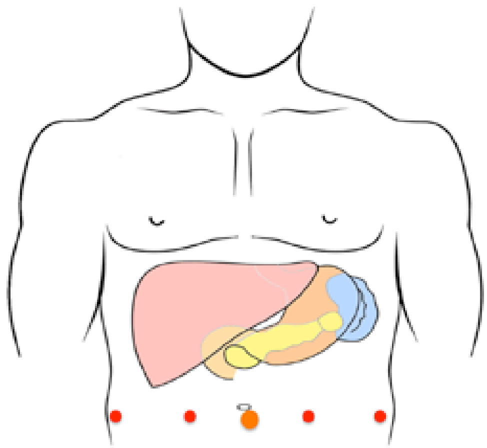

Figure 2 Trocar placement.

no prohibitive anatomy or pathology was identified, four 8 mm robotic trocars were placed (*Figure 2*) under direct visual guidance. After placement of all trocars, the da Vinci Xi system was docked from the patient's left side, with the assistant at the bedside to facilitate instrument exchange.

Exposure and dissection

In general, we perform the dissection starting with the bile duct, followed by the stomach, pancreas and jejunum. A robotic vessel sealer was used to divide the ligamentum teres and falciform ligament. This viable tissue flap may be used later to cover biliary anastomosis and the gastroduodenal artery (GDA) stump. We entered the lesser sac by dividing the gastro-colic ligament on the greater curvature of the stomach, exposing the pancreas. Once the superior and inferior borders of the pancreas were delineated, dissection of the porta hepatis was performed. We dissected the cystic duct and artery within Calot's triangle. After confirming the critical view, we double clipped them with Hem-o-lock clips and transected them with the robotic scissor. We isolated the common hepatic duct and transected it above the confluence of the cystic and common bile duct. Of note, the aberrant anatomy of the hepatic artery should be considered here to avoid injury on a replaced right or accessory right hepatic artery, as was the case in our patient.

We routinely perform portal lymphadenectomy, which helps skeletonize the proper hepatic artery and portal vein. Once isolated, we traced the proper hepatic to the common hepatic artery. The root of the right gastric artery was identified, clipped and transected with the vessel sealer. Next, the GDA takeoff from the hepatic artery was isolated. The GDA was test clamped to ensure adequate hepatic perfusion via the common hepatic artery. Once adequate perfusion was confirmed, the GDA was ligated with a 2-0 silk tie, double clipped with Hem-o-lock clips, and transected with scissors. The vessel sealer was used to take the omentum down from the greater and lesser curves of the stomach. An Endo-GIA stapler was used to divide the stomach approximately 5 cm proximal to the pylorus. The choice of a green or black staple cartridge depends on the thickness of the stomach.

We continued the dissection to mobilize the hepatic artery away from the portal vein along the superior edge of the pancreas. During this part of the portal vein dissection, care should be taken to avoid uncontrolled division of the superior pancreaticoduodenal vein on the lateral side of the portal vein. Dissection was continued along the inferior edge of pancreas. With the portal vein dissected out above the pancreas, the superior mesenteric vein (SMV) could be easily identified. A retropancreatic tunnel on top of the portal vein was carefully created with blunt dissection. We used an umbilical tape to suspend the pancreatic neck to avoid injury to the portal vein during the transection of the pancreatic neck. We continued the sharp dissection to mobilize the pancreatic neck and head off the portal vein. Dissection was continued along the SMV. The first tributary to the SMV is the gastrocolic trunk of Henle, which drains the right gastroepiploic vein and the right superior colic vein. The Henle trunk was carefully dissected out, clipped and transected with scissors. Once the SMV was isolated, the omentum and transverse colon were free from the head of the pancreas.

The Kocher maneuver was performed to mobilize the pancreatic head and duodenum from the retroperitoneum. The inferior vena cava and the abdominal aorta were exposed. The left renal vein often located across the ventral side of the aorta was carefully identified. The root of the superior mesenteric artery (SMA) was above the left renal vein and needed to be very carefully preserved. The ligament of Treitz can often be divided on the right side of the root of mesentery if the patient has minimal amount of intra-abdominal fat. When the patient is obese, it is easier to identify the ligament of Treitz at its normal position and divide it before the Kocher maneuver. After the first portion of the jejunum was pulled to the right upper quadrant, it was transected using an Endo-GIA stapler. The vessel sealer was used to divide the mesentery along the jejunum until the uncinate of the pancreas.

The transection of the uncinate along the right side of the SMA was the most challenging part. The current robotic vessel sealer is bulky and not suitable for fine dissection. When the tumor is not involving the uncinate, the vessel sealer can be used to divide the tissue along the right side of SMA. If the tumor is close to the uncinate, we often use combination of hook cautery and bipolar Maryland clamp to transect the tissue along the SMA. The inferior pancreaticoduodenal artery was identified, isolated, clipped and transected with the vessel sealer. The dissection along the SMA was performed from caudal to cephalad direction. In this particular case, the accessory right hepatic artery was identified as coming from the celiac axis and preserved.

Finally, the gallbladder was taken down from the liver cystic plate using the hook cautery. A large Endo-Catch bag was used to retrieve the Whipple specimen.

Reconstruction

After the specimen was removed from the peri-umbilical port site, we re-established the pneumoperitoneum. Hemostasis was confirmed before the reconstruction. The order of anastomoses performed during the RPD was the same as that in the open procedure, in which the pancreaticojejunostomy (PJ) was performed first, followed by the hepaticojejunostomy (HJ), and finally the gastrojejunostomy (GJ).

We performed a retrocolic standard end-to-side PJ in 2 layers. The posterior edge of the pancreatic neck was secured to the bowel with a running 3-0 V-Loc suture. A pin-hole enterotomy was made next to the pancreatic duct. The duct-to-mucosa anastomosis was performed using 5-0 PDS sutures applied in an interrupted fashion. The caliber of the main pancreatic duct dictates the number of sutures on the PJ and the size of a pancreatic stent. We routinely use pediatric feeding tube as pancreatic stent to across the duct-to-mucosa anastomosis. In general, 4–6 interrupted sutures are sufficient to secure the duct-to-mucosa anastomosis. The PJ was finished with a second anterior line of running 3-0 V-Loc suture between the pancreas and jejunum.

Approximately 5 cm distal to the PJ, an end-to-side HJ was created. The 5-0 PDS sutures were placed in an interrupted fashion to secure the hepatic duct to jejunum. In this case, a total of 12 interrupted sutures were placed to form the HJ. The number of sutures should be dictated by the caliber of the dilated CBD. If the diameter of the hepatic duct were larger than 5 mm in diameter, we would choose the running PDS suture for this anastomosis.

Lastly, the jejunum on the left side of the mesenteric root was identified for GJ anastomosis. We performed an antecolic side-to-side isoperistaltic GJ utilizing a 60 mm blue load Endo-GIA stapler. In order to achieve a tension-free GJ anastomosis, it may be necessary to divide the omentum for obese patients. The enterotomy site was closed with 3-0 V-Loc in 2 layers in a running fashion. In this case, the GJ anastomosis was covered with an omental flap and the ligamentum teres flap was utilized to cover the GDA stump.

We routinely use two 19-French Blake drains through the existing lateral robotic port sites. We find it helpful to have a systematic convention in which the right-sided drain was positioned posterior to the PJ anastomosis and the left-sided drain anterior to the PJ anastomosis.

Tips, tricks and pitfalls

- ❖ Selection of anatomically and pathologically favorable candidate patients is key for successful execution of RPD, especially for those new to the technique.
- ❖ Once isolated, the GDA should be test clamped prior to division to assess hepatic perfusion via the common hepatic artery alone; if adequacy of flow is in question, a Doppler may be introduced for further confirmation.
- ❖ Following retro-pancreatic tunneling, an umbilical tape is passed through the tunnel and used to retract the gland anteriorly to facilitate a controlled pancreatic division.
- ❖ To prevent excess blood loss during final mobilization, care should be taken to actively identify the inferior pancreaticoduodenal vein on the anterior surface of the PV as well as small branches of SMA perfusing the specimen.
- ❖ We perform a 2 layer end to side PJ: the pancreatic neck is secured to the bowel with a running 3-0 V-Loc suture and the pancreatic duct is secured to the jejunal mucosa with 4–6 interrupted 5-0 PDS sutures.
- ❖ The HJ is completed in an end to side fashion with 10–12 interrupted 5-0 PDS sutures; the number of sutures is dictated by the caliber of the dilated CBD.
- ❖ The tissue flap created on division of the ligamentum teres at the beginning of the case may be utilized for protection of the GDA stump.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.05.08

Cite this article as: Galvez D, Sorber R, Javed AA, He J. Technical considerations for the fully robotic pancreaticoduodenectomy. J Vis Surg 2017;3:81.

Robotic transgastric cystgastrostomy and pancreatic debridement in the management of pancreatic fluid collections following acute pancreatitis

Russell C. Kirks Jr, Richard Sola Jr, David A. Iannitti, John B. Martinie, Dionisios Vrochides

Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, Charlotte, North Carolina, USA
Contributions: (I) Conception and design: RC Kirks Jr, JB Martinie, D Vrochides; (II) Administrative support: None; (III) Provision of study materials or patients: JB Martinie, D Vrochides; (IV) Collection and assembly of data: RC Kirks Jr, R Sola Jr, JB Martinie; (V) Data analysis and interpretation: RC Kirks Jr, DA Iannitti, D Vrochides; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.
Correspondence to: Dionisios Vrochides, MD, PhD, FACS, FRCSC. Associate Professor of Surgery, Division of Hepatobiliary and Pancreatic Surgery, Department of General Surgery, Carolinas Medical Center, 1025 Morehead Medical Drive, Suite 600, Charlotte, North Carolina 28204, USA. Email: Dionisios.Vrochides@carolinashealthcare.org.

Abstract: Pancreatic and peripancreatic fluid collections may develop after severe acute pancreatitis. Organized fluid collections such as pancreatic pseudocyst and walled-off pancreatic necrosis (WOPN) that mature over time may require intervention to treat obstructive or constitutional symptoms related to the size and location of the collection as well as possible infection. Endoscopic, open surgical and minimally invasive techniques are described to treat post-inflammatory pancreatic fluid collections. Surgical intervention may be required to treat collections containing necrotic pancreatic parenchyma or in locations not immediately apposed to the stomach or duodenum. Comprising a blend of the surgical approach and the clinical benefits of minimally invasive surgery, the robot-assisted technique of pancreatic cystgastrostomy with pancreatic debridement is described.

