Robotic Spleen-Preserving Distal Pancreatectomy: The Warshaw and Kimura Techniques

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Abstract

Spleen-preserving distal pancreatectomy offers an alternative surgical approach to the traditional distal pancreatectomy combined with splenectomy for removing benign and low-grade malignant lesions in the distal pancreas, avoiding complications associated with splenectomy. This procedure can be accomplished either by resecting and ligating the splenic vessels (Warshaw technique) or by preserving them (Kimura technique). Currently, the widespread use of minimally invasive surgery has established laparoscopic and robotic approaches for spleen-preserving distal pancreatectomy as valid and safe options for treating such conditions. Our protocol aims to describe how the Warshaw and Kimura techniques of spleen-preserving distal pancreatectomy can be performed robotically. The first patient is a 36-year-old female with a neuroendocrine tumor (NET) in the pancreatic body who underwent a spleen-preserving distal pancreatectomy with the ligation of the splenic vessels (WT). The second patient is a 76-year-old male with chronic pancreatitis presenting with a dilated main pancreatic duct in the tail of the pancreas who underwent a spleen-preserving distal pancreatectomy with a vessel-preserving approach (KT).

Introduction

Distal pancreatectomy (DP) is performed to remove benign and malignant lesions located in the pancreatic body and tail. Traditionally, DP is combined with splenectomy[1]. However, a spleen-preserving approach is recommended when resecting benign and low-grade/pre-malignant lesions of the distal pancreas to avoid short and long-term complications associated with splenectomy[2]. Such complications include hemorrhage, thrombocytosis, thromboembolic incidents, pulmonary hypertension, and overwhelming post-splenectomy infection (OPSI)[3]. Nevertheless, spleen preservation can lead to complications such as splenic infarction, splenic vein thrombosis, and abscess formation. Secondary splenectomy, described in 0-2% of the cases of initially intended spleen preservation, is a potential complication[4,5,6,7].

Spleen-preserving distal pancreatectomy can be achieved using two different approaches[8]. The first approach, the Warshaw technique (WT), initially described by Warshaw in 1988, is a vessel-resecting technique[9]. In WT, the splenic artery and vein are resected and ligated, and perfusion of the spleen is provided by the left gastroepiploic artery and the short gastric vessels.The second technique, a vessel-preserving approach described by Kimura (KT) in 1996[10], involves ligating the small splenic branches posterior to the pancreas while preserving the splenic artery and vein. Recently, a third alternative that preserves the spleen with splenic vein scarifying and splenic artery preservation has been proposed by Kim et al.[11]. Patient anatomy plays a crucial role in deciding which approach to follow. The Kimura technique is more feasible when the splenic vessels are found in an extra-pancreatic position. However, if the splenic vessels cannot be separated from the posterior surface of the pancreas, the Warshaw technique is performed. Intraoperative findings and incidents can also alter the initial operative plan.

Here, we present two cases of robotic spleen-preserving distal pancreatectomy. Details about the patients are described below.

The first patient is a 36-year-old female presenting with atypical abdominal symptoms. She underwent a computed tomography (CT) that revealed a 26 mm round lesion in the pancreatic body without pancreatic duct dilation and without vascular involvement (**Figure 1**). The original differential diagnosis included a neuroendocrine tumor (NET) and an accessory spleen due to the lesion's enhancement. Consequently, the patient also underwent scintigraphy with Technetium-99m (^{99m}Tc) labeled heat-denatured erythrocyte scan, which was negative for splenosis. A positron emission tomography (PET) scan revealed strongly elevated somatostatin receptor expression in the lesion (**Figure 2**). Based on these results, an indication for a robotic spleen preserving distal pancreatectomy was determined. Due to the patient's anatomy and proximity of the splenic vessels to the posterior surface of the pancreas, the Warshaw approach was considered more suitable.

