Video Article

Application of End-to-end Anastomosis in Robotic Central Pancreatectomy

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Abstract

Central pancreatectomy is carried out for the treatment of benign or low-malignant potential tumors located in the pancreatic neck or proximal part of pancreatic body. With technological development, the robotic surgical system has shown its advantage in minimally invasive surgery and been increasingly applied in central pancreatectomy. However, reconstruction of the continuity of pancreas with end-to-end anastomosis after robotic central pancreatectomy has not been applied. In this study, we report surgical techniques for robotic central pancreatectomy with end-to-end anastomosis. The pancreas is reconstructed by duct-to-duct anastomosis of the pancreatic duct with a pancreatic stent inserted in the two stumps of pancreatic duct, and by end-to-end anastomosis of the pancreatic parenchyma. Compared with traditional central pancreatectomy with pancreaticoenteric anastomosis, this approach decreases the operative injury to the patient, and also conserves the integrity and continuity of the digestive duct and pancreatic duct. The robotic surgical system integrated with multiple instruments with flexible and precise movement is particularly suitable for the dissection and reconstruction of the pancreatic duct. We found that robotic central pancreatectomy with end-to-end anastomosis is safe and feasible, and we need more experience to evaluate its best indications and long-term outcomes.

Video Link

The video component of this article can be found at https://www.jove.com/video/57495/

Introduction

Central pancreatectomy is increasingly performed for the treatment of benign or low-malignant potential tumors located in the pancreatic neck or proximal part of pancreatic body[1]. Compared with the pancreaticoduodenectomy or distal pancreatectomy, central pancreatectomy resects less tissues and conserves more pancreatic parenchyma and function. Currently, the major approaches for the pancreas reconstruction are over-sewing the cephalic pancreatic stump and performing a pancreaticojejunostomy or pancreaticogastrostomy to the distal stump[2,3]. These two approaches are widely used in the open, laparoscopic and robotic central pancreatectomies[4,5,6,7]. However, the aforementioned two reconstruction approaches break the anatomic continuity of digestive tracts and the pathway for the excretion of pancreatic fluid. The directly contact of pancreatic stump with intestinal juice might increase the possibility of bleeding and fistula[8]. Although the gastric juice could inactive pancreatic enzymes to avoid the erosion of anastomosis, it might lead to pancreatic exocrine insufficiency, and in the long term jeopardize the patient's nutritional status[9,10].

With the development of minimally invasive surgery, robotic surgery has shown great advantages in its 3-D magnifying view, stability, and flexibility of movements, *etc.*, which provides enhanced dissecting and suturing capacity for anastomosis and hemostasis[11,12]. Based on our experience in robotic pancreatectomy and repair for injured pancreatic duct[13,14], we have performed a series of robotic central pancreatectomy with end-to-end anastomosis and seen favorable outcomes. Compared with pancreaticojejunostomy or pancreaticogastrostomy, end-to-end pancreas anastomosis avoids the damage to digestive tracts; thus, theoretically reducing the possibility of pancreaticoenteric fistula. But on the other hand, the end-to-end pancreas anastomosis poses greater technical difficulties. As an update of conventional central pancreatectomy, the candidates for conventional central pancreatectomy are also eligible for this surgery. Here, we present operative techniques for robotic central pancreatectomy with end-to-end anastomosis in a tertiary hepatopancreatobiliary center in this video case presentation.

Indications:

(1) Benign and low-malignant potential tumors located in the pancreatic neck and proximal body are suitable for this operation.
(2) The defect of the main pancreatic duct should be less than 5 cm after the central pancreatectomy, and the size of tumor is not the main concern for reconstruction.

Case Presentation:

The patient is a 31-year-old man. A lesion in the pancreatic neck was found accidently in a medical examination 2 years ago. He underwent regular re-examination and the lesion was found to be asymptomatically enlarged recently. He had no history of previous abdominal surgery.