Keywords: Pancreatitis; pseudocyst; walled-off pancreatic necrosis (WOPN); cystgastrostomy; robotic surgery

Received: 21 April 2016; Accepted: 29 June 2016; Published: 26 July 2016.
doi: 10.21037/jovs.2016.07.04
View this article at: http://dx.doi.org/10.21037/jovs.2016.07.04

Introduction

Acute pancreatitis results in approximately 250,000 hospitalizations yearly in the United States (1). This diagnosis is confirmed by a history of abdominal pain, elevated pancreatic enzymes, and characteristic findings on cross-sectional imaging (1,2). Approximately 5–15% of these cases develop pancreatic necrosis, which is characterized by hypoperfusion of a portion of the pancreatic parenchyma typically associated with necrosis of peripancreatic tissue (1-4). Pancreatic necrosis may not be evident on the first imaging study and can evolve over several days (4,5). Acute peripancreatic fluid collections may be visualized on imaging at the onset of pancreatitis; however, pancreatic pseudocyst or walled-off pancreatic necrosis (WOPN) both represent delayed, matured fluid collections that typically manifest at least 4 weeks after onset of symptoms. These separate entities develop by different mechanisms and are radiographically distinguishable. A pseudocyst develops from a disruption of the main pancreatic duct or an intraparenchymal ductal branch and contains amylase-rich simple fluid; characteristics include a well-defined, non-epithelialized wall and negligible to minimal solid material within the fluid collection (2). WOPN, conversely, develops from areas of pancreatic necrosis which may have been detected initially by imaging as acute necrotic collections characterized by hypoperfusion of pancreatic parenchyma (2). WOPN contains necrotic pancreatic tissue and potentially necrotic peripancreatic tissue along with a variable amount of fluid. WOPN is differentiated from an acute necrotic collection both by time from symptom onset (>4 weeks) as well as an enhancing, matured capsule of reactive tissue.

Pancreatic pseudocysts

Intervention is typically indicated for pseudocysts that fail to resolve after 6 weeks, are larger than 6 cm, and produce compressive symptoms due to their size and location; examples include gastric outlet obstruction and biliary obstruction (6,7). Pseudocysts may be treated endoscopically or surgically depending upon location (5,6). For those pseudocysts in the retrogastric or periduodenal locations, endoscopic puncture and stenting can allow for resolution via dependent internal drainage. Large series comparing surgical and endoscopic management of symptomatic pseudocysts show high rates of overall success in drainage. Endoscopically treated pseudocysts may require additional procedures to achieve complete resolution, while surgically treated pseudocysts typically require repeat procedures only for distant recurrence or bleeding due to larger anastomoses (8).

WOPN

WOPN can occur in locations similar to those of pseudocysts; however, WOPN requires intervention more often for systemic symptoms or failure to thrive, recurrent fevers, or infection. Due to the inclusion of solid, necrotic material, WOPN is unlikely to completely resolve with passive drainage and requires debridement (5,8). Endoscopic instrumentation has improved to allow some debridement of the encapsulated necrosum with primary success rates of 50–80% (8-10); however, surgical debridement allows access to WOPN not directly opposed to the stomach or duodenum, with paracolic gutter extent, or with large amounts of necrotic tissue. Primary success rates for drainage of pseudocysts and WOPN in surgical series ranges from 85–100% (5,8,9). Additionally, surgical debridement of WOPN resulting from biliary pancreatitis allows for concomitant cholecystectomy. We follow an algorithmic treatment pathway for the surgical management of necrotizing pancreatitis that was developed according to our institutional experience and analysis of clinical outcomes (*Figure 1*).

Technique for robotic cystgastrostomy

Multiple methods for accessing pseudocysts and WOPN exist and are employed based on the location of the collection. Open, laparoscopic, and robot-assisted laparoscopic (RAL) techniques can be used; access to the necrosum can be attained via the lesser sac, through a transduodenal, endogastric, or transgastric approach or via the infracolic approach (6,7). Internal drainage procedures such as cystgastrostomy, cystduodenostomy, or cystjejunostomy with debridement are often sought to decrease the incidence of pancreaticocutaneous fistulae, as an internal enteric fistula is created to avoid transabdominal drainage (6,11).

Initial descriptions of laparoscopic transgastric cystgastrostomy were elaborated as treatment for pseudocysts (12,13); this was subsequently extended to the treatment of WOPN with inclusion of pancreatic debridement (14,15). Depending on the type of trocar used for laparoscopic transgastric pancreatic cystgastrostomy, dislodgement of trocars is feared in descriptions of the procedure. As a combination of the principles of open transgastric cystgastrostomy and the benefits of minimally invasive surgery, RAL cystgastrostomy accesses the gastric lumen via an anterior gastrotomy created with monopolar electrocautery. The superior flap of the gastrotomy can be suspended with the fourth robotic arm or sutured to the posterior surface of the anterior abdominal wall to allow freedom of all robotic arms and instruments.

The WOPN cavity has been entered classically by puncturing the point of maximum indentation into the stomach. Intraoperative ultrasound is used prior to performing a posterior gastrotomy (*Figure 2* at min 2:06) to evaluate the location and extent of the necrosum relative to surrounding anatomy. After making an initial puncture into the fluid collection (*Figure 2* at min 2:20), the posterior gastrotomy is extended to 5–6 cm in length with electrocautery linked to the robotic shears or the vessel sealer device. The interior of the WOPN cavity is then visualized. Necrotic pancreatic tissue is bluntly debrided using fenestrated graspers and irrigation (*Figure 2* at min 2:40). Meticulous debridement of tiny pockets of necrotic tissue is not required due to the continued autodigestion of residual necrotic tissue by gastric acids facilitated by the cystgastrostomy.

Once the necrotic tissue is debrided, it is removed via a laparoscopic retrieval sac at the end of the case. Alternate reports of laparoscopic debridement describe pushing the necrotic tissue toward the pylorus for natural digestion (15). The cystgastrostomy is then sutured robotically in running fashion using absorbable barbed suture (3–0 polydioxanone V-Loc™ suture; Medtronic, Minneapolis, MN, USA) taking full-thickness bites of the cyst and gastric walls (*Figure 2* at min 3:22). A stapling

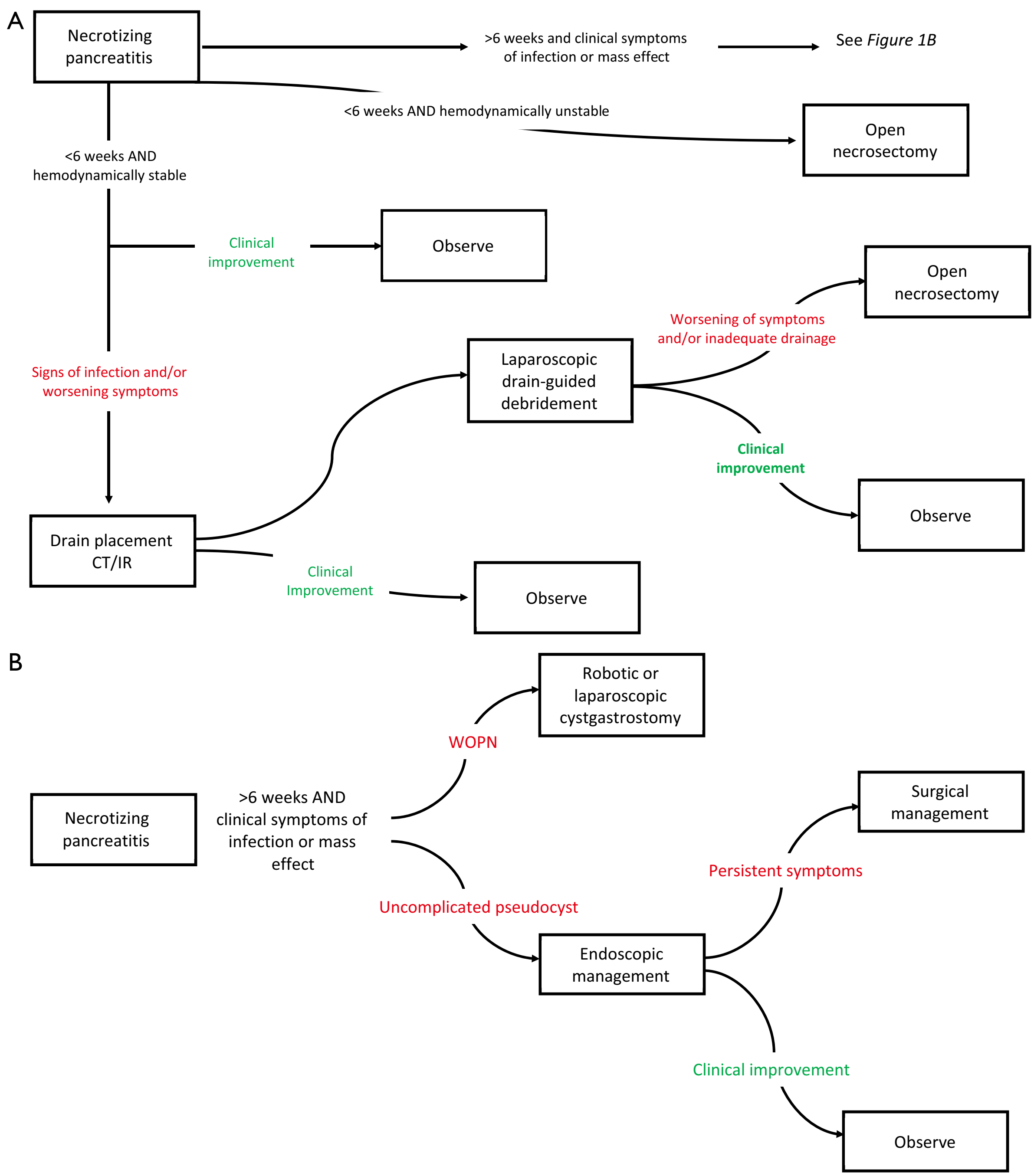

Figure 1 Treatment algorithm for the management of severe acute pancreatitis and its sequelae. (A) Treatment pathway for the management of necrotizing pancreatitis within 6 weeks of symptom onset; (B) treatment pathway for the management of necrotizing pancreatitis following 6 weeks of persistent symptoms. WOPN, walled-off pancreatic necrosis; CT, computed tomography; IR, interventional radiology.

device is not used routinely in the robotic procedure as described in laparoscopic cystgastrostomy (14). The matured cystgastrostomy prevents separation of the posterior wall of the stomach from the WOPN cavity and is performed to decrease the incidence of anastomotic bleeding from the gastric wall and cyst wall. Prior to closing the anterior gastrotomy, a nasogastric tube is directed into the WOPN cavity for use in postoperative

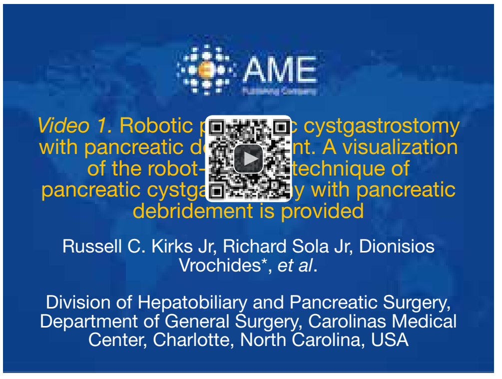

Figure 2 Robotic pancreatic cystgastrostomy with pancreatic debridement. A visualization of the robot-assisted technique of pancreatic cystgastrostomy with pancreatic debridement is provided (16).
Available online: http://www.asvide.com/articles/1050

irrigation of the cavity. Transabdominal drains are not routinely employed postoperatively.

