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Laparoscopic Distal Pancreatectomy Preserving the Spleen and Splenic Vessels for Benign and Low-Grade Malignant Pancreatic Neoplasm

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Abstract  Background/Aims: Laparoscopic spleen-preserving distal pancreatectomy (LSPDP) is expected to be less invasive than laparoscopic distal pancreatectomy with splenectomy. However, there are few reports regarding the details of the procedure for LSPDP, and its safety remains unclear. This study aimed to evaluate the feasibility and safety of LSPDP.

Methodology: Six patients underwent LSPDP from March 2009 to February 2013 in our center, and their clinical data and outcomes were reviewed retrospectively.

Results: A total of six laparoscopic distal pancreatic resections were attempted in four female and two male patients. All of the operations were successful, with an average operative time of 290.7 min (range: 211–377 min) and an average blood loss of 43.5 g (range: 0–142 g). The mean hospital stay was 11.8 days (range: 9–17 days). No obvious pancreatic fistulas occurred, although pseudocysts at the stump of the pancreas were recognized in three patients on CT scans performed at 7 days postoperatively. Postoperative pathological examinations revealed two cases of serous cyst adenoma in the body and tail of the pancreas, one case of serous oligocystic adenoma, one case of mucinous cyst adenoma, one case of neuroendocrine tumor, and one case of solid-pseudopapillary neoplasm.

Conclusions: LSPDP is minimally invasive, safe, and feasible for the management of benign pancreatic tail tumors, with the advantages of earlier recovery and less morbidity from complications.

Key words: Pancreas, Laparoscopic, LSPDP, Preserving, Spleen

Introduction

Advances in diagnostic imaging, such as computed tomography (CT) and ultrasonography (Echo), have made the diagnosis of benign lesions and borderline malignant tumors possible. In the case of pancreatic lesions, it is often difficult to obtain a good operative field for distal pancreatectomy because of the location of the pancreas deep inside the body cavity. Consequently, laparoscopic surgery offers some advantages for these lesions because reconstruction is not needed after the procedure. Moreover, given that national health insurance coverage in Japan for laparoscopic distal pancreatectomy, particularly that preserving the spleen and splenic vessels, started in 2012, it is not an overstatement to suggest that this surgery will become the primary treatment option for these lesions.
of choice for benign and low-grade malignant tumors in the body and tail of the pancreas. Unlike the more extensive surgery required for common invasive pancreatic cancer, preservation surgery may be indicated for benign lesions, intraductal papillary mucinous neoplasm (IPMN), borderline (low-grade malignant) mucinous cystic neoplasm, and endocrine tumors. These types of tumors, which mostly grow in the body and tail of the pancreas, have been conventionally treated by distal pancreatectomy with splenectomy, similar to the case for ordinary pancreatic cancer. However, Warshaw\textsuperscript{1} was the first to report preservation by resecting the splenic vessels while preserving the short gastric vessels, and this technique was later followed by splenic vessel preservation described by Kimura et al\textsuperscript{2}. Splenic preservation can prevent the occurrence of splenectomy-related hematologic abnormalities, such as sepsis and increased platelets, and is important from the perspective of tumor immunology.

According to a recent meta-analysis, the rate of postoperative complications after distal pancreatectomy ranges from 13.3\% to 64\%\textsuperscript{1}. The most common complication is pancreatic fistula, which extends the length of hospital stay and sometimes causes serious conditions through bleeding from an intra-abdominal abscess. Therefore, a safe and proper technique is needed to handle pancreatic stumps. The hand-sewing method, in which the pancreatectomy is performed using a surgical scalpel or high-frequency electric cautery and the stump is sutured by hand, has been the conventional surgical procedure for many years, with linear staplers and ultrasonic scalpels being used in various attempts to reduce the incidence of pancreatic fistula formation.