The second patient is a 76-year-old male with chronic pancreatitis, complaining of the pain in the lower left abdomen for the past 18 months. No history of acute pancreatitis or excessive alcohol use was reported. Initially, he underwent a CT colonography due to reported lower gastrointestinal symptoms. The scan did not show any pathological findings in the colon but described a suspected obstructive stone in the distal pancreas with a focally dilated main pancreatic duct. Endoscopic ultrasonography (EUS) confirmed the diagnosis of chronic pancreatitis but also found a lesion suspicious for a papillary tumor. Nevertheless, the fine needle aspiration (FNA) pathology revealed a low-grade adenoma. His most recent CT scan revealed an image of chronic pancreatitis with a dilated pancreatic duct in the tail up to 7 mm and an abrupt transition between the tail and the body of the pancreas. Multiple coarse calcifications were also present (**Figure 3**). The patient was scheduled for a robotic spleen preserving distal pancreatectomy. The patient's anatomy favored the selection of the Kimura technique, as the splenic vessels were in an extra-pancreatic position.

Protocol

NOTE: Both patients provided written and oral informed consent for the use of medical data and operative videos for educational and scientific purposes. The protocol was approved by our institution (Amsterdam University Medical Centers).

1. Case 1 (Warshaw technique)

1. Positioning
    1. Place the patient in a supine position with legs split in a French position.
    2. Abduct the left arm to 90° and lower the right arm alongside the body.
    3. Tilt the operating table 10° in reverse Trendelenburg position and 10° to the right.
2. Trocars position and robot docking
    1. Introduce a Veress needle on Palmers' point to insufflate the abdomen.
    2. Introduce four 8 mm robot trocars (R1-4). Start with the introduction of the camera port (R3) in a line from the crossing of the left midclavicular line and the inferior costal cartilage to the umbilicus, approximately 11 cm from the costal margin at the expected level of the pancreatic tail.
    NOTE: The trocars are placed in a semi-curved line above the umbilicus with a distance of 7 cm between them. R1 is placed in the right anterior axillary line, trocar R2 in the right midclavicular line and trocar R4 in the left midclavicular line (**Figure 4**).
    3. Introduce one assistant 12 mm trocar, 3 cm below the middle of R3 and R4.
    4. Place one 5 mm trocar in the right subcostal area for stomach and liver retraction.
    5. Dock the robot from the right shoulder of the patient.
3. Mobilization
    1. Identify the gastrocolic ligament and divide it with the vessel sealing device, so that the lesser sac is opened.
    2. Introduce the liver retractor from the patient's right side and retract both the liver and the stomach.
    NOTE: This enables optimal exposure of the surgical site. Alternatively, use a transabdominal stay suture through the posterior corpus of the stomach to retract it.
4. Resection
    1. Create a retropancreatic tunnel by mobilizing the pancreas. Start the mobilization cranially using robotic forceps and cautery hook and dissect all tissue around the pancreas. Then mobilize caudally. Ensure that the tunnel is complete by placing the forceps caudally and advancing it until it is visible cranially.
    2. Identify the splenic vein and the splenic artery.
    3. Place a vessel-loop around the pancreas using robotic forceps as a means of retraction. Pass the loop to surround the pancreas around the transection line through the tunnel and hold the ends of the loop together using metallic or Hem-o-lock clips.
    4. Dissect the pancreas using a linear stapler, performing gradual compression for 4 min. If the transection is not complete after that step, detach the specimen using a vessel sealing device, scissors, or the cautery hook.
    5. Place a vessel loop around the vessels to facilitate retraction prior to the stapler's entering. Transect first the splenic artery and next the splenic vein.

6. Mobilize the pancreas until the splenic hilum. In the Warshaw procedure, the splenic vessels are transected again using a stapler or hem-o-lock clips as close as possible behind the pancreatic tail to preserve all collateral vessels between the gastroepiploic vessels and the spleen.
7. Detach the pancreatic tail from the splenic hilum using the vessel sealing device or a stapler.
8. Place the specimen in an Endobag and remove it through a Pfannenstiel incision.

5. Spleen assessment
    1. Assess the spleen's condition prior to pneumoperitoneum exsufflation. Assess the color of the spleen and look for areas of demarcation suggesting splenic infarcts.