On physical examination, no positive sign existed. The pancreatic MRI showed a quasi-circular lesion approximately 14-mm in the pancreatic neck; this was presumed as a neuroendocrine tumor. On T1- and T2-weighted imaging, the lesion showed hypointense and hyperintense signal, respectively. On diffusion-weighted imaging, the lesion showed hyperintense signal. The lesion was slightly enhanced in the arterial phase and showed a progressive enhancement pattern in the parenchyma phase and delay phase (**Figure 1**). Severe fatty liver was also diagnosed by the MRI. No dilation or stricture was detected in the pancreatic duct. Routine blood examination, IgG isoform test, tumor biomarkers, electrocardiogram, and chest X-ray were normal. The biochemical test showed slightly elevated ALT (Alanine aminotransferase) at 147.3 U/L and AST (Aspartate aminotransferase) at 53.9U/L, which may be caused by fatty liver.

Protocol

Written informed consent was obtained from the patient for the publication of this report and any accompanying videos and images.

1. Preoperative Preparation

1. Carefully evaluate the preoperative images of CT or MRI for the exact location of the tumor and its relation to the surrounding tissues.
2. Give the patient a soft diet one day before the operation and begin fasting at midnight before the operation.
3. Place the patient on the operating table. Then, place a peripheral venous catheter and induce general anesthesia using standard procedures. Introduce a central venous catheter through the right internal jugular vein for medication fluids and a peripheral arterial catheter for blood pressure monitor.

2. Patient's Position and Port Placement

1. Place the patient in supine and 20° reverse Trendelenburg position with the legs split. Drape in normal sterile fashion for upper abdominal surgery.
2. Position the surgeon console at the left side of patient. Place the patient cart over the patient's head and the vision cart at the right side of the patient, respectively. Have the assistant surgeon stand between the patient's legs to perform the procedures. Position the back table for the instruments and supplies (see **Table of Materials**) at the left rear of the assistant.
3. Make a 1-cm incision with the scalpel 3 cm inferior and right lateral to the umbilicus. Insert a Veress needle into the abdominal cavity through this incision, and establish a CO_2 pneumoperitoneum of 14 mmHg with the automatic insufflation instrument.
4. Remove the Veress needle and then insert a 12-mm trocar through the 1-cm incision as the camera port. Insert the robotic endoscope and perform a diagnostic laparoscopy (have the assistant surgeon hold the robotic endoscope) to confirm the abdominal adhesion status and operative feasibility. Insert the remaining 4 trocars as follows under the view of the endoscope.
5. Place an 8-mm trocar in the left anterior axillary line (**Figure 2**) at the level of the umbilicus for the first robotic arm. Place a 12-mm trocar 2 cm inferior and left lateral to the umbilicus (**Figure 2**) as the assistant port.
6. Place a 12-mm trocar in the right midclavicular line (**Figure 2**) at the level of the umbilicus. Insert an 8-mm trocar into this 12-mm trocar in a "trocar in trocar" fashion for the second robotic arm. Place an 8-mm trocar under the costal margin in the right middle axillary line for the third robotic arm (**Figure 2**). After the docking of robotic army, dock the robotic endoscope in the camera arm.

3. Mobilization of the Pancreas Neck and Body

1. Grasp and keep elevating the anterior wall of the stomach by forceps on the third robotic arm to expose the gastrocolic ligament.
2. Tension the gastrocolic ligament with the bipolar forceps in the second robotic arm and the grasping forceps in the assistant's hand. Divide the gastrocolic ligament to enter the lesser sac and expose the anterior surface of the pancreas with the laparoscopic ultrasonic scalpel on the first robotic arm. Perform hemostasis with bipolar forceps on the second robotic arm, until reaching the level of the right gastroepiploic vein.
3. Carefully dissect the pancreatic neck from the superior and inferior direction with the cautery hook. Proceeding from the inferior to superior direction, divide the posterior wall of the pancreatic neck from the portal vein (PV), superior mesenteric vein (SMV), inferior mesenteric vein (IMV), and splenic vein (SV) with the cautery hook. Afterwards, create a tunnel between the PV-SMV-IMV-SV and posterior wall of the pancreatic neck.
4. Dissect the pancreatic body from the splenic vessels and connective tissues towards the pancreatic tail with the cautery hook and ultrasonic scalpel.

