Laparoscopic Distal Pancreatectomy: Evolution of a Technique at a Single Institution

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BACKGROUND: The pancreas remains an organ for which routine laparoscopic resection is uncommon.

STUDY DESIGN: This is a review of all distal pancreatectomies performed between January 2003 and December 2009 at Memorial Sloan-Kettering Cancer Center. Variables were compared between laparoscopic and open groups in unmatched and matched analyses.

RESULTS: During the 7-year study period, 343 distal pancreatectomies were performed; 107 (31%) were attempted laparoscopically and 236 (69%) were performed open. The conversion rate was 30%. Laparoscopic patients were younger (median 60 vs 64 years, $p < 0.0001$), experienced less blood loss (median 150 vs 350 mL, $p < 0.0001$), longer operative times (median 163 vs 194 minutes, $p < 0.0001$), shorter hospital stay (median 5 vs 7 days, $p < 0.0001$), and had fewer postoperative complications (27% vs 40%, $p = 0.03$) than open patients. The rates of complications of grade 3 or greater (20% vs 20%, p = NS) and pancreatic leak (15% vs 13%, p = NS) were similar between laparoscopic and open groups. Patients having procedures that were converted had a higher body mass index (BMI) than patients who did not (28 vs 25, $p = 0.035$). Patients with converted resections experienced higher rates of complications of grade 3 or greater (36% vs 20%, $p = 0.008$) and pancreatic leaks (27% vs 13%, $p = 0.03$) than open patients. Compared with matched open patients, laparoscopic patients had longer operative times (195 minutes vs 160 minutes, $p < 0.0001$), less blood loss (175 mL vs 300 mL, $p < 0.0001$), and shorter hospital stay (5 days vs 6 days, $p < 0.001$).

CONCLUSIONS: Patients who had laparoscopic distal pancreatectomy experienced decreased blood loss and a shorter hospital stay compared with matched patients undergoing open resection. Careful patient selection is important because patients who required conversion experienced higher rates of complications and pancreatic leak. (J Am Coll Surg 2010;211:503–509. © 2010 by the American College of Surgeons)

Despite the wide application of minimally invasive approaches to gastrointestinal surgery, the pancreas remains an organ for which routine laparoscopic resection is uncommon. The most widely accepted explanation for this is the technical considerations that make minimally invasive surgery a particular challenge in pancreatic resection. The pancreas is a retroperitoneal structure with a complex and intimate relationship to surrounding vasculature. As a result, the technical hurdles of dissection and resection are significant and are often compounded by the frequent presence of inflammation from pancreatitis or tumor desmoplasia.

The technical challenges associated with laparoscopic pancreatectomy have limited the reporting of large series of laparoscopic pancreatic resection to operations involving the distal pancreas. A recent systematic review by Briggs and colleagues[1] summarized the perioperative outcomes from all published series of laparoscopic distal pancreatectomy until June 2009. This review concluded that the safety profile of the operation seems similar to that of open resection and the perioperative outcomes are acceptable. Indeed, these findings were corroborated by another more recent comprehensive review that showed comparable complication rates and pancreatic fistula rates for laparoscopic distal pancreatectomy when compared with the open approach.[2] Although the early small experiences established the foundation for a technique in evolution, it is

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difficult to draw meaningful conclusions regarding possible benefit from a minimally invasive approach to pancreatic resection. Questions remain regarding optimal application of the laparoscopic approach, specifically regarding patient and/or disease selection.

