Robotic distal pancreatectomy: Cost effective?

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Background. Minimally invasive techniques and even robotics in pancreaticobiliary surgery are being used increasingly. Cost-effectiveness is a practical burden associated with the introduction of surgical innovation. This study compares the costs and the outcomes of open, laparoscopic, and robotic distal pancreatectomies. We hypothesized that robotic distal pancreatectomy is cost-effective.

Methods. Between August 2008 and August 2009, 77 distal pancreatectomies were performed at a single academic medical center. A retrospective analysis of prospectively collected data on demographics, short-term outcomes, and direct cost was performed.

Results. Thirty-two open distal pancreatectomies, 28 laparoscopic distal pancreatectomies, and 17 robotic distal pancreatectomies were performed. Age, American Society of Anesthesia preoperative risk score, and specimen length were similar. Indications for laparoscopic distal pancreatectomies and robotic distal pancreatectomies included more cystic neoplasms (49%) and fewer malignancies (29%) versus open distal pancreatectomies (16% and 47%). Spleen preservation occurred in 65% robotic distal pancreatectomies versus 12% and 29% in open distal pancreatectomies and laparoscopic distal pancreatectomies (P < .05). The operative time averaged 298 minutes in robotic distal pancreatectomies versus 245 and 222 minutes in open distal pancreatectomies and laparoscopic distal pancreatectomies (P < .05). Blood loss and morbidity were similar with no mortality. The length of stay was 4 days in robotic distal pancreatectomies versus 8 and 6 in open distal pancreatectomies and laparoscopic distal pancreatectomies (P < .05). The total cost was $10,588 in robotic distal pancreatectomies versus $16,059 and $12,986 in open distal pancreatectomies and laparoscopic distal pancreatectomies.

Conclusion. These data suggest direct hospital costs are comparable among all groups. They suggest a shorter length of stay in robotic versus laparoscopic or open approaches. Finally, spleen and vessel preservation rates may improve with a robotic approach at the expense of increased operative time. In summary, robotic distal pancreatectomy is safe and cost effective in selected cases. (Surgery 2010; j.j.: j-j.j.)

During the past decade, minimally invasive approaches have taken a more prominent role in pancreaticobiliary surgery. After the introduction and widespread acceptance of laparoscopic cholecystectomy, the positive impact of limiting the size and invasiveness associated with an operative approach has become evident. Benefits realized using laparoscopic approaches in other types of operations have driven the development and refinement of these techniques for patients with pancreatic disorders. A recent addition to the laparoscopic armamentarium is a minimally invasive resection of the distal pancreas.

Distal pancreatectomy is the most common operation performed for neoplastic or inflammatory lesions of the pancreatic body and tail. Conducting this complex operation in a minimally invasive fashion is a relatively new development in pancreatic surgery. As laparoscopic distal pancreatectomy (LDP) has become more common, the experience and data supporting its use as an alternative to the open approach have grown.1,2 Although no formal prospective investigation of this approach has been performed, several retrospective comparisons with its open counterpart have demonstrated that it is a safe and feasible approach for many patients. Existing data suggest advantages of a laparoscopic approach including decreases in length of stay, intraoperative blood loss, and morbidity in exchange for almost invariably increases in operative time.3-5 Distal
pancreatectomy is an operation commonly conducted for pancreatic cancer, and consequently, the question of oncologic adequacy results. Clearly, any improvements in short-term morbidity outcomes must not come at the expense of sound oncologic principles. Though limited, comparisons of lymphadenectomy and margin clearance seem to support the laparoscopic approach as a feasible alternative in terms of oncologic adequacy.5

The development and advancement of robotic technology has opened the door for its use as a tool to improve on the benefits observed with the conventional laparoscopic surgical technique. The use of robotic systems as an adjunct, although relatively new in operative procedures, has been integrated into the practice of surgeons more extensively in several particular areas. These areas include urologic,6-8 gynecologic,9-12 and foregut surgery.13-19 Robotic surgery presents several theoretical advantages over conventional laparoscopy, which include improved depth perception, reduced operator fatigue, versatile instrumentation, motion stabilization, and scaling.20 In its current form, robotic assisted surgery also presents several recognized limitations, including lack of haptic feedback, significant equipment setup and maintenance, increased operative times, and a learning curve even for the experienced laparoscopic surgeon. One of the foremost barriers in the adoption of robotic surgical technology into widespread practice is a concern for increased cost.21 In the current climate of medical cost control and limited resources, the importance of cost effectiveness cannot be ignored when evaluating a novel technique or procedure. Recently, a large series comparing open, laparoscopic, and robotic assisted approaches with prostatectomy demonstrated a significant increase in operative and overall cost associated with both robotic assisted and laparoscopic approaches as compared with open surgery.22