4. Transection of the Pancreatic Parenchyma

1. Insert the laparoscopic ultrasound probe through the assistant trocar and perform the ultrasonography on the pancreas to reconfirm the location and size of the lesion. According to the result of the ultrasonography, mark two transection lines at about 1 cm away from the lesion, on the pancreatic surface with the cautery hook.
2. Lift the pancreatic body with the forceps inserting through the inferior margin of the pancreas and further detach the proximal part of pancreatic body from the splenic vessels and connective tissues with the cautery hook or ultrasonic scalpel.
3. After mobilizing the pancreatic neck and proximal pancreatic body form the posterior vessels and tissues, incise the pancreas parenchyma along the distal and proximal transection line with the ultrasonic scalpel and expose the pancreatic duct. Then transect the parenchyma around the pancreatic duct.
4. Carefully protect and mobilize the pancreatic duct from the transected pancreatic parenchyma. Then sharply transect the pancreatic duct about 1 cm away from the stump, using laparoscopic scissors from the assistant port.

5. Reconstruction of the Pancreatic Continuity

1. To reduce the tension of anastomosis, further mobilize the pancreatic stump from the posterior vessels and connective tissues, using the cautery hook and bipolar forceps.
2. Based on the size of the pancreatic duct stumps, choose a 10-cm plastic pancreatic stent with a proper diameter (1.2 mm in diameter in this case). Cut both ends of the stent to oblique planes and make several side perforations. Implant the stent into the abdominal cavity through the assistant port.
3. Hold the side wall of pancreatic duct stump in the pancreatic body with micro forceps, and insert the stent caught by the needle driver into the distal pancreatic duct stump gently. Suture the pancreatic duct with the stent by using 5-0 absorbable suture, so that the stent is closely encircled by the pancreatic duct.
4. Insert the other end of the stent into the proximal pancreatic duct stump using a similar approach but without suture.
5. Suture the proximal and distal pancreatic stumps using the horizontal mattress suture (4-0 non-absorbable suture).
6. Pull the two pancreatic stumps closer, and continue to insert the proximal end of stent into the proximal pancreatic duct stump. Finally, keep the whole stent within the pancreatic duct and do not bring it into the duodenum lumen.
7. Perform the end-to-end anastomosis of the pancreatic duct stumps using interrupted suture with 5-0 non-absorbable suture.
8. Knot the remaining ties on the pancreatic stumps.
9. Suture the anterior portion of the pancreatic stumps using continuous suture with 4-0 non-absorbable suture (**Figure 3**).

6. Hemostasis and Drainage

1. Carefully check for bleeding sites and conduct thorough hemostasis. Encircle the anastomosis site with absorbable hemostatic gauze.
2. Put the resected specimen in the plastic bag and remove the bag from an enlarged incision in the camera port.
3. Place two drains along the superior and inferior border of the anastomosis site and extract the drains from the port for the third robotic arm.

7. Posteoperative Care

1. After surgery, give the patient intravenous antibiotics (ceftriaxone sodium), parenteral nutrition (glucose, compound vitamin, compound amino acid, fat emulsion, insulin, KCl, and NaCl), analgesic (sufentanil, ondansetron), somatostatin, proton pump inhibitors (lansoprazole) and other treatment as the same as that of conventional central pancreaticectomy. Keep the patient fasting, then remove the nasogastric tube and feed a clear fluid diet on the 2^{nd} postoperative day. Gradually transition to normal diet if the patient can tolerate it.
2. Test the drain fluid for the amylase and bacterial culture after the 3^{rd} postoperative day. When there is no evidence of pancreatic fistula and infection, and the drain volume is less than 10 mL/day, remove the drains.