Answers to some of these questions are beginning to emerge. Recently a large multicenter retrospective study was published by Kooby and associates[3] reporting results of a matched analysis that reported laparoscopic distal pancreatectomy to be associated with a shortened hospital stay, less blood loss, and longer operative time than in a cohort of open distal pancreatectomy patients matched for tumor size, body mass index, and age. Complications were comparable between the groups as were pancreatic fistula rates. This study involved cases performed at 8 academic centers and only 3 of those centers met their criteria for a "high-volume" center (30 laparoscopic distal pancreatectomies or more). This number was selected because only 3 of the 29 reports in the literature at the time described an experience with more than 30 laparoscopic distal pancreatic resections.[4-6]

The primary objective of this single-institution study was to evaluate differences in outcomes between matched patients having laparoscopic or open distal pancreatectomy. Intent-to-treat and actual treatment analyses were performed to evaluate the clinical impact of conversion. The secondary objective was to document and analyze changes over time in the surgical approach to patients with tumors of the distal pancreas and to determine if such changes were associated with differences in outcomes.

METHODS

This is an Institutional Review Board-approved retrospective review of all distal pancreatic resections performed between January 2003 and December 2009 at Memorial Sloan-Kettering Cancer Center (MSKCC). This study was performed using a prospectively maintained pancreatic database. Only patients who had a distal pancreatectomy with or without splenectomy were included. Patients who had additional organ resection, such as stomach, colon, or kidney, at the same operation were excluded.

Demographic, operative, and perioperative data were collected. In addition to tracking treatment characteristics such as operative time and estimated blood loss, other operative details such as conversion to open operation, drain use, hand-port use, and the method of pancreatic stump closure were also recorded. Length of stay in hospital and the need for readmission were detailed. Similarly, pathologic data regarding diagnosis, tumor size, and lymph node harvest were collected.

Postoperative complications were recorded prospectively into the Department of Surgery complication database (MSKCC Surgical Secondary Events Program). All complications were entered by attending surgeons and house staff who were directly involved in patient care. This system of complication reporting has been previously validated and focuses on simplified definitions of the postoperative complication, and grading the severity of these events by using a therapy-oriented severity grading system. Complications were graded in a standardized fashion using a previously reported 5-point complication grading schema.[7] Pancreatic leaks and fistulae were similarly graded using this classification system.

Definitions

A distal pancreatectomy was defined as resection of the pancreas to the left of the portal vein with or without splenectomy. More extensive resections that included pancreas resection to the right of the portal vein (ie, distal subtotal) were included, but central pancreatectomy and enucleations were not. Hand-assisted laparoscopic cases were included in the laparoscopic group. Conversion to open was defined as the surgeon specifying conversion in the operative note, or if any portion of the operation other than extraction of the specimen had to be completed through a laparotomy incision. For example, if the operating surgeon stated in the operative note that mobilization or pancreatic transection was completed through a larger incision, those scenarios were counted as conversion. Similarly, if the surgeon used the term *left subcostal incision*, the case was considered an open case because a laparoscopic approach does not require this incision.

Technique for laparoscopic distal pancreatectomy

All cases were performed with the patient in the lithotomy position, with the primary operating surgeon positioned between the patient's legs. Resection was typically performed through 4 or 5 ports, with initial access in a supraumbilical position at or just to the left of the umbilicus. If a hand port was used, it was typically placed in the upper midline.

After performing exploratory laparoscopy to rule out metastatic disease (in patients with malignant or suspected malignant disease), mobilization commenced with opening of the lesser sac through the gastrocolic ligament. The lesser sac was further exposed by division of the short gastric vessels up to the level of the gastroesophageal junction using ultrasonic shears. The stomach was then carefully dissected away from the anterior surface of the pancreas. The splenic flexure of the colon was then mobilized away from the left upper quadrant to expose the inferior edge of the pancreas and the lower pole of the spleen. In many cases, laparoscopic ultrasonography was then performed in order to confirm proper margins. Subsequently, the infe-

rior edge of the pancreas extending to the lower pole of the spleen was mobilized and the posterior plane leading to the splenic vein was defined. When splenic preservation was not performed, the splenic vein and artery were isolated and divided using vascular staplers. At the same level, the pancreas was stapled using a vascular stapler with or without a Seamguard (WL Gore & Associates) attachment. Mobilization of the plane posterior to the splenic vein and pancreas then proceeded laterally to ultimately encompass the remaining attachments of the spleen to the retroperitoneum and diaphragm.