2. Case 2 (Kimura technique)

1. Positioning
    1. Place the patient in a supine position with legs split in a French position.
    2. Abduct the left arm to 90° and lower the right arm alongside the body.
    3. Tilt the operating table 10° in reverse Trendelenburg position and 10° to the right.
2. Trocars position and robot docking
    1. Introduce a Veress needle on Palmers' point to insufflate the abdomen.
    2. Introduce four 8 mm robot trocars (R1-4). Start with the introduction of the camera port (R3) in a line from the crossing of the left midclavicular line and the inferior costal cartilage to the umbilicus, approximately 11 cm from the costal margin at the expected level of the pancreatic tail.
    NOTE: The trocars are placed in a semi-curved line above the umbilicus with a distance of 7 cm between them. R1 is placed in the right anterior axillary line, trocar R2 in the right midclavicular line and trocar R4 in the left midclavicular line (**Figure 4**).
    3. Introduce one assistant 12 mm trocar 3 cm below the middle of R3 and R4.
    4. Place one 5mm trocar in the right subcostal area for stomach and liver retraction.
    5. Dock the robot from the right shoulder of the patient.
3. Mobilization
    1. Identify the gastrocolic ligament and divide it with the vessel sealing device, so that the lesser sac is opened.
    2. Introduce the liver retractor from the patient's right side and retract both the liver and the stomach. This enables optimal exposure of the surgical site. Alternatively, use a transabdominal stay suture through the posterior corpus of the stomach to retract it.
4. Intraoperative ultrasonography
    1. Optionally, before the pancreas transection, introduce an ultrasonography probe to identify the dilated pancreatic duct and assess the parenchymal transection.
    2. Use the cautery hook to demarcate the transection line.
5. Resection
    1. Create a retropancreatic tunnel by mobilizing the pancreas. Start the mobilization cranially using

robotic forceps and cautery hook and dissect all tissue around the pancreas. Then mobilize caudally.

2. Identify the splenic vessels. Mobilize the splenic vein and the splenic artery and preserve them.

3. Ensure that the tunnel is complete by placing the forceps caudally and advancing it until it is visible cranially.

4. Place a vessel-loop around the pancreas using robotic forceps as a means of retraction. Pass the loop to surround the pancreas around the transection line through the tunnel and hold the ends of the loop together using metallic or Hem-o-lock clips.

5. Dissect the pancreas using a linear stapler, performing gradual compression for 4 min. If the transection is not complete after that step, detach the specimen using a vessel sealing device, scissors, or the cautery hook.

6. After the transection of the pancreas, the small splenic branches posterior to the pancreas are carefully ligated using metallic or Hem-o-lock clips.

7. Mobilize the pancreas until the splenic hilum. Carefully dissect all tissue around the pancreas using the vessel sealing device until you reach the hilum of the spleen.

8. Detach the pancreatic tail from the splenic hilum using the vessel sealing device or a stapler.

9. Place the specimen in an Endobag and remove it through a Pfannenstiel incision.

6. Drain placement

   1. Introduce an 18-20 French drain from the left side of the patient and advance it next to the pancreatic stump. Ensure the drain makes no direct contact with either the pancreas or vessels (stumps).

3. Post-operative care:

1. Day 0
   1. Ensure the patient returns to the department after spending 6 h in the recovery room.
   2. Measure glucose levels four times daily[12].
2. Day 1
   1. Measure gastric retention via the nasogastric tube. Remove the nasogastric tube if the retention is below 300 mL.
   2. Start feeding after the removal of the nasogastric tube.
   3. Measure glucose levels four times daily[12].
3. Day 3
   1. Measure amylase levels to test for post-operative pancreatic fistula if a drain is present. If drain amylase is <400 U/L and production is < 300ml/24hr, remove the drain.
   2. Measure C-reactive protein (CRP) levels[13].
4. Day 4
   1. Repeat CRP levels if CRP> 150 on day 3. CRP levels must be >10% lower than on day 3. If not, perform a CT scan.