Representative Results

The operation process was smooth. The operative time was 141 mins and the intraoperative blood loss was about 50 mL. The size of the resected pancreas was about 5.5 × 2.5 × 2.5 cm (**Figure 4**). The patient recovered smoothly after surgery and discharged on the 6^{th} postoperative day. When the patient was discharged, he had a normal diet and normal defecation, and had no fever, no abdominal pain or distension. The routine blood examination and blood biochemical test had no obvious abnormality. Postopertative CT scan showed slight exudation around the pancreas and no dilation or stricture in the pancreatic duct (**Figure 5**). The abdominal drain volume was about 100 mL/day. The pathological examination confirmed a solid pseudopapillary tumor with negative margin and the immunohistochemistry test showed that the tumor was B-catenin (nucleus and capsule +), PR (+60%), Vimentin (+), Cga (-), CD10 (+), syn (+), CK (focal+), CD56 (+), ki-67 (+ 2%). The drains were removed on the 20^{th} postoperative day.

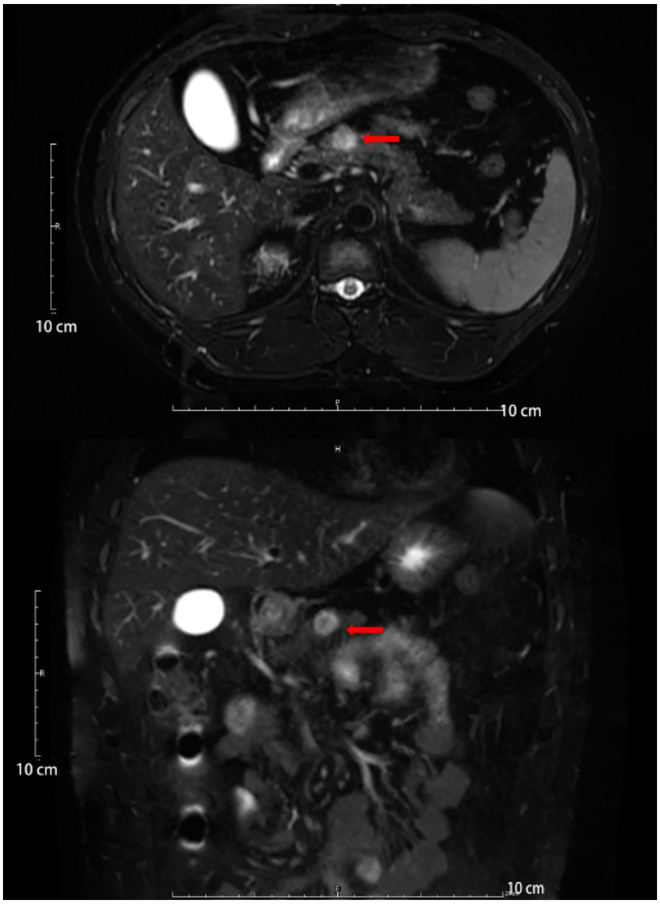

Figure 1: Preoperative MRI of the patient. Red arrow indicates a quasi-circular lesion in the pancreatic neck. Please click here to view a larger version of this figure.

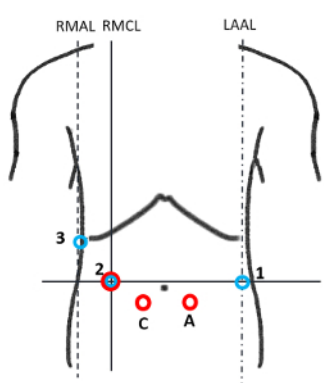

Figure 2: Port placement. Five ports were used. 1: port for the first robotic arm; 2: port for the second robotic arm ("trocar in trocar" fashion); 3: port for the third robotic arm; C: camera port; A: assistant port; red circle: 12-mm trocar; blue circle: 8-mm trocar; RMAL: right middle axillary line; RMCL: right midclavicular line; LAAL: left anterior axillary line. Please click here to view a larger version of this figure.