To close the anterior gastrotomy, multiple techniques have been described using permanent or absorbable suture and performing the closure in running or interrupted fashion as well as in one or two layers (12-15). We close the anterior gastrotomy in a single layer using 4–0 V-Loc™ suture (Medtronic) in a single layer taking full-thickness bites of the gastric wall (*Figure 2* at min 4:02). Two sutures are routinely employed for closure, each starting at an apex and meeting at the midpoint of the gastrotomy, where a locking plastic clip is placed on the tails of the suture. The barbed suture is secured in place with the plastic clip and does not require a knot to be tied. We routinely reinforce the gastrotomy closure with an aerosolized fibrin sealant (TISSEEL™; Baxter Healthcare, Deerfield, Illinois, USA). At this time, other indicated procedures may be performed, such as cholecystectomy if the initial pancreatitis resulting in WOPN was biliary in origin. In the absence of other procedures or following their completion, the procedure is terminated. The abdomen is desufflated and robotic ports are removed.

Postoperative management

With the exception of nasogastric tube care, standardized enhanced recovery after surgery (ERAS) pathways are employed in the care of every patient undergoing robotic cystgastrostomy and pancreatic debridement. Specifically, deviation from ERAS pathways occurs in the use of the nasogastric tube to irrigate the retrogastric cavity with normal saline every 6 hours. The nasogastric tube is typically removed on the morning of the second postoperative day. An oral contrast swallow study is not performed to evaluate for anastomotic leak. Similarly, routine postoperative laboratory assessments are obtained on the first postoperative day but do not continue in the absence of clinical or postoperative laboratory evidence indicating repeated evaluations. Once the nasogastric tube is removed, the patients are given a noncarbonated clear liquid diet and advanced as tolerated to a regular diet. Typically, patients are discharged on postoperative day 3–5 depending on tolerance of diet and pain control. Patients are seen in clinic approximately 2 weeks after surgery and then 1 month after surgery, at which time an abdominal computed tomography (CT) scan with intravenous contrast is obtained to evaluate for resolution of the WOPN or pseudocyst.

Tips, tricks, and pitfalls

During creation of the cystgastrostomy, we demonstrate the use of the robotic shears with linked electrocautery. Using an energy device for this portion of the procedure has been described (13,15). Alternatively, though not performed during our robotic cystgastrostomy procedures, multiple firings of an endoscopic or robotic stapler could be used to create the anastomosis as in laparoscopic cystgastrostomy (8,14).

During debridement of the WOPN cavity and mobilization of the necrotic tissue, no haptic feedback exists as with laparoscopic debridement. Converting from laparoscopic to robotic debridement progressively develops a surgeon's visual perception of tissue strain. Only after gaining sufficient robotic experience is a surgeon able to perceive how aggressively to pull and handle the tissue. We argue that the autodigestion afforded by anastomosis to the stomach allows surgeons to leave small traces of necrotic tissue in the cavity in order to prevent tearing of the cavity wall during debridement during initial experience with robotic cystgastrostomy.

Closure of the cystgastrostomy is achieved with one V-Loc™ suture initiating at each apex of the cystgastrostomy. In the video, a locking plastic clip is placed at the midpoint of the cystgastrostomy to anchor the ends of the suture. Alternatively, to avoid opening a clip applier, these barbed sutures can be continued in their respective directions beyond the midpoint to create a double-reinforced central portion of the gastrostomy closure. In this case, no clip or knot would be required.

Acknowledgements

The authors acknowledge Jennifer C. Barnes, PhD, ELS, CMPP for critical review and editing assistance.

Footnote

Conflicts of Interest: Dr. Martinie serves as a consultant and proctor for Intuitive Surgical. Dr. Iannitti serves as a consultant and proctor for Medtronic. All other authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2016.07.04
Cite this article as: Kirks RC Jr, Sola R Jr, Iannitti DA, Martinie JB, Vrochides D. Robotic transgastric cystgastrostomy and pancreatic debridement in the management of pancreatic fluid collections following acute pancreatitis. J Vis Surg 2016;2:127.

Robotic distal pancreatectomy: greatest benefit for the frail?

Ioannis T. Konstantinidis, Laleh G. Melstrom

Division of Surgical Oncology, Department of Surgery, City of Hope National Medical Center, Duarte, CA, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: IT Konstantinidis; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: IT Konstantinidis; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Laleh G. Melstrom, MD, MS, FACS. Division of Surgical Oncology, Department of Surgery, City of Hope National Medical Center, Medical Office Bldg., 1500 East Duarte Road, Duarte, CA 91010, USA. Email: lmelstrom@coh.org.

Abstract: Pancreatic cancer is more common in the elderly who represent a rapidly growing part of the population. Elderly patients are a heterogeneous group and vary greatly in terms of physiologic reserves. Frailty represents a state of reduced capacity to compensate against stressors such as surgery or chemotherapy. Frailty assessment before pancreatectomy or initiation of systemic therapy correlates strongly with postoperative adverse effects, treatment related toxicity and patient outcomes. Robotic assisted surgery represents a lesser physiologic insult compared to open surgery. Most frail patients can better compensate to the stress of a robotic procedure. Robotic distal pancreatectomy is associated with a faster recovery and a reduction in major morbidity proportionate to the degree of frailty. This benefit is lost in the event of conversion to traditional open surgery. In this article we summarize current concepts on the relationship of frailty and surgical outcomes, the importance of frailty assessment for pancreatic cancer patients undergoing surgery and the benefits of robotic-assisted pancreatectomy for the frail.

Keywords: Pancreatic cancer; frailty; pancreatectomy; geriatric assessment (GA)

Received: 13 November 2017; Accepted: 15 January 2018; Published: 01 February 2018.

doi: 10.21037/apc.2018.01.03

View this article at: http://dx.doi.org/10.21037/apc.2018.01.03

Introduction—general concepts

During the last century, life expectancy has doubled. By 2030, there will be 9 million people over the age of 84 in the United States (1). Elderly patients are more and more frequently referred for cancer treatment yet they are paradoxically excluded from clinical trials (2). Pancreatic cancer is predominantly a disease of the elderly with a median age at presentation of 71 years and more than 60% of newly diagnosed patients being over 65 years old (3).

Elderly patients represent a heterogeneous group in terms of physiologic reserves. It is known that elderly patients who survive the first year after surgery may have the same cancer-related survival as younger patients (4). Therefore, appropriate patient selection is needed to avoid early mortality. Frailty represents a more holistic way of patient assessment compared to age. It is associated with the aging process but it is distinct from it. It represents the patient's vulnerability and propensity to have adverse outcomes from medical interventions. It is very frequent amongst cancer patients and correlates strongly with chemotherapy intolerance, postoperative complications and mortality (5,6).

Routine assessment tools, such as the American Society of Anesthesiology Physical Status Classification System (ASA) or the Eastern Cooperative Oncology Group score (ECOG), are not sensitive enough to correlate with the degree of patient frailty and to serve as accurate estimates of the associated operative risk (7). The two most commonly used methods to assess frailty are the physical frailty phenotype and the accumulation of deficits theory (8). The physical frailty phenotype model, is based on five elements: weight loss, physical activity, exhaustion, grip strength, and walking speed (9). The accumulation of deficits model considers comorbidities and disability to accumulate and eventually lead to physiologic decline (10). In geriatric medicine, a geriatric assessment (GA) is a systematic evaluation of an individual's functional status, comorbidities, polypharmacy, cognitive status, nutritional status, emotional status, and social support and represents a thorough assessment of the patients multilevel vulnerabilities (11). GA preoperatively predicts 6-month mortality and post-discharge institutionalization in patients undergoing major thoracic and abdominal operations (12). Identification of patient vulnerabilities provides an opportunity to intervene and realize improved outcomes. An example of GA with assessment options and specific courses of action from a Delphi Consensus of Geriatric Oncology Experts was recently published (13).

As a result of the strong association between GA and cancer treatment outcomes, the International Society of Geriatric Oncology recommends that GA should be used in older patients with cancer to detect unaddressed problems (14). Similarly, the American College of Surgeons, in collaboration with the American Geriatric Society, created best-practice guidelines to identify high-risk patients, to prevent perioperative adverse outcomes, and to achieve optimal perioperative care of the surgical patient (15). Currently, although there are multiple ways to obtain a GA and an estimate of patient's frailty (16) the optimal and universally accepted method that is both comprehensive and time effective in daily clinical practice remains to be determined (5).

Geriatrics, frailty and pancreatic surgery

Single institution studies have shown that with appropriate patient selection, pancreatic surgery can be performed safely for the elderly with similar short and long term outcomes to younger patients (17,18). However, in statewide and national data the outcomes seem to be less favorable for the elderly (19,20). There is a proportionate increase of in-hospital mortality, length of stay, and discharge to nursing facility in the older age groups. Even in this setting though, high volume institutions are associated with lower morbidity and mortality reflecting appropriate patient selection and management (20).