**Patients and Methods**

**Patients**

A total of six patients, comprising four females and two males with a mean age of 46.5 years (range: 30–74 years), were recruited from March 2009 to February 2013. All six patients underwent laparoscopic spleen-preserving distal pancreatectomy (LSPDP). The preoperative symptoms of the patients included upper abdominal distention in two cases, with no apparent symptoms in the remaining four patients on CT or magnetic resonance imaging (MRI). Physical examinations indicated that four patients had no positive signs, while two patients had a solid mass without cystic sensation in the upper or epigastric left abdomen that showed tenderness. Preoperative ultrasonography examinations revealed five cases of cystic lesion and one case of solid lesion located in the body and tail of the pancreas. The wall of each space-occupying cyst was intact, relatively thick, and non-uniform, with track lines and substantial projections into the cyst. Preoperative CT results showed the cysts were multilocular in the body and tail of the pancreas with track lines. The thickness of the cystic wall was non-uniform and there was calcification around the track lines in the cysts in five cases. The margins of the cysts were clear without conglutination. Splenic vein compression was observed in one patient. The mean diameter of the cysts was 5.2 cm (range: 4.2–6 cm). All patients also underwent MRI examinations, which indicated that the cysts were in the body and tail of pancreas with track lines, clear margins, and no conglutination with neighboring organs. The tumor markers CA19–9, CA125, CEA, and AFP were all negative in the five patients with a cystic tumor. The sixth male patient had a solid tumor diagnosed by Echo, CT, and MRI, and tumor markers such as CA19–9 and CEA were slightly elevated to 39.6 and 6.9, respectively. A preoperative endoscopic transgastric echo-guided biopsy was performed. The histological diagnosis was solid–pseudopapillary neoplasm. A laparoscopic distal pancreatectomy preserving the spleen and splenic vessels was planned.

**Surgical indications**

Benign and low-grade tumors in the body and
tail of the pancreas located on the left side of the body were indicated for LSPDP. Ordinary pancreatic cancer and main-duct IPMN were excluded.

**Surgical position and trocar placement (Fig. 1)**

1. Distal pancreatectomy for the tumor located in the pancreatic body

   Patients with a tumor in the pancreatic body were placed in the supine position with their legs apart. Since this surgical position would later be changed to the right lateral decubitus position for detachment of the tail portion by rotating the surgical table, a vacuum mattress and two retainers were placed on the patient’s right side to prepare for the rotation. After creating a midline umbilical incision, a 12-mm laparoscopic trocar was inserted into the abdominal cavity, followed by insertion of two trocars into the right upper abdomen. On the left side of the body, a 5-mm trocar was inserted at the lateral border of the left rectus abdominis muscle and another along the anterior axillary line. The surgeon operated on the right side of the patient, with the assistant standing on the left, and the camera operator standing between the patient’s legs.

II. Distal pancreatectomy for the tumor located in the pancreatic tail

   The patients were placed in the right lateral decubitus position, with a vacuum mattress and retainers placed to the side. As described above, creation of a midline umbilical incision was followed by insertion of a 12-mm trocar below the incision site and insertion of one 5-mm trocar each along the midline of the upper abdomen, the lateral border of the left rectus abdominis muscle, and the anterior axillary line (total of four trocars). The surgeon and person in charge of the intraoperative video monitoring stood on the right side of the patient and the assistant stood on the left.

**Surgical procedures**

1. Distal pancreatectomy for the tumor located in the pancreatic body (Fig. 2)

   1) Elevation of the lateral segments of the left hepatic lobe

   Since the lateral segments of the left hepatic lobe often obstructed the view of the body and tail of the pancreas, the left hepatic lobe was maintained in an elevated position during surgery, similar to the case for laparoscopic gastrectomy.

   2) Dissection of the greater omentum and division of the pancreas from the stomach

   While the greater curvature of the distal stomach was being lifted toward the cranioventral side by the assistant using forceps, an incision was made in the greater omentum to reach the area between the posterior wall of the stomach and the anterior of the pancreas. Detachment proceeded until the surgeon reached the superior side of the splenic artery beyond the superior margin of the pancreas, leaving the anterior pancreatic fascia intact.