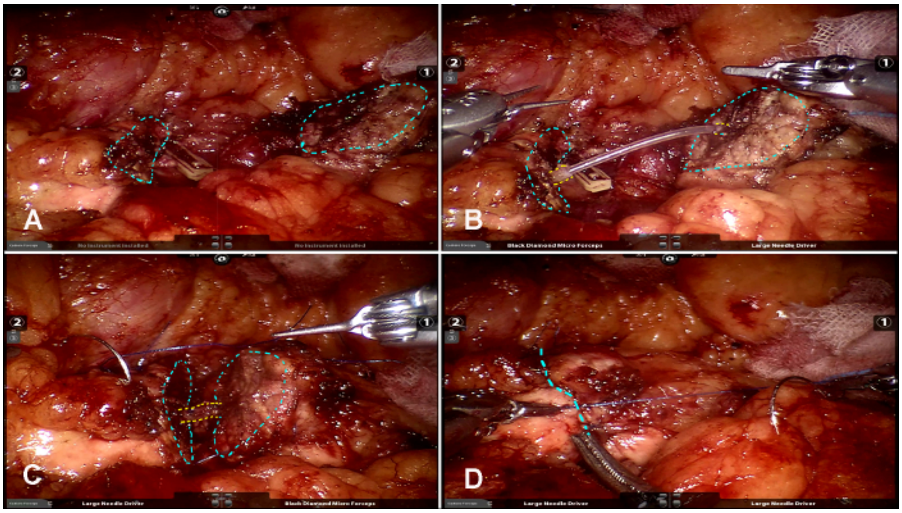

Figure 3: Reconstruction of the pancreatic continuity. (**A**) The middle portion of the pancreas was resected and the stumps of pancreatic duct were dissected. (**B**) The pancreatic stent was inserted into the pancreatic duct. (**C**) The duct-to-duct anastomosis of the pancreatic duct was completed during suturing and pulling together two stumps of the pancreas. (**D**) The end-to-end anastomosis of the pancreas was completed. Yellow dash line: stumps of the pancreatic duct; Cyan dash line: cutting margin of the pancreas. Please click here to view a larger version of this figure.

Figure 4: Gross morphology of the resected central pancreas. Please click here to view a larger version of this figure.

Figure 5: Postoperative CT scan of the patient. Slight exudation around the pancreas and no dilation or stricture in the pancreatic duct. White arrow indicates the stent in the pancreas. Please click here to view a larger version of this figure.

Discussion

Malignant tumors located in the pancreas neck and the proximal part of the pancreatic body are often treated with pancreaticoduodenectomy or distal pancreatectomy. However, for benign or low malignant potential tumors in those sites, the standard pancreaticoduodenectomy or distal pancreatectomy will remove excessive normal tissues and result in excessive injury. Therefore, the central pancreatectomy or pancreatic enucleation, known as "parenchyma-sparing pancreatectomy", becomes a preferable choice for the treatment of benign and low malignant potential tumors in the pancreatic neck and body.

As early as 1908, Ehrhardt had reported the central pancreatectomy[15]. Currently, the most commonly used reconstructions for pancreatico-intestinal continuity after central pancreatectomy are as follows: (1) over-sewing the proximal pancreatic remnant and performing pancreaticojejunostomy for the distal pancreatic remnant; (2) over-sewing the proximal pancreatic remnant and performing pancreaticogastrostomy for the distal pancreatic remnant. These two reconstruction approaches ensure an appropriate tension for anastomosis. However, they disrupt the anatomic continuity of digestive tracts and changes the exocrine pathway of the pancreas. Because the pancreatic enzymes could be activated by intestinal juice in the pancreaticojejunostomy, the possibility of Grade C pancreatic fistula is relatively higher in central pancreatectomy, so that the short-term complications such as bleeding also increase[8,16]. Moreover, as the pancreatic stump directly contacts gastric juice in the pancreaticogastrostomy, enzymes could be inactivated, thus, theoretically ameliorating the erosion of anastomosis. But it might also lead to pancreatic exocrine insufficiency, and in the long term jeopardize the patient's nutritional status[9,10].