Representative Results

For the patient undergoing the Warshaw technique (Patient 1), the total operation time was 190 minutes with 200 mL of blood loss. No drain was placed. On the third and fourth POD, C-reactive protein was measured, showing a non-decreasing trend. Hence, a CT scan was performed revealing a hypodense fluid collection of approximately 5 cm which was drained percutaneously using a 10 French pigtail catheter. The fluid contained high amylase (24.109 U/L, International Study Group of Pancreatic Fistula grade B). The patient was discharged on POD 5. Once drain amylase had normalized on POD 22, it was removed. The pathology revealed a grade 1 (number of mitosis 0 per 2 mm^2, Ki67 proliferation: 2%) invasive NET, with 100% positive tumor cells for chromogranin and synaptophysin and 1 positive regional lymph node (station 11p) classifying it as T2N1R1 (the posterior margin was <1mm) (**Figure 5**). Imaging 6 months after the resection revealed no recurrence or metastasis (**Figure 6**).

For the patient who underwent the Kimura technique (Patient 2), the total operation time was 180 min with 50 mL of blood loss. One drain was placed. The drain was removed on POD 6 and the patient was discharged the following day. On POD 18, the patient presented to the outpatient clinic complaining about pain in the lower left abdomen. A CT scan was performed revealing a fluid collection of 7 cm at the site of the resection. An endoscopic transgastric drainage was performed with a stent placement (ISGPS grade B). The follow-up CT revealed no collection (**Figure 7**). The histopathological examination revealed chronic atrophic pancreatitis with no sign of malignancy (**Figure 8**). Table 1 summaries the representative results of the two techniques.

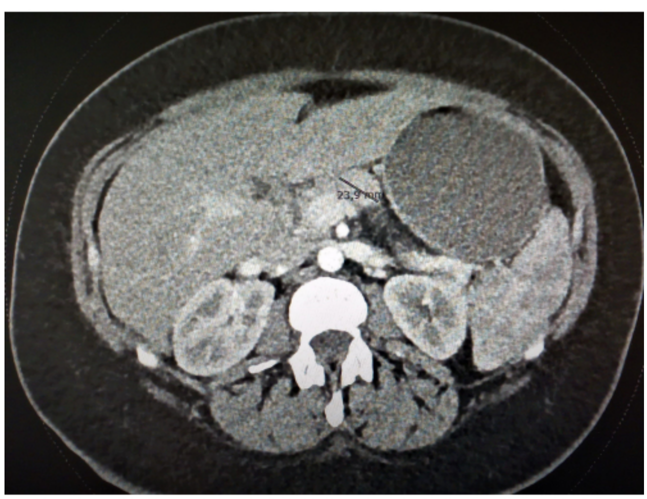

Figure 1: Pre-operative CT scan of the Warshaw patient. Please click here to view a larger version of this figure.

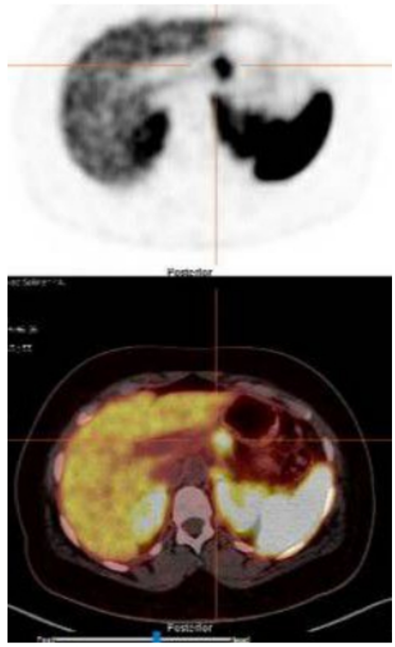

Figure 2: Pre-operative PET scan of the Warshaw patient. Please click here to view a larger version of this figure.