Frailty predicts outcomes after pancreatic surgery. A National Surgical Quality Improvement Program (NSQIP) study on 13,020 patients who underwent either pancreaticoduodenectomy or distal pancreatectomy between 2005 and 2010, demonstrated a stepwise increase of major morbidity and mortality from non-frail to frail patients after adjusting for demographics, nutritional factors and type of pancreatectomy (21). In a prospective study with older patients undergoing pancreaticoduodenectomy, preoperative GA predicted major complications, longer hospital stays and ICU admissions after controlling for age, BMI, ASA score and comorbidities (22). A significant proportion of patients, up to half in that study, had unrecognized GA deficits with self-reported exhaustion being the most important GA predictor of important outcomes (22).

In this context, the increasing use of minimally invasive surgery changes the landscape of pancreatic surgery. Laparoscopic and robotic approaches are being increasingly utilized for pancreatic resections, thus it becomes of great interest to investigate the outcomes of minimally invasive pancreatectomies for the frail.

Robotic distal pancreatectomy for the frail

Since the first reports of robotic assisted pancreatectomies, the number of pancreatic resections performed with the utilization of the robotic platform has increased significantly (23). The utilization of small incisions, with less analgesic requirements represents a smaller physiologic insult compared to open surgery, leads to faster patient recovery and appears as an ideal option for the frail patients who cannot compensate well to physiologic stressors. Not surprisingly, minimally invasive compared to open distal pancreatectomies are associated with shorter hospitalizations and reduced complications (24). The existing data comparing robotic to laparoscopic pancreatectomies point towards comparable outcomes (25). However the existing studies do not stratify for the frailty status of the patients (24).

In a report utilizing NSQIP data on 1,038 elective distal pancreatectomies we found a proportionate increase of major complications with worsening frailty (26). Minimally invasive distal pancreatectomy (MIDP) was associated with a lower risk compared to open distal pancreatectomy (ODP), but this benefit was lost in the event of conversion (26). Robotic distal pancreatectomies were particular advantageous as they had a lower risk of conversion compared to laparoscopic distal pancreatectomies in that series which is similar to findings of other studies (25,27,28). Approximately a third of the patients in that study were 70 years old or more at the time of surgery. There was no difference in the utilization of minimally invasive surgery for the elderly and, similar to younger patients, they experienced a lower rate of major complications with minimally invasive surgery. Even though robotic distal pancreatectomies were more frequently performed for benign lesions, their equivalent oncologic outcome to open surgery when performed for cancer has been demonstrated (29).

Summary—conclusions and future perspectives

Frailty assessment is essential in modern oncogeriatrics. As the TNM system stages cancer, frailty assessment stages the patients suitability for surgery and detects unrecognized with traditional risk assessment tools defects that are associated with worse outcomes and can guide treatment decisions and perioperative management. With cancer being an increasingly common problem in the very elderly, the ability to assess and intervene in patient's frailty is a critical component of contemporary oncologic care. The development of frailty assessment tools with universal acceptance and adoption will allow comparisons between studies and will facilitate the evolution of the field.

A large proportion of pancreatic cancer patients are frail, which is associated with worse postoperative outcome, major morbidity and mortality. GA of the patient with pancreatic cancer can reveal unrecognized deficits and has the potential to improve patient outcomes through prehabilitation.

Robotic distal pancreatectomy represents a smaller physiologic insult compared to open pancreatectomy that frail patients are better able to tolerate. Not surprisingly, it is associated with fewer major complications. The benefits of minimally invasive pancreatectomy are lost in the event of conversion and robotic assisted resections are beneficial especially because of the low conversion rates. Prospective clinical trials in pancreatic cancer need to incorporate frailty assessment tools and the access of the elderly to these is absolutely essential.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/apc.2018.01.03
Cite this article as: Konstantinidis IT, Melstrom LG. Robotic distal pancreatectomy: greatest benefit for the frail? Ann Pancreat Cancer 2018;1:7.

Robotic single-site plus ONE-port distal pancreatectomy

Chang Moo Kang[1,2]

[1]Division of HBP Surgery, Department of Surgery, Yonsei University College of Medicine, Seoul, Republic of Korea; [2]Pancreatobiliary Cancer Clinic, Yonsei Cancer Center, Severance Hospital, Seoul, Republic of Korea

Correspondence to: Chang Moo Kang, MD, PhD. Division of Hepatobiliary Pancreatic Surgery, Department of Surgery, Yonsei University College of Medicine, Seoul, 50-1 Yonsei-ro, Seodaemun-gu, Seoul, 03722, Republic of Korea. Email: cmkang@yuhs.ac.

Abstract: Laparoscopic distal pancreatectomy (DP) is regarded as an appropriate surgical option to treat benign and low-grade malignant lesions in the left side of the pancreas. Some expert surgeons tried to reduce the number of trocars in conventional laparoscopic surgery to enhance DP's cosmetic and minimally invasive effects. However, it is thought to be too difficult to generalize this approach in clinical practice. In theory, robotic surgical system was introduced to overcome limitations of laparoscopic surgery. More specialized robotic surgical system has been introduced for single site minimally invasive surgery. If an additional robotic arm is used to this robotic surgical system, a wrist-like motion of instrument can be used, allowing for a more effective surgical movement during robotic single site surgery. In this paper, preoperative preparations and surgical techniques for robotic single-site plus ONE-port DP will be discussed.

Keywords: Robotic; distal pancreatectomy (DP); single-site; splenectomy

Received: 12 December 2017; Accepted: 15 January 2018; Published: 27 February 2018.

doi: 10.21037/apc.2018.01.04

View this article at: http://dx.doi.org/10.21037/apc.2018.01.04

Introduction

With the advance of laparoscopic techniques and instruments, laparoscopic pancreatectomy has become increasingly common. More specifically, laparoscopic distal pancreatectomy (DP) is regarded as an appropriate surgical option to treat benign and low-grade malignant lesions presenting in the left side of the pancreas. Although there are no randomized controlled studies comparing laparoscopic DP and open DP, an increasing number of case reports and literatures strongly suggest that the perioperative outcomes after laparoscopic DP are better than those following open DP, in terms of hospital stay duration and estimated intraoperative blood loss (1-5).

Recently, some expert surgeons tried to reduce the number of trocars in conventional laparoscopic surgery to enhance DP's cosmetic and minimally invasive effects. Barbaros *et al.* (6) reported the first single-incision laparoscopic DP which was performed in a 59-year-old female to treat pancreatic metastasis from renal cell carcinoma. Since then, the number of cases treated with either laparoscopic single port (LSP) or laparoscopic reduced port (LRP) DP procedures has increased (7-13).

Despite the increasing number of LSP/LRP-DP and advances of laparoscopic instruments, fatigue and stress resulting from limited motion for instrument manipulation in the narrow surgical space (in current single port system) needs to be considered when performing LSP/LRP-DP. Therefore, in order to improve intraoperative surgical quality and reduce limitations, technical innovation is essential. In theory, robotic surgical systems can overcome limitations of laparoscopic surgery. This robotic technology is expected to work during performance of LSP/LRP-DP.

A robotic single-site surgical system has been known to facilitate laparoscopic single-port surgery (14-16). In addition, a stable, 3-D operation field can enhance surgeon's ergonomic environment, and prevent the situation of right and left disorientation for triangular configuration during laparoscopic single-port surgery. It is believed that most intraoperative stress and fatigue result from the mechanics of laparoscopic single-port surgical system, such as fulcrum effect and limited motions of effector instrument. However, robotic surgical system automatically calculates the movement of surgeon's console with the help of specially

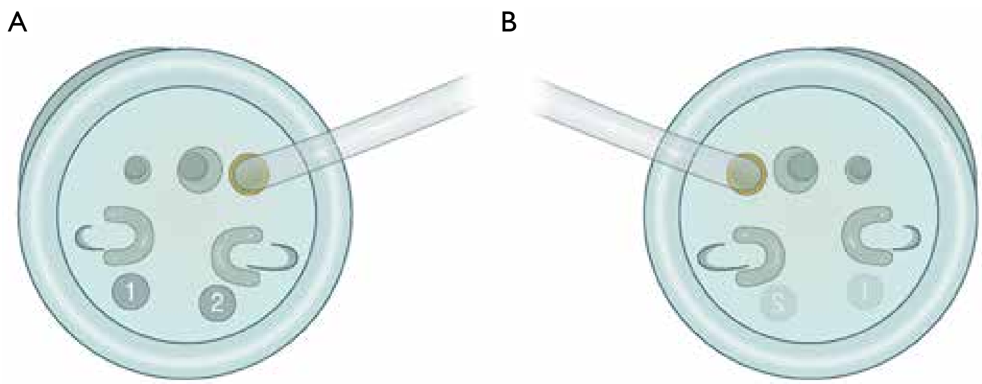

Figure 1 Specialized port system for RSS+1 distal pancreatectomy. (A) Original commercialized port system; (B) reverse port system. RSS, robotic single-site.

designed curved trocars and semi-flexible instruments, making it possible for the surgeon's right and left hand to control the right- and left-sided screen instruments even if the instrument is attached to the left and right robotic arm, respectively.

If an additional robotic arm is used through another trocar in the abdomen, a wrist-like motion of instrument can be produced in the robotic single-site surgical system, which allows for a more effective reduced-port surgery. Considering there is no wrist like-motion in pure robotic single site robotic surgical system, technical advantages from additional port would be very helpful. Also, preoperative surgical rehearsal is another advantage of robotic surgery. Surgical techniques can be tested before they are applied directly to patients, which can enhance surgical quality and safety. Since October 2015, this author has been using our *robotic single-site plus ONE port DP* (RSS+1 DP) technique in selected cases (17).

Indication

Based on author's experience, the best indications for RSS+1 DPS would be benign and low grade malignant tumors of the pancreas with the following conditions:

(I) Pancreatic tail tumor abutting splenic hilum, or involving spleen;
(II) Pathologic conditions that require less than 30% DP;
(III) No internal obesity; it was found that heavy omentum and redundant colon-splenic flexures derived from internal obesity made this surgical procedure very difficult and even impossible, as these factors concealed the main surgical field;
(IV) Super-selected pancreatic cancer with above-mentioned tumor conditions; minimally invasive radical pancreatectomy in selected distal pancreatic cancer showed comparable oncologic outcomes in many clinical literatures. However, it should be reminded that margin-negative radical pancreatectomy is very important. Most pancreatic cancers in tail of the pancreas involving spleen or splenic hilum are usually large, and they can also invade surrounding organs, such as the spleen, stomach, and even colon mesentery. Since it may be very difficult to produce effective oncologic surgery by RSS+1 DPS, application of this procedure should be reconsidered, even for pancreatic cancer, and performed in only super-selected patients by highly experienced surgeons.