Though robotic surgery presents many potential benefits with regard to pancreatic surgery, many questions remain with regard to its future role as an important tool for the pancreatic surgeon. Surgeons are beginning to develop and report large experiences using robotic assistance for pancreatic resection and even gastrointestinal and pancreaticobiliary reconstructions.23 Our aim is to compare short-term operative and postoperative outcomes of open, laparoscopic, and robotic resection of the distal pancreas. Additionally, we address the question of cost effectiveness as it relates to implementing this technology. We compare the direct costs, associated costs, and short-term outcomes associated with concurrent open, laparoscopic, and robotic distal pancreatectomies (RDPs) performed during a 1-year period at a single institution with a high-volume pancreatic surgery practice.

We assert that RDP is comparable with laparoscopic pancreatectomy with regard to safety and short-term outcomes, and that this procedure is a cost-effective alternative to both the standard laparoscopic and open approaches for selected patients.

METHODS

All operative data included in this study were collected into a prospectively maintained database. Perioperative outcomes, pathology, and radiology data were gathered via electronic chart review. Cost data were obtained from prospectively maintained hospital accounting records. These data all were gathered and analyzed under formal institutional review board approval at Indiana University Hospital. Study period limit dates of August 2008 and August 2009 were set for inclusion in this analysis. During this period, all resections of the distal pancreas performed for any indication by any surgeon at a single high-volume pancreatic surgery center were gathered for analysis. Open, laparoscopic, and robotic assisted approaches were included for analysis. The operative approach chosen was based primarily on surgeon and patient preference. Patients were not randomized to a given approach. Cases were analyzed on an intent to treat basis, that is, laparoscopic or robotic patients who ultimately underwent conversion to an open surgical approach were evaluated within the groups for the initial approach used at the onset of the operation. Patients were excluded from final analysis and intergroup comparison for the following reasons: emergent or urgent surgery, concurrent major surgery (ie, distal pancreatectomy and concomitant colon resection), and an indication for surgery of pancreatitis (acute or chronic). Parameters assessed included patient and disease factors. Age, sex, comorbidities, indications for resection, radiologic and pathologic tumor size, operative approach, length of resection, and intraoperative factors were evaluated. Short-term outcome measures also included conversion rates, splenic preservation rates, splenic vessel (artery and vein) preservation rates, blood loss, operative time, length of stay, morbidity, and mortality. Cost analysis included operative time and supplies, anesthesia, nursing, laboratory, and overall hospital stay costs. The direct cost of
operation as well as the direct cost of the entire associated hospital stay were analyzed separately and together. No postdischarge care, follow-up, or home nursing costs were included in this analysis. The cost of the robotic system as amortized by case including its maintenance are reported and included in the adjusted operative cost.

Operative technique. Open distal pancreatectomy: After an abdominal incision, an exploration of the abdomen is performed. The lesser sac then is entered (through greater gastrocolic omentum or at reflection of colon and omentum). Then the splenic flexure of the colon is mobilized if necessary. The superior and inferior borders of the pancreas are defined, and splenic vessels are identified and preserved or ligated depending on whether (and how) splenic preservation will be performed. The gland is mobilized and then transected and stapled or oversewn.

Laparoscopic distal pancreatectomy: For this approach, 4–5 ports are used (4, 12 mm ± 1, 5 mm). After the placement of ports and the development of pneumoperitoneum, an exploration of the abdomen is performed. The lesser sac then is entered (through greater gastrocolic omentum). The remainder of the operation is performed laparoscopically with the same technique as the open distal pancreatectomy (ODP).

Robotic distal pancreatectomy: For this approach, 5 ports are used (3, 8 mm; 2, 12 mm). After the placement of ports and the development of pneumoperitoneum, the robot is docked into position. The remainder of the operation is similar to that of the conventional laparoscopic approach. Once the gland is divided, the robot is undocked, and the specimen is placed in a plastic bag for extraction laparoscopically.