   3) Localization of the tumor

   Localization of the tumor was performed from the anterior side of the pancreas. If necessary, Echo was performed to determine the location of and detailed information about the tumor and to investigate the relationship of the tumor with the main pancreatic duct. When invasive growth and/or malignancy were suspected, the surgical procedure was switched to distal pancreatectomy with splenectomy and, if necessary, lymph node dissection. The routes of the splenic vessels were carefully observed and a surgical resection line was predetermined.

   4) Dissection of the splenic artery

   Dissection of the splenic artery from the superior margin of the pancreas started from the cranial side of the vessel and proceeded to the dorsal side until the entire circumference was dissected. The splenic artery was encircled by elastic traction tape. During the above procedures, we tried to preserve the anterior pancreatic fascia.

   5) Dissection of the inferior margin of the pancreas
In pancreatectomy, the anterior pancreatic fascia can be preserved. To achieve this, the dorsal side of the pancreas was reached via an incision on the anterior transverse mesocolon made as far from the inferior margin of the pancreas as possible.

6) Dissection of the splenic vein from the dorsal side of the pancreas

Toldt’s fascia is a posterior pancreatic fascia formed by fusion of the dorsal mesentery of the stomach and the retroperitoneal membrane, and consists of three layers. The splenic vein was reached from the dorsal side by performing detachment as far back as possible while leaving the posterior pancreatic fascia as intact as possible.

7) Dissection of the splenic vein and tunneling

The splenic vein was reached from the dorsal side and separated from the posterior side of the pancreas. Extreme care was taken while performing the dissection, because the splenic vein has a number of small branches that enter the pancreatic parenchyma. With minimum dissection, tunneling of the superior margin of the pancreas was performed on the inferior side of the splenic artery. Cotton tape was passed from the anterior cranial side to lift the pancreas. Although dissection of the splenic vein was kept to a minimum for preservation of the posterior pancreatic fascia, it was necessary to transect one or two of the branches before and after lifting the pancreas.

8) Pancreatectomy: key points for resection with linear stapling

a) Selection of trocars for a linear stapler

An Echelon™ 60 linear stapler (green cartridge; Ethicon Endo Surgery) or a Tri-Stapler linear stapler (black cartridge; Covidien) was used. Since the dissection of the splenic vein and mobilization of the pancreas were kept to a minimum, determination of a proper location for insertion of the linear stapler was key for a precise pancreatectomy. Although we selected a trocar that stayed as horizontal as possible to the predetermined resection line, it was sometimes necessary to set up an additional port,
depending on the site. The resection site needed to be carefully selected so that the linear stapler could reach the site in a straight line.

b) Pre-compression and coagulation (Fig. 3)

The following procedures were performed when the thickness of the pancreas at the planned transection line was > 15 mm. Using cotton tape, the pancreas was lifted and two removable intestinal or vessel clips were placed side by side horizontal to the resection line. The pancreas was compressed for around 5 min, and the clips were removed as soon as the thickness of the pancreatic parenchyma reached approximately 5 mm. While irrigating the 1-cm-wide compressed area with physiological saline, coagulation was performed using a BiClamp (VIO) at effect 3 for milder compression. After coagulation, the linear stapler was inserted into the abdominal cavity and carefully placed over the coagulated resection line. Firing was performed slowly to feel the tightening of one line at a time.

c) Post-coagulation (Fig. 4)

If the thickness of the pancreas at the planned transection line was estimated to be < 15 mm, the linear stapler was used for transection without prior compression by removable clips. As described above, closing and firing of the stapler were done slowly. After transection of the pancreas, the stapled stump was coagulated with irrigation under gentle compression.