Single-port preparation (reverse-port technique)

Conventional commercialized port system (*Figure 1A*) will not be appropriate for RSS+1 DPS. According to original configuration, assist port site should be placed on the left side of the patient In our surgical technique, #② curved robotic arm is responsible for lifting the stomach, and this will narrow the space between #② external robotic arm and camera holding robotic arm, where assistant surgeon is supposed to be during surgical procedure. In this circumstance, the assistant surgeon cannot provide any help.

Therefore, RSS+1 DPS requires a specialized port system where the assist-port site is placed on the left side of patient, *reverse-port* (16) (*Figure 1B*). In fact, the author simply modified the original port-system for properly retracting the gallbladder toward upward lateral side to produce wide Calot triangle for safe cholecystectomy during RSS-cholecystectomy (16,18). When performing RSS+1 distal pancreatosplenectomy (DPS), patient's left-sided assist-port placement makes some room for proper intervention by assistant surgeons during surgical procedure (*Figure 2*). Furthermore, it will be much easier for the assistant surgeon to change the robotic arm-instrument of additional ONE-port. Alternatively, currently available glove-port system (19,20) may be helpful in overcoming the disadvantages of conventional commercialized port system during RSS+1 DPS. Some of Korean robotic surgeons use it when performing this procedure.

Figure 2 Assist surgeon position. By using reverse port system, the assist surgeon can be placed at the left side of the patients, where the additional ONE-port will be place, so that assist surgeon can help surgical procedure effectively.

Operation room setting

Alignment between patient and the patient-side cart of robotic surgical system is important. An imaginary line was appropriately drawn between the umbilicus and body of the pancreas, and the patient-side cart of robotic surgical system was moved to the patient table along this imaginary line (*Figure 3A*). According to current instructions, patient-side cart of the robotic surgical system is roughly supposed to approach the patient over his or her left-sided shoulder (*Figure 3B*). The other process for robot-docking is almost identical to that of usual robotic single site surgical procedure (15,18), except for an additional ONE-port site that must be considered by surgeons.

Placement of additional ONE-port

Placement of additional ONE-port is very important. Through this, surgeons can use effector instrument in wrist-like motion. Additional ONE-port should be a 12-mm conventional laparoscopic trocar (reason for this will be explained in the next section). In our early experiences, malposition of additional ONE-port resulted in severe external inter-arms collisions, especially between #① external robotic arm and #③ external robotic arm that is docked to the additional ONE port), leading to conversion to multiport robotic DP. In order to avoid extracorporeal inter-arms collisions, it would be helpful to find the appropriate site for additional ONE port using following steps (*Figure 4*).

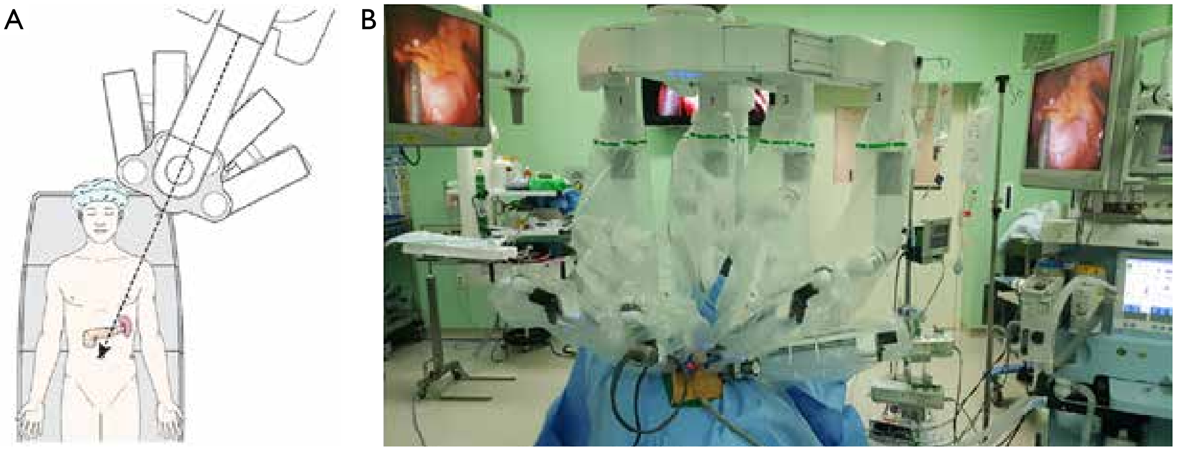

Figure 3 Operation room setting. Patient-side cart of the robotic surgical system is roughly supposed to approach the patient over his or her left-sided shoulder (A). OR view after robotic docking (B). OR, operation room.

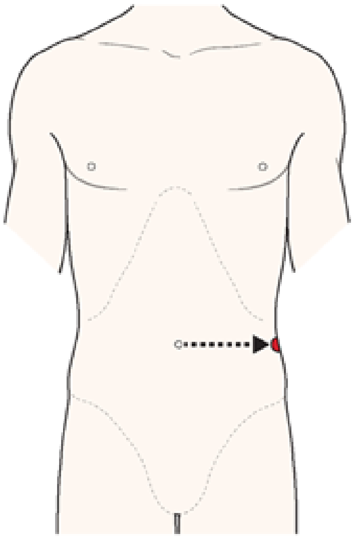

Figure 4 Placement of additional ONE-port (black arrow). Full lateral position of additional ONE-port will enhance the cosmetic effect in postoperative period.

Figure 5 Trocar in trocar technique. Note (dotted circle) robotic trocar in the conventional 12-mm laparoscopic trocar in the left flank of the patient.

(I) Extend the imaginary line horizontally from the umbilicus to the left-sided flank.

(II) Palpate the left-sided flank area and identify the position just above descending colon-peritoneal flexure under camera scope vision.

(III) Place the 12-mm conventional trocar over that point.

Full lateral position of additional ONE-port will enhance the cosmetic effect in postoperative period. Lateral positioning of ONE-port would be barely seen from front-sided view of the patient.

Trocar in trocar technique

Introducing endo-GIA for dividing the pancreas through reverse-port is impossible, due to the size discordance between robotic assist-trocar and diameter of endo-GIA (10 *vs.* 12 mm). Therefore, endo-GIA should be applied through the additional port. For this purpose, placing robotic 8-mm trocar docked to the robotic surgical system into 12-mm conventional laparoscopic trocar is useful (*Figure 5*). During dissection of splenic vessels, an articulating robotic instrument can be used through this additional robotic 8-mm trocar in 12-mm conventional laparoscopic trocar. If necessary, endo-GIA can be introduced through 12-mm conventional laparoscopic trocar after temporarily removing robotic 8-mm trocar out of 12-mm trocar. This procedure can be simply performed by an assistant surgeon without difficulty; for this purpose, it would be ideal for assistant surgeon to be placed on the patient's left side. This is another advantage of reverse-port system during RSS+1 DP.

Of course, robotic endo-GIA (EndoWrist® Stapler) can also be used. Although this advanced technology can make the surgical procedure independent of an assistant surgeon's skills, we found that surgeons cannot control the cutting speed of robotic endo-GIA for dividing the pancreas, and eventually leads to crushing of the pancreas rather than "dividing". This phenomenon may be related to postoperative pancreatic fistula.

Surgical simulation

Before applying this procedure in clinical practice, a preoperative surgical rehearsal is recommended to help surgeons understand procedural concepts and to get used to new surgical environment for improving quality of surgery in actual performance. Since surgeons may encounter some technical issues during surgical simulation, they should prepare their own tactics to resolve potential problems that can arise during real clinical practice (*Table 1*, *Figures 6* and *7*).

Case and surgical technique

A 24-year-old female patient was admitted to hospital due to incidental finding of a mass in the pancreatic tail (*Figure 8*). All informed consents were given. Under the diagnostic impression of a solid pseudopapillary pancreatic

Table 1 Potential technical issues to consider during surgical simulation for RSS+1 DP

Potential technical issues	Tactics in Yonsei
How to divide gastrocolic and gastrosplenic ligaments?	Use advanced robotic technology
	Apply EndoWrist® vessel sealer
How to lift stomach wall to expose distal part of the pancreas?	Use #② curved robotic arm to actively lift stomach wall
	Use long-curved trocar to provide steady lifting power (sometimes)
How to dissect splenic vessels?	Place EndoWrist® monopolar cautery instrument and EndoWrist® bipolar cautery instrument through additional port
	Use intracorporeal tie and clip to ensure safe surgical procedure
How to apply endo-GIA?	Use modified lasso technique* (21) to simplify surgical procedure
	Train assist-surgeon on how to apply endo-GIA during surgical stimulation
	Consider using advanced robotic technology, but this may be inappropriate due to problem of pancreatic division speed
Is it appropriate for the assist surgeon to manipulate near the patient's side?	Test conventional commercialized single port system if it is appropriate for this surgical procedure

*, modified lasso technique will be discussed later in this chapter. RSS, robotic single-site; DP, distal pancreatectomy.