Specimen extraction was then performed through extension of the initial access site with the specimen in a protective bag. If a hand port was used, extraction was performed through the hand port site. If a drain was placed, it was brought out using a 5-mm port site on the left side of the patient. All ports larger than 5 mm were closed with fascial sutures.

Technique for open distal pancreatectomy

Patients were placed in the supine position. In cases with a confirmed or suspected diagnosis of adenocarcinoma, the operation typically began with staging laparoscopy to rule out metastatic disease. In the absence of metastases, open peritoneal access was obtained either through an upper midline or left subcostal incision, as per surgeon preference. Division of the short gastric vessels and mobilization of the splenic flexure and inferior border of the pancreas were then performed. After mobilization and isolation of the portion of pancreas to be transected, the splenic artery and vein were isolated as well. The method of ligation of these structures varied from surgeon to surgeon. Some surgeons performed all of the above ligations with staples, or via suture ligation, or a combination of techniques.

Statistical analysis

In the unmatched comparison, data were first compared in an intention-to-treat manner such that patients with procedures that were converted to open were analyzed in the laparoscopic group; a second comparison of the actual therapy rendered was performed with these patients divided into 3 groups: laparoscopic, converted, and open distal pancreatectomy. Categorical variables were compared using Fisher's exact test in the intention-to-treat analysis and the chi-square test in the actual therapy comparison. Medians for continuous data were compared using the Mann-Whitney test in the intention-to-treat analysis. Medians were compared using the Kruskall-Wallis test in the actual therapy comparison. For this analysis, a post-test Dunn's multiple comparison test was performed to see which differences accounted for any of the observed effects. In all cases, p values less than 0.05 were considered statistically significant. Continuous data are presented as medians.

For the analysis of laparoscopic to matched resections, preoperative demographic and clinical variables were compared between the 2 groups using Wilcoxon rank-sum tests for continuous variables and chi-square tests for categorical variables. Based on the initial analysis of all patients, malignancy, age, and tumor size were the only factors that significantly differed between the 2 groups, so matching was performed in a 1:1 fashion, with patients who underwent laparoscopic resection matched to those who underwent open resection based on malignancy (yes/no), age ($\leq$65 vs $>$65 years), and tumor size (nearest 0.1 cm). After matching, the remaining preoperative variables were compared between the matched groups using matched-data methods (signed-ranks test and McNemar's test). Long-term outcomes were compared between the 2 matched groups using the test score from a marginal Cox regression model, which was estimated by generalized estimating equations to account for matching.

RESULTS

During the 7-year study (January 2003 to December 2009), 409 distal pancreatic resections with or without splenectomy were performed. Sixty-six cases (16%) were excluded because they involved resection of another organ such as the stomach or kidney. None of these excluded cases was attempted laparoscopically. Therefore, 343 distal resections were eligible: 107 (31%) were attempted laparoscopically and 236 (69%) were approached using an open technique. In the laparoscopic cohort, there was a 30% conversion rate to open resection. With the exception of 1 surgeon who had performed 2 attempted laparoscopic resections, all remaining surgeons had performed open resections. Of the surgeons who currently perform pancreatic surgery at Memorial Sloan-Kettering Cancer Center, all except 1 surgeon perform laparoscopic resections.

A comparison of patient, tumor, and treatment-related variables between the 2 cohorts is presented in Table 1. Patients in the laparoscopic group were significantly younger (median 60 vs 64 years, $p = 0.0005$), experienced less blood loss (median 150 vs 350 mL, $p < 0.0001$), longer operative times (median 193 vs 164 min, $p < 0.0001$), shorter hospital stay (median 5 vs 7 days, $p < 0.0001$), and fewer postoperative complications (27% vs 40%, $p = 0.029$) than those in the open group. Patients approached with the laparoscopic technique were less likely to have a diagnosis of cancer on final pathology (17% vs 47%, $p < 0.0001$), but had similar sized tumors, with a p value demonstrating a significant difference. This significance occurred due to the wider and larger range of tumors