9) Mobilization of the pancreas with preservation of the splenic vessels

a) Lifting of the pancreas

While the assistant carefully grasped and raised
the transected pancreatic stump toward the ventral side, the mobilization of the pancreas was continued to the pancreatic tail. If the pancreas or lesion was thought to be fragile, the cotton tape placed at the time of transection was secured over the staple line at the transection site using a clip to help lift the pancreas.

b) Dissection of the gastroplenic ligament

Dissection of the splenic ligaments proceeded toward the superior pole of the spleen. However, to prepare for unsuccessful preservation of the splenic vein, detachment of the gastroplenic ligament was kept to a minimum and the short gastric vessels were preserved as much as possible.

c) Dissection of the splenic artery from the pancreatic parenchyma

The splenic artery runs superior to the splenic vein and is separated from the pancreatic parenchyma by some connective tissues. In general, it is easy to observe the entire artery up to the tail of the pancreas. Some branches of the splenic artery entering the body and tail of the pancreas may be as large as the great pancreatic artery. Large branches were securely clipped on the proximal side, and the distal side was coagulated using the BiClamp prior to transection. Compared with the splenic vein, it was relatively easy to detach the splenic artery from the pancreatic parenchyma because there were few branches.

d) Dissection of the splenic vein from the pancreatic parenchyma (Fig. 5A)

For the most part, the splenic vein is buried in the pancreatic parenchyma, running near the center of the body and tail of the pancreas. In addition, small branches from the pancreas enter the splenic vein, making it difficult to detach the two organs and to perform other procedures, such as ligation and clipping. Furthermore, any bleeding from the vein is difficult to stop and may lead to thrombus formation and stenosis of the main splenic vein. If the vein was large enough to withstand some extent of detachment, we transected the vessel after securely placing a clip on the proximal side and coagulating the distal side using the BiClamp prior to transection. If the vessel was narrow and short, we coagulated the vessel using the BiClamp without clipping prior to transection at the distal side. When removing the BiClamp after coagulation, bleeding can occur because of adhesion between the apparatus and the vessel. Therefore, the important points to remember were that bleeding should be completely stopped prior to coagulation and that, during coagulation, the vessels should be irrigated with physiological saline under gentle compression. Moreover, the BiClamp should be removed completely from the vessel to confirm successful coagulation prior to transection. Transection was performed as distal or close to the pancreas as possible (Fig. 5B). Although it was possible to perform additional hemostatic treatment of the vessel on the side of the pancreas, which was to be resected later, such treatment on the side of the main splenic vein carried a high risk of thrombus formation and stenosis.

Postoperative treatment

The drainage tube was removed when the postoperative level of amylase in the drain was sufficiently low. Before removal, Echo was performed to evaluate the condition of the pancreatic stump and to confirm the absence of lesions such as pseudocysts. In the case of suspicious findings, CT was performed.

Results

A total of six patients underwent LDPSP, comprising four female and two male patients. All of the operations were successful, with an average operative time of 290.7 min (range: 202–377 min) and an average blood loss of 43.5 g (range: 0–142 g). The mean hospital stay was 11.8 days (range: 9–17 days). No obvious pancreatic fistulas occurred, although pseudocysts at the stump of the pancreas were recognized in
three patients on CT scans performed at 7 days after the surgery. Postoperative pathological examinations revealed two cases of serous cystadenoma in the body and tail of the pancreas, one case of serous oligocystic adenoma, one case of mucinous cystadenoma, one case of neuroendocrine tumor, and one case of solid–pseudopapillary neoplasm (Table 1). All six patients’ spleens and splenic vessels were successfully preserved. The ureter tube was withdrawn on 1 day postoperatively, and out-of-bed activity was allowed on day 2 postoperatively. When the patients passed gas on days 3–5 postoperatively, the stomach tube was withdrawn on the same day. On the first day after surgery, fluid rich in amylase (up to 7000 IU) from the intraoperatively placed drains was observed. However, the amount of drainage and the amylase concentration in the drainage fluid rapidly decreased. The abdominal drain was removed on postoperative days 4 to 7. No obvious pancreatic fistulas occurred. On postoperative day 7, a CT scan were performed in all six patients. Pseudocysts of 4–7 cm in diameter were recognized at the stump of the pancreas. Since two of the patients also had mild abdominal pain, they were fasted for a few days. The pseudocysts reduced on a daily basis on abdominal Echo examinations and the symptoms such as abdominal pain were relieved. These patients recovered fully without any other treatments, and were discharged at postoperative days 13 and 17, respectively. The mean hospital stay after the surgery was 11.8 days (range: 9–17 days) (Table 1). Postoperative pathological examinations revealed two cases of serous cystadenoma in the body and tail of pancreas, one case of serous oligocystic adenoma, one case of mucinous cystadenoma, one case of neuroendocrine tumor, and one case of Solid–pseudopapillary neoplasms (Table 1).