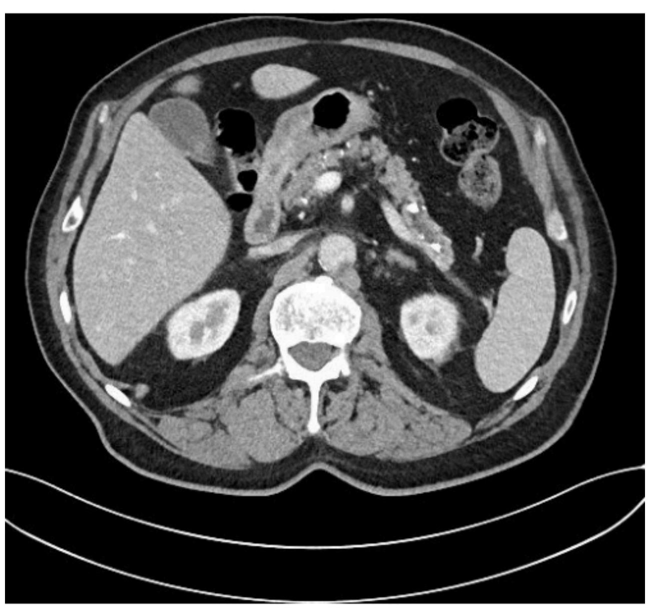

Figure 3: Pre-operative CT scan of the Kimura patient. Please click here to view a larger version of this figure.

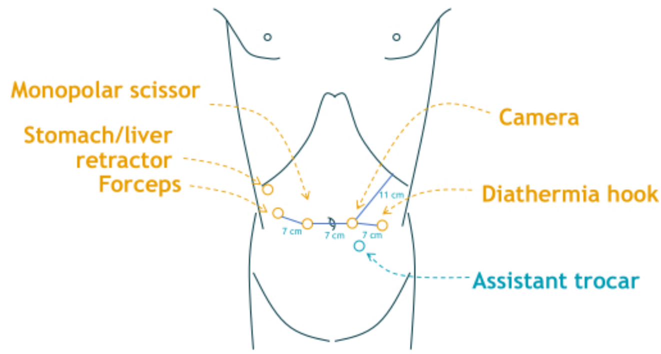

Figure 4: Trocars' positions. This is adapted with permission from ref[14]. Please click here to view a larger version of this figure.

Figure 5: Specimen-Warshaw patient. Please click here to view a larger version of this figure.

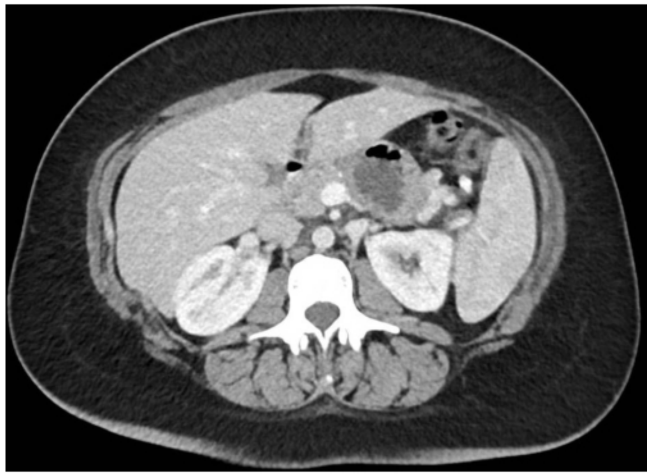

Figure 6: Postoperative CT scan of the Warshaw patient. Please click here to view a larger version of this figure.

Figure 7: Postoperative CT scan of the Kimura patient. Please click here to view a larger version of this figure.