Table 1. Intention-to-Treat, Unmatched Comparison of Laparoscopic and Open Distal Pancreatectomy

Variable	Laparoscopic (n = 107)	Open (n = 236)	p Value
Age at operation, y	60	64	0.0005
Female, %	59	58	0.91
Body mass index, kg/m^2	27	27	0.50
Operative time, min	193	164	<0.0001
Blood loss, mL	150	350	<0.0001
Tumor diameter, cm*	3	3	0.028
Lymph nodes, n	6	7	0.53
Margin negative, %	97	96	0.76
Length of hospital stay, d	5	7	<0.0001
Readmission rate, %	18	20	0.77
Complication rate, %	27	40	0.029
Severe complication rate, %	20	20	1.00
Leak rate, %	15	13	0.73
Cancer as final diagnosis, %	17	47	<0.0001
Spleen preserved, %	21	14	0.15

Sample sizes are in parentheses. Continuous variables are expressed as medians.
*Significant difference in tumor diameter because of estimate of variance using nonparametric Mann-Whitney test.

treated with open surgery despite the same median value. Each group had a similar number of lymph nodes pathologically assessed. There was no difference between laparoscopy and open surgery in terms of spleen preservation (21% vs 14%, p = 0.15).

Although the overall number of complications was less in the laparoscopic group than in the open group, the numbers of significant complications (20% vs 20%, p = NS) and pancreatic leak rates (15% vs 13%, p = NS) were similar. The placement of surgical drains after distal pancreatectomy decreased from 55% in 2004 to 23% in 2009,

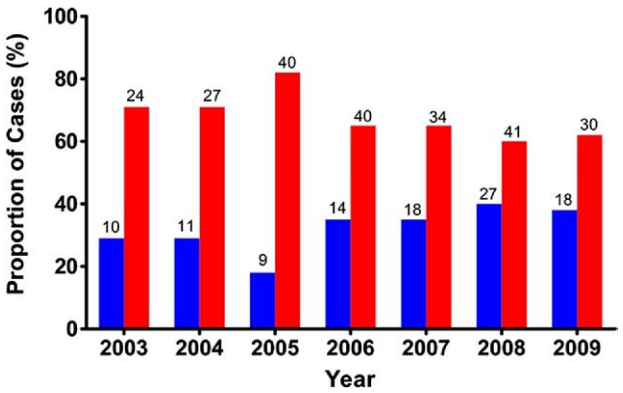

Figure 2. Distal pancreatectomies over time and increasing use of laparoscopy. Numbers at the top of the bars represent number of cases. Blue bar, laparoscopic; red bar, open.

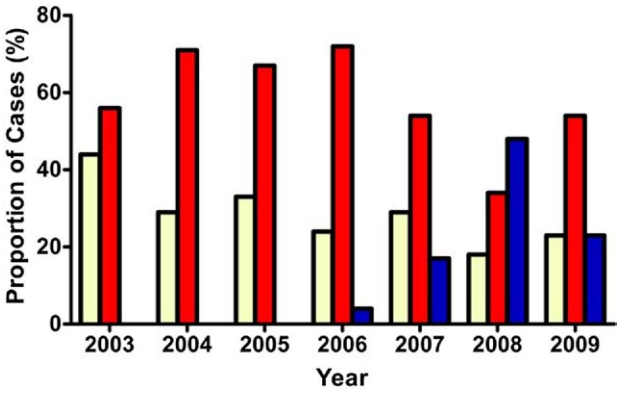

Figure 1. Changes in stump closure. White bar, sewn; red bar, stapled; blue bar, Seamguard.

and this change over time was significant (p = 0.025). The pancreatic leak rate was similar between drained and undrained patients (17% vs 10%, respectively, p = 0.13).