### Table 1 Preoperative characteristics and surgical results of spleen and splenic vessels preserving distal pancreatectomy.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Gender</th>
<th>Age</th>
<th>BMI</th>
<th>Operative time (min)</th>
<th>Blood loss (mL)</th>
<th>Patholog</th>
<th>Postoperative complications</th>
<th>Hospital stay (days)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>30</td>
<td>19.2</td>
<td>269</td>
<td>5</td>
<td>Serous oligocystic adenoma</td>
<td>–</td>
<td>11</td>
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<tr>
<td>2</td>
<td>F</td>
<td>52</td>
<td>21.9</td>
<td>211</td>
<td>30</td>
<td>Serous cystadenoma</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>74</td>
<td>24.3</td>
<td>377</td>
<td>64</td>
<td>Pancreatic neuroendocrine tumor</td>
<td>–</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>46</td>
<td>20.7</td>
<td>202</td>
<td>0</td>
<td>Mucinous cystadenoma</td>
<td>Pseudocysts of the pancreatic stump</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>41</td>
<td>22.5</td>
<td>349</td>
<td>20</td>
<td>Serous cystadenoma</td>
<td>Pseudocysts of the pancreatic stump</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>36</td>
<td>29.7</td>
<td>336</td>
<td>142</td>
<td>Solid–pseudopapillary neoplasm</td>
<td>Pseudocysts of the pancreatic stump</td>
<td>10</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.5</td>
</tr>
<tr>
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</table>

Discussion

Leakage of pancreatic juice is the most serious complication after pancreatectomy. Formation of a pancreatic fistula that is potentially associated with further complications, such as an intra–abdominal abscess and massive bleeding from pseudoaneurysm formation, is the main cause of surgical morbidity. Leakages after distal pancreatectomy increase the cost of care and subsequent utilization of health care resources.

There are some reports about the risk factors for pancreatic juice leakage. It has been proposed that a soft, friable, and normal pancreas of normal size with a thin–walled main pancreatic duct shows an increased risk for pancreatic fistula formation. Age, American Society of Anesthesiologists score, body mass index, and concomitant gastrointestinal tract resection had no influence on the incidence of pancreatic fistula formation. Use of a double–row stapler and a thick pancreatic stump were significant risk factors for pancreatic fistula formation in multivariate analyses. The compression index was also found to be an important factor in cases where the pancreas was divided by a stapler. In
the process of hand–suturing, excessive knot strength can easily lead to cutting of the pancreas and result in pancreatic leakage, while too little stress can lead to insufficient ligature during the suturing or postoperatively\(^3\). Traditional oversewing of the gland with sutures does not completely close the stump, leading to persistent extravasation of enzyme–rich pancreatic fluid, and subsequent duct disruption and leakage. Furthermore, the sutures themselves may cause tears within the pancreatic parenchyma and increase pancreatic leaks.

The conventional treatment of pancreatic stumps after distal pancreatectomy of the tail has been to close the main pancreatic duct by ligation and close the pancreatic stump by hand–sewing. However, with the advances made to surgical tools and apparatuses in recent years, there have been various attempts to reduce the incidence of pancreatic fistula formation, such as resection using a linear stapler or an ultrasonic dissection device, spraying of fibrin sealant, ensuring secure placement of the jejunum and stomach onto the pancreatic stump, and anastomosis of the jejunum and pancreatic duct at the stump\(^4\)–\(^10\). The technique of the wrapping pancreatic stump with bovine pericardium combined with closure by hand–sewing was reported to prevent pancreatic fistula formation\(^11\).