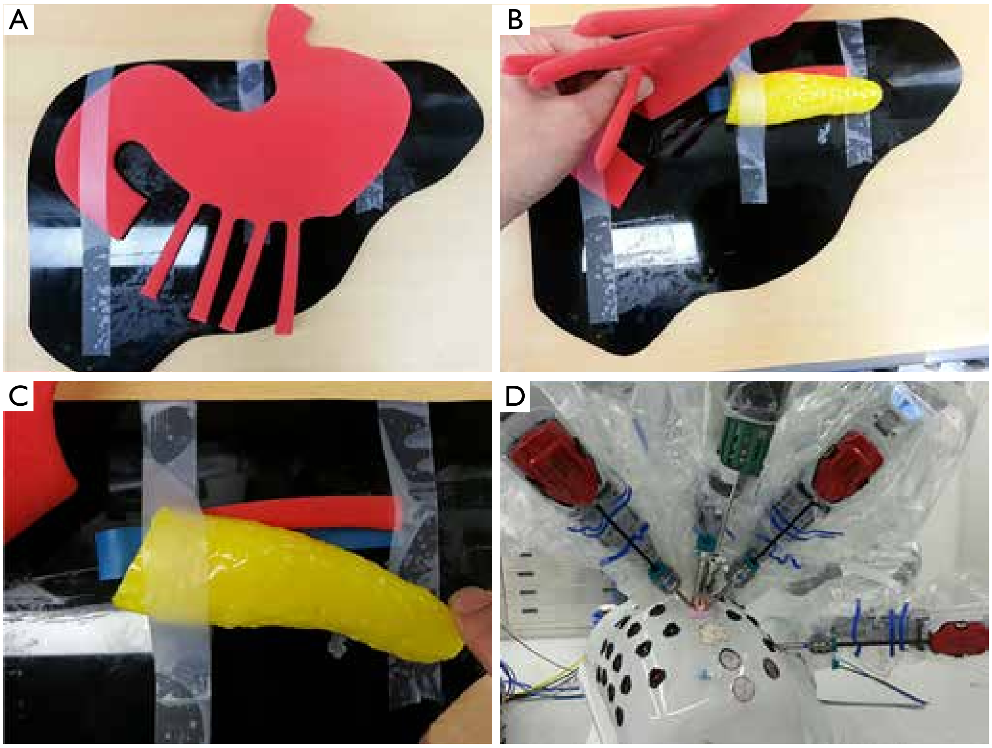

Figure 6 Preoperative surgical simulation. Home-made model for distal pancreatectomy (A) when lifting stomach, distal part of the pancreas is exposed (B). Splenic artery (red) and vein (blue) are noted above the silicone pancreas (C). Designing port placement (D).

neoplasm, she underwent robotic single-site plus ONE port DPS (*Figure 9*). Total operation time was 160 minutes, and the estimated intraoperative blood loss was less than 50 mL. When dissecting splenic vessels, angulating motion of surgical instrument through additional port made surgical procedure more effective and easy. Modified lasso technique was applied. No POPF was noted. Patient was discharged on the seventh postoperative day. Postoperatively, the wound appeared to be healing well (*Figure 8*). This case suggests that the main obstacles of LSP/LRP system, which includes surgical stress and ineffective instrument manipulation, can be resolved by using a robotic surgical system. More experience is required to determine the exact role of robotic single-site surgical system for performing LSP/LRP-DP.

Figure 7 Preoperative surgical simulation for robotic single site plus ONE-port DPS (22). DPS, distal pancreatosplenectomy.
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Special considerations

Modified lasso technique (21)

Lasso technique was originally proposed by Velanovich (24) in 2006 for simple and effective laparoscopic DPS. It contains the following surgical procedures:

(I) Dissecting pancreas, splenic artery, and splenic vein altogether from the retroperitoneum;
(II) Encircling these structures altogether by the Penrose drain ("lasso");
(III) Endo-GIA application to divide all of these structures at once.

Although the technique looks simple and effective, the original lasso technique harbors some potential risk of postoperative bleeding from the staple line in remaining splenic artery stump. We experienced a very similar potential complication after laparoscopic splenectomy (25). To prevent this potential safety issue, we always dissect splenic artery first and ligate it before applying lasso technique. Therefore, the pancreatic division line would be distal to splenic artery ligation site.

Spleen-preserving technique

Spleen-preserving procedure is both time and labor-consuming. In order to perform splenic vessel-conserving technique, small tributary vessels need to be controlled. In multi-port robotic surgical system, small metal-clips and wrist-like motion of instruments are very useful in this procedure, as they provide good surgical field. Our experiences have shown that multiport robotic surgical

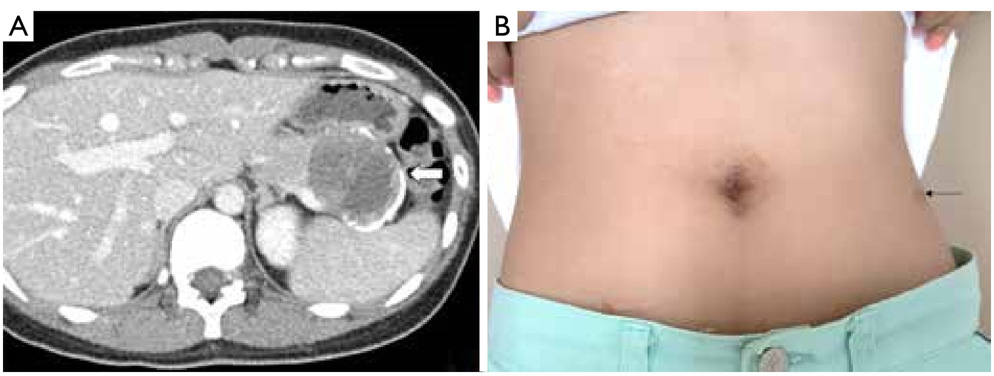

Figure 8 Case presentation. Pancreatic tail mass with peripheral calcification is abutting splenic hilum (white arrow) (A). Postoperative wound. Note the wound of additional ONE-port (black arrow) (B).

Figure 9 Robotic single site plus ONE-port DPS for young female patient with solid pseudopapillary tumor of the pancreas (23). DPS, distal pancreatosplenectomy.
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system is very useful in spleen-preserving DP (26-30). However, in RSS+1 system, ensuring surgical field may not be enough to perform spleen-preserving process, as the effector movement is not fully articulated except placing robotic instruments through additional ONE-port. Therefore, splenic vessel-conserving technique will not be effective by RSS+1 system. Both splenic vessel-sacrificing techniques may be acceptable in selected cases, but not all the time. Therefore, the best indication for RSS+1 DP would be pancreatic tail tumor involving splenic hilum or spleen which requires DP with splenectomy. Such indication would help prevent potential debates regarding the rationale on combined splenectomy in benign or low grade malignant tumor of the pancreas.

Acknowledgements

This study was supported by InSuk (Chi, Hoon Sang) Best Teacher Award (2015) of Severance Surgeon's Alumni, Department of Surgery, Yonsei University College of Medicine, Seoul, Republic of Korea. The authors are also grateful to Dong-Su Jang (Medical Illustrator, Medical Research Support Section, Yonsei University College of Medicine, Republic of Korea) for his help with the figures.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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doi: 10.21037/apc.2018.01.04
Cite this article as: Kang CM. Robotic single-site plus ONE -port distal pancreatectomy. Ann Pancreat Cancer 2018;1:12.

Robotic total pancreatectomy en masse without division of the pancreatic neck

Aslam Ejaz, Lara Espin, Jin He

Department of Surgery, Johns Hopkins Hospital, Baltimore, MD, USA

Contributions: (I) Conception and design: J He; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Jin He, MD, PhD, FACS. Department of Surgery, Johns Hopkins Hospital, 600 N. Wolfe Street, Blalock 665, Baltimore, MD 21287, USA. Email: jhe11@jhmi.edu.

Abstract: Total robotic pancreatectomy for pancreatic neuroendocrine tumor has not been routinely performed. Here we review a robotic total pancreatectomy en masse without division of the pancreatic neck for a large neuroendocrine tumor that occupied the pancreatic head, neck, and body. The patient had a great outcome and remains disease-free 2 years after surgery.

Keywords: Robotic pancreatectomy; pancreatic tumor

Received: 08 January 2018; Accepted: 02 February 2018; Published: 31 March 2018.
doi: 10.21037/apc.2018.02.02
View this article at: http://dx.doi.org/10.21037/apc.2018.02.02

Introduction

Neuroendocrine tumors (NETs) are epithelial neoplasms with neuroendocrine differentiation that can arise in a variety of organs. NET that arise in the pancreas (PanNETs) comprise less than 3% of all pancreatic neoplasms (1). The most recent classification by the World Health Organization classifies NET based on the degree of differentiation (well *vs.* poorly), tumor grade, mitotic count, and Ki-67 index (2). Likely due to increased cross-sectional imaging, there has been an increasing incidence of these tumors.

Though a robotic operation is now considered a standard approach for various general, urological, and gynecological procedures, utilization of robotic surgery for complex pancreatic resections remains low (3). In fact, the majority of pancreatic resections in the US are performed in a traditional open manner despite studies showing robotic approach to be equally safe to an open approach (3,4). This low utilization is undoubtedly multifactorial and may be largely related to the complexity of the pancreatic resection and the absence of an adequate number of structured robotic training programs throughout the country (5-10). Common contraindications for robotic pancreatectomy include difficult access to abdominal cavity due to severe intraabdominal adhesions from previous surgeries or peripancreatic inflammation, intolerance of pneumoperitoneum due to cardiopulmonary dysfunction, difficult anatomy due to involvement of major vessels around the pancreas, and inadequate robotic skills. Despite this, there are few contraindications to a robotic approach to pancreatic resections. Here we review a robotic total pancreatectomy en masse without division of the pancreatic neck for a large NET that occupied the pancreatic head, neck, and body.

Case presentation

A 56-year-old female presented to our surgical clinic with a large biopsy-proven NET that was found after cross-sectional imaging for abdominal pain. On imaging, the patient had a PanNET that infiltrated the pancreatic head, neck, and body (*Figure 1*) and measured approximately 9 cm in length. Given the size and symptomatology of this tumor, the patient was offered a robotic total pancreatectomy en

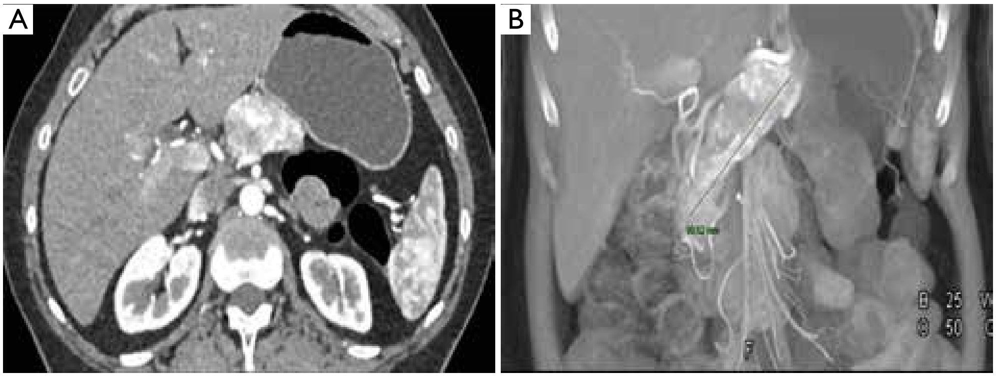

Figure 1 Cross-sectional imaging in the (A) axial and (B) coronal view showing a large pancreatic NET involving the head, neck, and tail of the pancreas. NET, neuroendocrine tumor.