As a rarely utilized approach, the end-to-end anastomosis of pancreatic stumps might resolve the drawbacks of the aforementioned reconstruction approach; it does not need the pancreaticoenteric anastomosis and could maintain the integrity and continuity of the digestive tract. It could also keep the pancreatic juice secreting from its original physiological structure. However, perhaps because of its technical complexity, only a few cases of open central pancreatectomy with end-to-end anastomosis are reported, and this approach was not applied consecutively[17,18,19,20].

As the most advanced representative of minimally invasive surgery, the robotic surgical system has been applied in the central pancreatectomy, and the current reconstruction approaches are over-sewing the proximal pancreatic remnant and performing pancreaticojejunostomy or pancreaticogastrostomy for the distal pancreatic remnant[6,21,22,23]. Our surgical team has rich experience in robotic pancreaticoduodenectomy, central pancreatectomy, and distal pancreatectomy[13,24]. We have also performed robotic pancreatic enucleation with main pancreatic duct invasion and injury. In that surgery, we repaired the pancreatic duct injury by inserting a pancreatic stent and using end-to-end anastomosis[14]. Based on our experience in robotic pancreatic surgery, we have modified the traditional robotic central pancreatectomy with end-to-end anastomosis, to maximize the residual pancreatic parenchyma and minimalize the injury to patients.

Currently, we used the robotic surgical system to perform the central pancreatectomy and reconstruct the pancreatic continuity through the pancreatic duct plasty and end-to-end pancreatic anastomosis. We found that the short-time outcomes were favorable. As the robotic surgical system has a magnifying 3-D view, multi-degree of freedom for the movement of instruments, the elimination of physiological fibrillation, and other characteristics, this surgical system shows inherent advantages in the dissection, plasty, and anastomosis of the pancreatic duct. Compared with conventional reconstruction approaches, this approach avoids the pancreaticoenteric anastomosis of the distal pancreatic stump, shortens the operation time, and reduces the injury. The direct anastomosis of the two pancreatic stumps avoids the pancreatic stump to contact with digestive fluids, which theoretically could reduce the risk of pancreatic fistula and bleeding. The placement of the stent also enables the anastomosis of the pancreatic duct to be more secure and rapid. In addition, continuous support by the stent also helps to prevent the postoperative stricture of the pancreatic duct. On the other hand, even if pancreatic fistula occurred, the pancreatic fluid could flow into the duodenum through the stent instead of flowing outside the pancreas, thereby reducing the damage of pancreatic fistula to the surrounding organs. Because the stent is sutured to the pancreatic duct with absorbable suture, the stent will spontaneously fall off within a few months.

The critical step of the procedure is the anastomosis of the pancreatic duct and parenchyma without tension. To achieve a tension-free anastomosis, the pancreatic stumps should be sufficiently mobilized from their posterior vessels and tissues, especially the distal stump. It should be noted that the transection of the pancreatic duct was performed by scissor instead of energy instruments, which could reduce the damage of the pancreatic duct and facilitate a better duct-to-duct anastomosis. Additionally, the stumps of the pancreatic duct should be dissected from the resected pancreas as much as possible for plasty. For the pancreatic stent, we usually sterilize plastic tubes with different diameters and lengths by the operation center and choose the correct size during the operation.

We found that in selected patients, the robotic central pancreatectomy with end-to-end anastomosis is safe and feasible. This surgical approach reduces the extent of the central pancreatectomy and maintains the integrity and continuity of physiology and anatomy, which reflects the minimally invasive characteristics of the robotic surgical system in pancreatic surgery. As this operation is at an initial phase, many issues are still unclear, such as how to rationally use somatostatin postoperatively; for patients with long defect of pancreatic duct, whether we should choose central pancreatectomy; if the stent does not fall off spontaneously, what is the side-effect, *etc.* Its technical modification and long-term efficacy also remain to be explored.

Disclosures

No competing financial interests exist.

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