A randomized controlled trial conducted in 2011 to investigate the incidence of pancreatic fistula formation reported the rate was slightly, albeit not significantly, lower in the hand–sewing group (28%) than in the automated suturing group (32%)\(^12\). In laparoscopic distal pancreatectomy of the pancreatic tail, transection is mostly performed using a linear stapler, and owing to small differences in the transection methods, the reported incidences of pancreatic fistula formation vary. However, because the pancreas is not protected by a serous membrane of its own, the outer membrane is often abraded during detachment from the surrounding organs or dissection of the lymph nodes. Moreover, compared with another parenchymal organ, the liver, there is too little collagen in the pancreas to withstand powerful ligature by hand–sewing or compression suturing with a linear stapler. In our experience, severe and potentially fatal pancreatic fistula formation can be prevented if a linear stapler is used extremely carefully and differently depending on the firmness and thickness of the pancreas. However, in reality, it is not entirely possible to prevent the development of grade A or B pancreatic fistulas. Therefore, extreme care must be taken to prevent pancreatic fistula formation when performing distal pancreatectomy while preserving the spleen and splenic vessels for benign and low–grade tumors, because of the exposure of the pancreatic stump to splenic vessels.

**Conclusions**

This paper has presented in detail the procedures we perform for LDPSP at our department. Compression of the pancreas, selection and proper use of linear staplers, and coagulation with an energy device are all important factors for successful pancreatectomy. However, owing to the histological structure, there is currently no transection method available that can completely prevent pancreatic fistula formation, and we therefore await the development of improved surgical tools and innovative transection techniques.

**References**


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良性疾患もしくは良悪性境界病変に対する腹腔鏡下脾および脾動静脈温存膵体尾部切除術

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脾体尾部切除術は術野が体腔深く、視野がとりづらい部位にあるが、再建が必要であることから、鏡視下手術の利点を十分に享受しうる術式と考えられる。腹腔鏡下脾体尾部切除術特に脾および脾動静脈を温存する術式は平成24年度から保険収載され脾体尾部の良性・低悪性度腫瘍に対する第一選択の術式として位置づけられてくると言っても過言ではないであろう。良性・低悪性度腫瘍に対しても従来は通常型膵癌と同様に脾切除を伴う脾体尾部切除を行うのが一般的であった。Warshawが最初に短胃動静脈を温存し腎動脈動静脈を切離する方を報告し、Kumuraが脾動静脈を温存する方を報告した。脾臓温存の意義は脾摘によってもたらされる敗血症、血小板上昇などの血液学的異常を防御できることである。また、癌に対する腫瘍免疫学的側面からも脾温存は重要である。

我々は良性および低悪性度脾腫瘍に対して最も低侵襲と考えられる。脾および脾動静脈を温存する脾体尾部切除術を腹腔鏡下手術の適応としている。脾および脾動静脈温存脾体尾部切除において問題となる点は、先ず特に重要な臓実質より合流する細かく静脈を処理して確実に脾静脈を温存する為の器具の選択と使用方法。そして、現在の所完全な解決方法は明らかとなっていないが、完全に剥離された脾動静脈が脾切端に露出する手術方法であることから、重大な合併症となり得る膵液瘻を最大限予防し得る脾切断方法である。

6症例（女性4名、男性2名）に対して脾および脾動静脈温存脾体尾部切除術を行った。全例で腹腔鏡下に完遂され、手術時間は平均290.7分（211-377分）、平均出皿血量は43.5g（0-142g）、術後平均在院日数は11.8日（9-17日）。GradeB以上の明らかな膵液瘻は認められなかったが、術後7日目に行った腹部CT検査にて膵切離断端に仮性囊胞を3症例に認めた。術後病理診断はserous cystadenomaが2症例、serous oligocystic adenoma、mucinous cystadenoma、neuroendocrine tumor、solid-pseudopapillary neoplasmが各々1症例であった。

腹腔鏡下脾および脾動静脈を温存する脾体尾部切除術は良性および低悪性度脾腫瘍に対して安全に施行可能な低侵襲で有るが、術後の膵液瘻を予防する膵切離方法に関しては、今後更なる改善策が必要と考えられた。