Pancreatic remnant stumps were closed in both laparoscopic and open operations using 1 of 3 different methods: sutures, staples, or staples with a Seamguard attachment. Over time, there was a shift toward greater use of staplers and staples with the Seamguard, with a corresponding decrease in sutured stump closure (Fig. 1). None of these closure techniques was associated with a significant decrease in pancreatic leak rate; the leak rate for sutures was 16% compared with 12% for stapled and 15% for the Seamguard adjunct (p = 0.58).

There were no mortalities in the laparoscopic group. Reoperation was required in 2 patients (2%): 1 for pancreatic duct leak, and 1 for hemorrhage. In the open group there were 2 mortalities: 1 patient died of sudden cardiac arrest and the other died from severe sepsis and multiorgan dysfunction syndrome secondary to pancreatic leak. In the open group, reoperation was required in 4 patients (2%) for hemorrhage.

During the 7-year study there was a gradual increase in the total annual number of distal pancreas resections. Figure 2 demonstrates the increase in the annual number of cases performed, from 34 in 2003 to 68 cases in 2008, with a slight decrease in the last year of the study. In 2003, laparoscopic distal pancreatectomy was attempted in 29% of cases, which increased to 40% in 2008 and 38% in 2009. These changes over time were not statistically significant (p = 0.23).

With the increase in the percentage of patients submitted to the laparoscopic approach, there was a similar rise in the conversion rate. During the first 3 years of the study period, the conversion rate ranged from 10% to 22% and increased to 52% to 56% during 2007 to 2008. Over the same time, there was a transition in the approach to laparoscopic resection, with decreasing use of the hand port. In

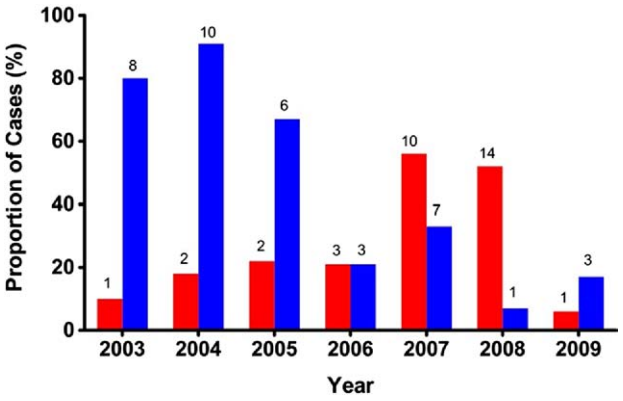

Figure 3. Conversion and hand port use trend over time. Numbers at the tops of the bars represent numbers of cases. Red bar, conversion rate; blue bar, hand port use.

2003, 80% of laparoscopic cases were performed with a hand port; that rate dropped to only 7% and 17% in 2008 and 2009, respectively. This shift occurred predominantly in 2007 and correlated with the time of the increased conversion rate. These trends are illustrated in Figure 3.

The non-intention-to-treat analysis of actual treatment rendered to all patients is presented in Table 2. Patients with a successfully completed laparoscopic resection were significantly younger than patients with converted and open resections. Patients with conversions had a significantly higher BMI than patients whose procedures were not converted (28 vs 25 kg/m^2, $p = 0.035$) and were more likely to be male. Procedures completed laparoscopically or converted had significantly longer operative times than open resections (laparoscopic, 194 minutes vs converted, 192 minutes vs open, 164 minutes, $p < 0.0001$). Patents with successful laparoscopic resections had lower blood loss (100 mL) compared with both converted (300 mL) and open patients (350 mL) ($p < 0.0001$). Laparoscopically treated patients were more likely to be discharged home earlier than patients having converted or open operations (laparoscopic, 5 days vs converted, 6 days vs open, 7 days, $p < 0.0001$). Conversion was also associated with significantly greater number of complications, a higher rate of pancreatic leak, and a higher rate of readmission to hospital compared with laparoscopy and open surgery. Similar to patients treated with open surgery, patients having converted procedures were more likely to have a diagnosis of cancer than laparoscopy patients. There were no significant differences in spleen preservation rates noted in this portion of the analysis (laparoscopic, 19% vs converted, 24% vs open, 14%, p = NS).