Figure 2 Passage of the umbilical tape through the retro-pancreatic tunnel used to provide cephalad and lateral retraction during dissection of the uncinate process.

masse without division of the pancreatic neck in order to prevent any inadvertent tumor spillage in the abdomen.

Surgical technique

A comprehensive robotic surgical team is required to effectively perform complex robotic operations and this team includes an anesthesiologist, nursing staff familiar with the robotic instruments and setup, an operating console surgeon, and a bedside surgical assistant for port-placement, instrument exchange, and perhaps most importantly, retraction and suctioning. Both the bedside scrub nurse and room circulator should be proficient at robotic operations to facilitate efficient instrument setup and exchange.

The patient was positioned in a supine position with legs spread on a split-leg operating table and arms out at 90 degrees. Peripheral intravenous access, an arterial monitoring line, and a Foley catheter were placed as well as a nasogastric tube for decompression of the stomach. Monitors were placed over both the left and right shoulders of the patient to allow adequate view for the surgical assistant and scrub technician. The first assistant stands between the legs of the patient while the scrub nurse stands to the left of the patient. The abdomen was entered using the Veress technique through a supraumbilical incision. Upon inspection of the abdomen, no metastatic disease was appreciated. Four additional robotic 8 mm ports were placed in a straight line across the mid abdomen under direct visualization. The robot (DaVinci Xi system) was then docked from the patient's left side.

Exposure and dissection

The dissection begins at the hepatic flexure and the right colon was carefully dissected away from the liver. The ligamentum teres was dissected from the abdominal wall and encircled using an endostitch. A stab incision was then made in the right sub-xyphoid area and the endostitch was pulled through the abdominal wall and secured in order to expose the porta hepatis. A cholecystectomy was then performed by dissecting Callot's triangle using the hook cautery. The cystic duct was identified, clipped, and transected. If needed for exposure, a stitch can be placed through the infundibulum of the gallbladder and the suture can be pulled percutaneously to provide cephalad retraction in a similar fashion to the retraction of the ligament teres. The common bile duct was then transected and a clip was placed on the proximal duct to prevent ongoing spillage of bile in the abdomen during the remainder of the operation.

The porta hepatis was carefully dissected using the hook cautery until the common hepatic, proper hepatic, and gastroduodenal arteries were carefully identified. The gastroduodenal artery was test clamped to confirm adequate blood flow to the proper hepatic artery via the common hepatic artery. The gastroduodenal artery was sequentially tied using a 0-silk suture and Hem-o-lok clips, and then transected. The stomach was carefully dissected around the pylorus and divided using an endo-GIA stapler. Once this was performed, the lesser sac was entered by dividing the gastrocolic ligament along the greater curvature of the stomach using the robotic vessel sealer device. The stomach was retracted cephalad to expose the anterior surface of the pancreas. A Kocher maneuver was performed and the ligament of Treitz was divided from the right side of the abdomen. Once transected, the mobilized jejunum was brought through the ligament of Treitz defect and divided at approximately 20 cm downstream with an endo-GIA stapler.

Attention was turned to the inferior border of the pancreas. Sharp dissection was performed using a combination of hook cautery and the vessel sealer device. Careful dissection was performed on the inferior margin of the pancreas until the superior mesenteric vein was visualized. Once this was visualized, an infra-pancreatic tunnel was bluntly dissected under direct visual guidance. Using a long tip-up blunt grasper, an umbilical tape was passed underneath the neck of the pancreas and used to retract the pancreas in a superior/lateral direction (*Figure 2*). The use of the umbilical tape to provide anterior retraction was a key step of the operation as it provided adequate visualization and exposure of the superior mesenteric vein (SMV) and uncinate process without division of the pancreatic neck.

The splenic artery was then dissected from the superior border of the pancreas. Once identified and dissected cleanly, this artery was tied using a 0-silk tie and double clippled with Hem-o-lok and then transected sharply using robotic scissors. The splenic vein was then identified through further dissection of the inferior border of the pancreas in combination with cephalad/superior retraction of the pancreas using the umbilical tape. The splenic vein was similarly tied, clipped, and transected.

Attention was then turned to the uncinate process. In cases where the neck of the pancreas was not divided due to tumor involvement, retraction of the pancreas anterior and lateral was performed using the umbilical tape and the 3rd robotic arm. The uncinate process was transected using a combination of the harmonic scalpel, the vessel sealer, and monopolar cautery. Individual branches to the SMV are individually ligated as necessary.

The inferior and superior border of the pancreas were then dissected more in a median to lateral fashion. The short gastric vessels were transected, and the spleens were mobilized. The specimen was then placed in an endocatch bag along with the gallbladder and extracted through a 6 cm Pfannenstiel incision.

Reconstruction

Reconstruction began with the hepaticojejunostomy. A small enterotomy was made in the jejunum which was brought up through the ligament of Treitz defect. The size of the enterotomy matched the size of the hepatic duct. A 5-0 PDS suture with an RB1 needle was placed at the corner and tied. The posterior row was then completed using 5-0 PDS sutures in an interrupted fashion. The posterior row may be completed in a running fashion depending on the size of the hepatic duct. A pediatric feeding tube can be placed as a stent to aid in reconstruction of the anterior layer of this hepaticojejunostomy. The anterior row of the hepaticojejunostomy was completed in a similar fashion using interrupted 5-0 PDS sutures.

The gastrojejunostomy was performed by bringing the jejunum in an antecolic side-to-side fashion. A traction suture was placed in the jejunum and stomach and used to aid in stapler placement. A jejunotomy and gastrotomy were created using the harmonic scalpel approximately 3 cm away from the gastric staple line. The anastomosis was performed using an endo-GIA stapler. The common enterotomy was then closed in two lawyers using a running 3-0 V-Loc™ suture.

The abdomen was then thoroughly irrigated and one drain was placed through the left port site. This drain was placed in the splenic fossa and travels across the pancreatic bed, terminating below the hepaticojejunostomy anastomosis. The abdomen was desufflated and the assistant 10 mm port was closed using an interrupted #1 PDS suture.

Patient outcome

Following the operation, the patient remained in the hospital for a total length of stay of 7 days mainly for glucose control and diabetes teaching. There were no immediate postoperative complications. Final pathology revealed a 9×3×2.5 centimeter well differentiated NET with negative margins and negative nodal involvement.

Rationale

Though pancreatic NET are a relatively rare group of neoplasms, long-term prognosis varies due to the wide-ranging grade and metastatic potential found among these group of these tumors (11). As such, attention to strict oncological principles during surgical extirpation of these tumors is important. As a relatively rare tumor, implications of tumor capsule violation and tumor spillage has not been previously reported in patients with pancreatic NETs. However, tumor spillage during surgical resection of various other tumors has been shown to be an independent risk factor for recurrence and poor long-term outcomes (12-15). In the case presented, division of the pancreatic neck during total pancreatectomy would have violated the tumor capsule and caused inadvertent tumor spillage in the abdomen. As such, total pancreatectomy without division of the pancreatic neck is important to prevent this occurrence and is possible during a robotic approach.

The use of a robotic approach for total pancreatectomy has previously been reported. In a report from 2010, Giulianotti *et al.* reported on the safety and feasibility of robotic total pancreatectomy using the da Vinci robotic system (16). To our knowledge, however, this is the first report of a total pancreatectomy en masse without division of the pancreatic neck for a large tumor spanning the near entirety of the pancreas. This report shows that a robotic approach is safe and feasible and particularly helpful in cases when division of the pancreatic neck may cause inadvertent tumor spillage.

Conclusions

In conclusion, robotic total pancreatectomy en masse without division of the pancreatic neck can be performed safely in instances where a large tumor was traversing longitudinally along the pancreas without involvement of major vessels. Tumor size and the level of pancreatic involvement are not contraindications to a robotic approach. Meticulous dissection and adequate exposure are key steps to perform this operation.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Informed Consent: Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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doi: 10.21037/apc.2018.02.02
Cite this article as: Ejaz A, Espin L, He J. Robotic total pancreatectomy en masse without division of the pancreatic neck. Ann Pancreat Cancer 2018;1:14.

Robotic distal pancreatectomy with celiac axis resection for locally advanced pancreatic cancer

Joal D. Beane, Amer H. Zureikat

Division of Surgical Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Amer H. Zureikat, MD, FACS. Division of Surgical Oncology, University of Pittsburgh Medical Center, 3550 Terrace Street, Suite 497 Scaife Hall, Pittsburgh, PA 15261, USA. Email: zureikatah@upmc.edu.

Abstract: With improved outcomes following the addition of neoadjuvant therapy some surgeons have taken an aggressive approach to operating on patients with locally advanced pancreatic cancer with vascular involvement. A modified Appleby operation has been described for lesions of the body or tail of the pancreas with celiac axis involvement and includes distal pancreatectomy and splenectomy with en bloc celiac axis resection (DP-CAR). Efforts to improve the safety of pancreatectomy have led to the development and implementation of minimally invasive and robotic approaches to pancreatectomy. Herein we review our experience with robotic DP-CAR.

Keywords: Robotic pancreatectomy; distal pancreatectomy (DP); celiac axis resection

Received: 28 November 2017; Accepted: 19 January 2018; Published: 02 February 2018.
doi: 10.21037/apc.2018.01.07
View this article at: http://dx.doi.org/10.21037/apc.2018.01.07

Introduction

Surgery provides the only opportunity for patients with pancreatic adenocarcinoma (PDAC) to achieve long-term survival. However, due to a combination of aggressive tumor biology and the anatomic location of the pancreas, only 20% of patients present with resectable disease at the time of diagnosis. Neoadjuvant chemotherapy with or without radiation therapy has been used to downstage patients and facilitate surgical resection with curative intent in patients with locally advanced tumors (1). Such multimodal therapy has been used with success in select patients to increase the chances of an R0 resection and treat regional lymph node basins (2). This approach when followed by adjuvant chemotherapy can result in improved survival (3).

With improved outcomes following the addition of neoadjuvant therapy and increased experience with pancreatectomy, surgeons have become more aggressive in patients with locally advanced tumors with vascular involvement (4). In 1953, Lyon Appleby first described *en bloc* resection of the celiac trunk, total gastrectomy, and distal pancreatectomy (DP) as an approach to patients with locally advanced gastric cancer (5). A variation of this approach has been used in patients with pancreatic body or tail tumors that invade the celiac axis. The modified Appleby operation preserves the stomach but includes distal pancreatectomy and splenectomy with en bloc celiac axis resection (DP-CAR) (4,6).