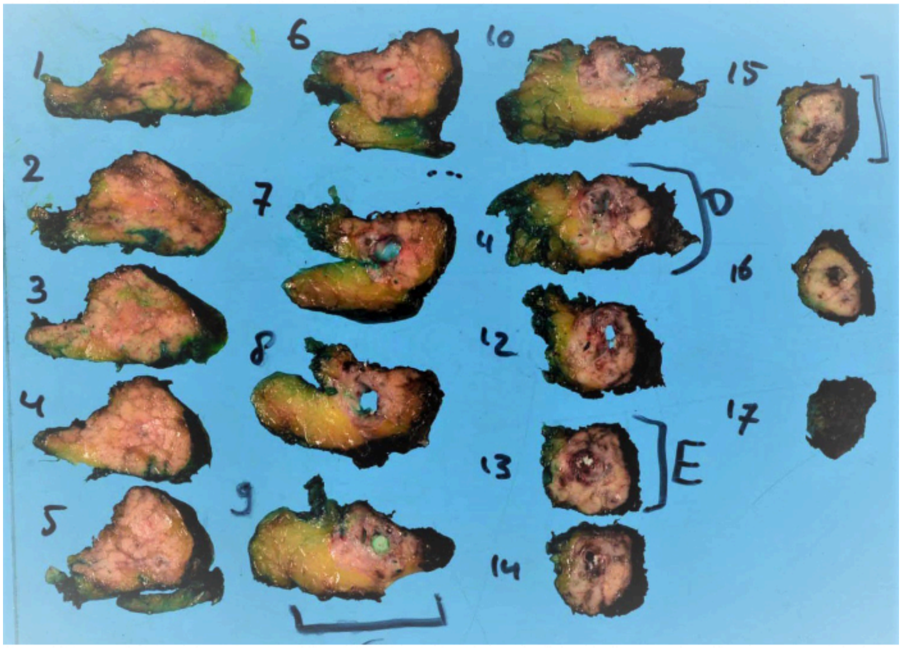

Figure 8: Specimen-Kimura patient. Please click here to view a larger version of this figure.

	Operation time (min)	*Blood loss (ml)*	*Drain placement*	*Complications*	*Pathology*
WT patient	190	200	No	ISGPS grade B	T2N1R1
KT patient	180	50	Yes	ISGPS grade B	Chronic atrophic pancreatitis
WT: Warshaw technique, KT: Kimura technique, ISGPS: International Study Group of Pancreatic Fistula					

Table 1: Postoperative outcomes.

Discussion

The critical steps concerning spleen-preserving robotic DP include positioning and robot docking, mobilization, intraoperative ultrasonography (if necessary), dissection and management of the splenic vessels, spleen assessment and drain placement. In the case of uncontrollable bleeding, conversion to laparotomy is recommended. The assessment of the spleen's viability should be performed before exsuflating the abdomen.

Modifications of the technique include the use of a second assistant trocar, the introduction of the liver retractor on either the left or the right side of the patient and the use of the energy device by either the table side surgeon or the robotic console surgeon. During training, some steps of the mobilization can be initially performed laparoscopically until complete familiarization with the robotic console is achieved. If the linear stapler is not available, multiple Hem-o-lock or metallic clips can be used to ligate the vessels.

The introduction of minimally invasive surgery in recent years has established laparoscopic and robotic approaches to spleen preserving DP as safe and feasible surgical options. A recent meta-analysis of two randomized controlled trials[15,16] was published, comparing minimally invasive DP to open DP. The meta-analysis revealed no significant differences between the two approaches in major complications, but a significantly reduced the length of hospital stay and delayed gastric emptying favoring the minimally invasive technique[17]. The rate of spleen preservation in minimal invasive DP ranges between 29% and 86%[5]. However, limitations of robotic surgery include the loss of haptic feedback, the surgeons' learning curve and the higher cost associated with the robotic platform and consumables[18].

Comparative studies between the two techniques have addressed clinical outcomes such as safety, short- and long-term complications, operative time and intraoperative blood loss. The results of these retrospectivity studies are mixed, with some reporting comparable short- and long-term outcomes[19,20,21] for the two techniques, while others suggest the KT is superior due to fewer complications associated with the WT (splenic infarction, secondary splenectomy and incidence of gastric varices)[4,22]. The most recent systematic review and meta-analysis of the existing studies concluded that while the two techniques are generally comparable in most postoperative outcomes, KT is superior to WT, showing significantly lower incidence of splenic infarction (OR= 0.14, p<0.0001) and reduced risk of gastric varices (OR=0.1, p<0.0001).[23]

In conclusion, robotic spleen-preserving distal pancreatectomy is a feasible and safe procedure in experienced hands. Patient's anatomy may play a crucial role in deciding the optimal surgical technique. Further research is necessary to comprehensively understand the comparative clinical outcomes of the two techniques.

Disclosures

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