Comparison of laparoscopic (n = 100) and open resection (n = 100) was also performed on an intent-to-treat basis using the matching algorithm described above (matched for age, tumor size, and diagnosis). The matched analysis is shown in Table 3. Matched laparoscopic patients experienced longer operative times than open patients (195 minutes vs 160 minutes, $p < 0.0001$), less blood loss (175 mL vs 300 mL, $p < 0.0001$), and shorter hospital stay (5 days vs 6 days, $p < 0.001$) than those undergoing open resection. There were no other significant differences, including overall complications, severe complications, or pancreatic leak rates.

Table 2. Actual Therapy Rendered, Unmatched Comparison of Laparoscopic (n = 74), Converted (n = 33), and Open (n = 236) Distal Pancreatectomies

Variable	Laparoscopic (n = 74)	Converted (n = 33)	Open (n = 236)	p Value
Age at operation, y	55	62	64	0.0008
Female, %	66	38	58	0.069
Body mass index, kg/m^2	25	28	27	0.035
Operative time, min	194	192	164	<0.0001
Blood loss, mL	100	300	350	<0.0001
Tumor diameter, cm	3	3	3	0.084
Lymph nodes, n	7	4	7	0.37
Margin negative, %	97	100	96	0.42
Length of hospital stay, d	5	6	7	<0.0001
Readmission rate, %	12	33	20	0.022
Complication rate, %	18	45	40	0.001
Severe complication rate, %	11	36	20	0.0084
Leak rate, %	8	27	13	0.026
Cancer as final diagnosis, %	14	45	47	<0.0001
Spleen preserved, %	19	24	14	0.24

Sample sizes are in parentheses. Continuous variables reported as medians.

Table 3. Matched Analysis (Intention-to-Treat)

Variable	Laparoscopic (n = 100)	Open (n = 100)	p Value
Female, %	58	65	0.3
Body mass index, kg/m^2	27	27	0.9
Operative time, min	195	160	<0.0001
Blood loss, mL	175	300	<0.0001
Lymph nodes, n	6	5	0.4
Margin negative, %	97	98	0.65
Length of hospital stay, d	5	6	<0.001
Readmission rate, %	17	22	0.4
Complication rate, %	26	33	0.3
Severe complication rate, %	20	17	0.6
Leak rate, %	15	13	0.7

DISCUSSION

This study demonstrates that at a single large-volume institution, laparoscopic distal pancreatectomy can be performed safely and effectively and is associated with decreased blood loss and a shorter hospital stay than is open resection. When resected patients were matched for age, tumor size, and diagnosis, the laparoscopic approach was associated with longer operative times, less blood loss, and shorter hospital stay. These findings are in keeping with other reports on laparoscopic abdominal surgery. In general, laparoscopic resection has been associated with shorter hospitalization and lower blood loss at the expense of longer operative times.[8,9]

The apparent benefit of shorter hospital stay in the matched analysis must be tempered by the outcomes of the subset of patients who were approached laparoscopically but underwent conversion to an open resection. These cases were associated with higher operative blood loss and a higher complication rate, including pancreatic leak (8% laparoscopic, 27% converted, 13% open, p = 0.03). This was significantly higher than in patients initially approached with an open technique. Patients having conversion had a higher BMI (28 vs 25 kg/m^2, p = 0.035), were more likely to be male, and were more likely to have a malignant diagnosis than those whose operations were successfully completed laparoscopically. These factors should be considered when evaluating patients for resection because it may be better to approach high-risk patients with a planned open resection, particularly early in a surgeon's learning curve.