Using an aggressive surgical approach in a cancer with notoriously aggressive tumor biology requires a careful assessment of the risks and benefits. A recent analysis of the NSQIP database found that DP-CAR was associated with increased operative time, higher post-operative acute kidney injury, as well as higher 30-day mortality compared to DP alone (7). However, a more recent meta-analysis of 18 studies found no statistically significant differences in morbidity or mortality following DP-CAR compared to DP alone (8). In addition, the 1-, 2-, and 3-year survival rates were 62.2%, 30.2%, and 18.7% following DP-CAR and were similar to patients following DP. More so, those

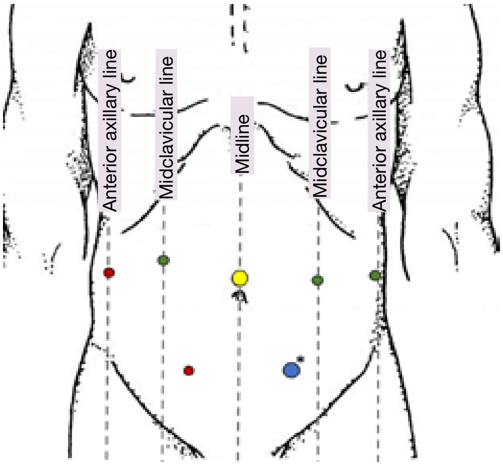

Figure 1 Port placement for robotic DP-CAR (yellow is a 12-mm camera port, blue is a 12-mm port for the endoscopic stapler, green are 8 mm robotic arms, red are 5 mm assistant ports; * denotes extraction port site) (12). DP-CAR, distal pancreatectomy with celiac axis resection.

treated with DP-CAR had improved 1-year survival compared to patients who received palliative treatments (8). As such, the survival advantage of an aggressive surgical approach relies heavily on minimizing operative morbidity and mortality.

Outcomes of robotic DP-CAR: University of Pittsburgh Experience

Efforts to improve the safety of pancreatectomy have led to the development and implementation of minimally invasive and robotic approaches to both pancreatoduodenectomy and segmental pancreatectomy (9,10). As our experience at the University of Pittsburgh has grown, the complexity of cases has increased. We have reported the operative outcomes of 30 DP-CARs (11). Twenty-eight patients had PDAC, and of these, all but one (96%) received neoadjuvant therapy. Nineteen were completed robotically without the need for conversion to open. This included four patients who required a concomitant tangential venous resection that was able to be performed. We found that robotic DP-CAR had comparable morbidity and mortality to the 11 that were performed in open fashion, however the robotic approach was associated with a statistically significant ($P<0.05$) reduction in operative time (316 *vs.* 476 min), intraoperative blood loss (393 *vs.* 1,736 mL), and blood transfusion rate (0% *vs.* 54%) (11). The incidence of post-operative pancreatic fistula (POPF), Grade B/C POPF, and serious morbidity (Clavien-Dindo grade 3–4) were comparable between the two cohorts. The advantages for the robotic approach in this series may have been related to selection bias, since the robotic cases were performed after the learning curve with the open approach was reached. Importantly, both groups had similar lengths of stay, readmission rates, and receipt of adjuvant therapy (11). The median survival was nearly three years for the entire cohort and was comparable amongst the two approaches. In our experience, robotic DP-CAR is safe and effective and may improve survival in carefully selected patients.

Patient selection

The importance of patient selection for DP-CAR cannot be overstated. Anatomic, tumor specific, and patient factors are important in determining resectability. There are four criteria that a patient must meet to be considered an operative candidate at our institution. These have been published previously and include: (I) tumor of the body/tail of the pancreas with involvement of any branch(es) of the celiac axis, but not of the celiac trunk itself; (II) the gastroduodenal artery (GDA) must be preserved and without tumor involvement; (III) treatment with neoadjuvant chemotherapy (with or without radiation) to treat micro metastatic disease and allow for assessment of tumor biology prerequisite; (IV) good performance status (12).

Operative approach

Our robotic approach to DP-CAR has been published previously (12). Following port placement (*Figure 1*) a careful exploration of the abdomen is performed. Entrance into the lesser sac is achieved after dividing the omentum from the transverse colon. The stomach is retracted allowing for traction to be placed on the left gastric artery and vein. The common hepatic artery (CHA) is identified and traced distally until the takeoff of the GDA. To ensure the GDA is able to provide collateral flow to the liver after sacrificing the celiac trunk, we clamp the CHA and perform a laparoscopic duplex ultrasound of the GDA. After confirming triphasic perfusion at the porta hepatis, the pancreatic neck is dissected from the retroperitoneum and transected using a laparoscopic stapler (*Figure 2A*). Next, the splenic vein is identified and transected at the insertion with the superior mesenteric vein/portal vein confluence.

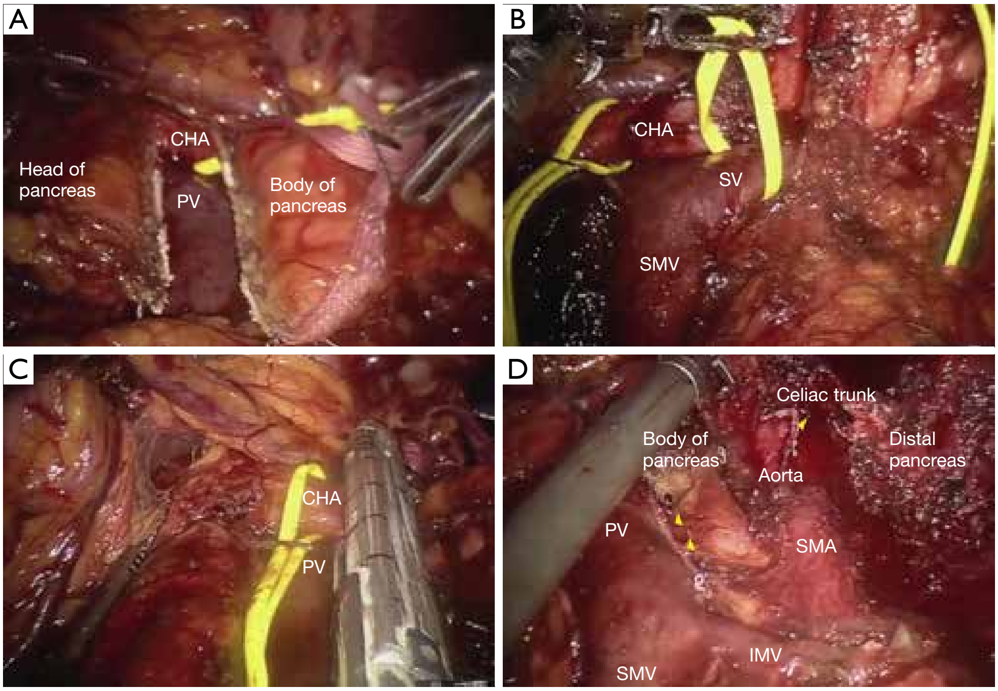

Figure 2 Intraoperative pictures of robotic distal pancreatectomy with celiac axis resection. (A) After confirming dissecting out the CHA and confirming adequate perfusion retrograde through the GDA, the neck of the pancreas is dissected and then transected using a laparoscopic stapler; (B) the splenic vein is then dissected and transected at its insertion at the superior mesenteric vein/portal vein confluence; (C) the CHA is then transected just proximal to the GDA. Next, we identify the left gastric artery and vein and transect them with a vascular stapler. The supra celiac aorta is exposed by dissecting it from the crural fibers, and the aorta is followed until the celiac axis is identified inferiorly. Once properly exposed, the celiac axis is transected using a laparoscopic vascular stapler (D, single arrow indicates the cut edge of the celiac trunk, the double arrows denote the cut end of the splenic vein) (12). CHA, common hepatic artery; PV, portal vein; SV, splenic vein; SMV, superior mesenteric vein; IMV, inferior mesenteric vein; SMA, superior mesenteric artery; GDA, gastroduodenal artery.

Attention is then turned towards transection of the splenic attachments and the spleen and tail of the pancreas are mobilized from lateral to medial with the retroperitoneal fascia until left lateral wall of the celiac axis is encountered.

After dissection of the body/tail of the pancreas and spleen, we then proceed with the dissection of the celiac axis superiorly. The CHA is identified and transected just proximal to the GDA (*Figure 2B,C*). Next, we identify the left gastric artery and vein and divide these with a vascular stapler. The supra celiac aorta is exposed by transecting the crural fibers, and the aorta is followed inferiorly to reach the celiac trunk. The robotic hook cautery is used to expose the celiac trunk through division of the celiac plexus and surrounding lymphatics. Once properly exposed, the celiac axis is transected using a laparoscopic vascular stapler (*Figure 2D*). The specimen is placed in an Endo Catch specimen pouch and removed after enlarging the 12 mm port in the left lower quadrant (*Figure 1*). After ensuring adequate hemostasis, the pancreatic bed is drained and 12 mm port sites closed.

Conclusions

The robotic approach to DP-CAR is safe, with comparable morbidity and mortality to an open approach once the learning curve for open DP-CAR and robotic surgery are reached. Data on the robotic approach is scarce, however based on our experience, use of the robotic platform may be associated with reductions in operative time, intraoperative blood-loss and transfusion rate. While some patients may benefit, the importance of appropriate patient selection cannot be overstated.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/apc.2018.01.07
Cite this article as: Beane JD, Zureikat AH. Robotic distal pancreatectomy with celiac axis resection for locally advanced pancreatic cancer. Ann Pancreat Cancer 2018;1:11.

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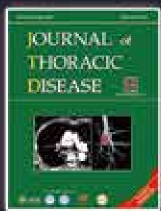

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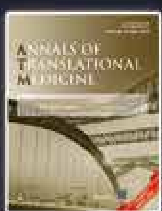

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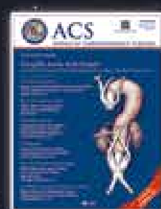

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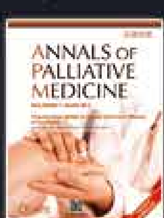

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SCI收录：2019年1月

Updated on Jan. 11, 2019