In this study, each surgeon selected cases slightly differently for laparoscopy. One of the most common preoperative factors taken into consideration was the proximity of the tumor to the celiac axis. Tumors that were more distant were more likely to be approached laparoscopically even if larger or if a diagnosis of cancer was suspected. The observed higher complication rate among patients having conversion to open resection underscores the importance of this patient selection. The conversion rate was higher in the more recent time period and most likely represents a willingness to attempt laparoscopic resection for more difficult resections. Lending support to this argument is the finding that the higher conversion rate occurred in patients with larger tumors (>3 cm) and in patients with malignancy. In the intention-to-treat analysis, inclusion of these patients in the laparoscopic cohort did not change the statistical significance of the findings; however, their exclusion shows that appropriate selection and successful completion of minimally invasive resection may have greater benefit to the individual patient. Many of the conversions occurred during the transition period of experience, when surgeons shifted from a hand-assisted to a totally laparoscopic approach. The hand-assisted approach has been typically used early in a surgeon's experience and has been shown to be a safe method of introducing laparoscopic techniques to distal pancreatectomy.[10,11]

It is unclear why patients who had conversion from a laparoscopic procedure had significantly increased risk of pancreatic leak. We conducted an extensive review of the intraoperative conditions under which conversion occurred. The operative notes suggested that the reasons for conversion tended to be bleeding that obscured proper visualization and failure to progress. Although operative records and database did not state exactly when conversion occurred in the operating room, other disciplines have shown that late conversion to open surgery may be associated with higher morbidity rates.[12-14] In our series, this association is not clear. Given the increased BMI and blood loss in the group of patients having conversion, one could hypothesize a more technically difficult pancreatic remnant closure with subsequent increased risk of leak.

In the matched analysis, laparoscopic distal pancreatectomy took approximately 30 minutes longer to perform than an open resection. Other advanced minimally invasive operations such as colorectal resection have also been shown to take longer to perform than open operations.[9,15-17] Although our finding is statistically significant, it may not be clinically significant. This additional operating time (median of 30 minutes in this study), though potentially adding to the cost of the procedure, probably does not affect patient flow through the operating room to any significant degree. Moreover, there is likely minimal additional cost related to the laparoscopic approach because many surgeons use high cost disposable devices, such as staplers, vessel-sealing devices, and ultrasonic shears, just as often for open as for laparoscopic cases. The increase in cost associated with the laparoscopic approach, which is likely modest, is probably offset by the small decrease in length of stay, which was 1

day in the matched analysis. A more detailed, prospective cost analysis may be warranted.

Without randomized data and considering the limitations of retrospective analysis of patient outcomes, it is impossible to comment on the benefit of laparoscopic distal pancreatectomy compared with an open operation. Furthermore, the oncologic outcomes of this approach remain unknown. We assume, however, given the identical technical approach to that of open resection and the similarity of surrogate markers such as margin status and nodal assessment, that the oncologic results are similar.[2]

This series demonstrates that in a large-volume center, laparoscopic distal pancreatectomy can be performed safely and effectively in selected patients and can reduce hospital stay and possibly operative blood loss. However, major postoperative complications, including pancreatic leak, were not reduced. The learning curve is likely long for this operation. Many of the conversions to open procedures were experienced as our technique evolved. Proper patient selection is imperative and should include both patient and tumor parameters. Avoidance of laparoscopic resection in patients who are at high risk for conversion may be warranted because our data identified an increased risk of pancreatic leak in patients who had conversion. As a result of our experience, in our center, laparoscopic distal pancreatectomy is becoming the preferred and routine operative approach in nonobese patients with benign lesions.

Author Contributions

Study conception and design: Jayaraman, Gonen, Brennan, D'Angelica, DeMatteo, Fong, Jarnagin, Allen
Acquisition of data: Jayaraman, Allen
Analysis and interpretation of data: Jayaraman, Gonen, Allen
Drafting of manuscript: Jayaraman, Gonen, Brennan, D'Angelica, DeMatteo, Fong, Jarnagin, Allen
Critical revision: Jayaraman, Gonen, Brennan, D'Angelica, DeMatteo, Fong, Jarnagin, Allen

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