Statistical analysis. These data were collected and maintained in Microsoft Excel (Microsoft, Redmond, WA) Spreadsheet format. Statistical analysis was performed using GraphPad Prism software (GraphPad Software Inc., San Diego, CA). The mean values of continuous data sets were compared using the 2-tailed Student’s t test or analysis of variance when multiple groups required comparison. Alternatively, categorical data were compared using Fisher exact contingency tables. Statistical significance was defined at $P < .05$.

RESULTS

In a 1-year period (August 2008–August 2009), 77 distal pancreatectomies were performed at Indiana University Hospital. Three different operative approaches were employed. These patients underwent 32 (42%) ODPs, 28 (36%) LDPs, and 17 (22%) RDPs. After exclusion for pancreatitis, 22 ODP, 18 LDP, and 17 RDP approaches were analyzed.

In examination of the entire group of distal pancreatectomies notable differences were observed in the indications for surgery. A significant number of patients underwent distal pancreatectomy as therapy for pancreatitis (acute or chronic) in the open (19%) and laparoscopic (30%) groups as compared with the robotic group (0%). Because of the relatively high morbidity in this group, these patients were excluded from further consideration. After excluding this group of patients, the total number of analyzed patients undergoing distal pancreatectomy was 57. After the exclusion of operative cases for pancreatitis, the overall indications for operation included 13 (22%) for adenocarcinoma, 14 (25%) for neuroendocrine tumor (NET), 12 (21%) for noninvasive intraductal papillary mucinous neoplasm (IPMN), 8 (14%) for mucinous cystic neoplasm (MCN), 3 (5%) for serous cystadenoma (SCA), and 6 (10%) patients underwent pancreatectomy for other indications including simple cysts, lymphoepithelial cysts, and so on. No statistically significant difference was observed in the number of procedures performed for the indication of adenocarcinoma between the laparoscopic 2 (11%) and the robotic 0 (0%) groups ($P = .49$). Notably, a higher portion of cases was performed for invasive adenocarcinoma in the ODP group (68%), which did reach statistical significance when compared with the robotic experience ($P = .03$; Table I).

Demographic analysis of these groups was compared, and no statistically significant differences were observed in the mean age ($P = .08$), the sex composition ($P = .5$), or the American Society of Anesthesiology preoperative risk score (ASA) ($P = .23$). Of note, the RDP group had an older patient population (64 years) compared with 53 years in the other 2 groups, though this did not reach significance (Table I).

To compare further the similarity of these groups, lesion size and pancreatic specimen length were evaluated. The mean specimen length was similar in all 3 groups with 10 cm in ODP and 9 cm in LDP and RDP groups ($P = .87$), suggesting a similar extent of operation. Mean lesion size was evaluated radiographically and by pathologic specimen as shown in Table I. The open group demonstrated the largest lesions in either case with 5 and 6 cm, respectively. The laparoscopic lesion size was 3 cm and 4 cm, respectively, and the robotic lesion size was 2 cm in radiographic and pathologic size measurements. A statistically significant difference was noted in the radiographic lesion size ($P = .01$).
although this observation was not apparent in the pathologic group because of a higher size variability. This suggests a bias of smaller lesion size in laparoscopic and robotic cases.

Intraoperative results are demonstrated in Table II, including mean lymph node harvest of 14 in ODP and 11 and 5 in laparoscopic and robotic cases, respectively ($P = .06$). Note that the spleen is a major source of lymph node retrieval, so higher splenic preservation rates in laparoscopic and robotic cases correlate with lower lymph node yields. The positive margin rate was 18% (2 cases) in open with no positive margins observed in the laparoscopic or robotic cases ($P = .48$). Significant differences were observed in spleen preservation and in the manner in which the splenic artery and vein were addressed (Fig 1). Overall, the spleen was salvaged in only 14% and 28% of ODP and LDP, respectively, compared with 65% in RDP ($P = .04$). When adenocarcinoma is excluded from analysis, the spleen salvage rate is 25% in ODP, 31% in LDP, and 65% in RDP, although this does not reach statistical significance. The splenic vessels (artery/vein) were preserved in every robotic case, whereas this preservation only occurred in 18% of LDP and 9% of ODP ($P = .06$). No conversions from RDP to LDP in this series. Conversion to open occurred in 2 laparoscopic cases. One conversion occurred from robotic to open. This conversion took place as a result of an inability to maintain adequate control of the splenic artery and intraoperative hemorrhage. A second robotic conversion to conventional laparoscopic occurred because of a failure to progress and difficult visualization. No significant difference was observed in operative blood loss in the robotic group (279 mL) compared with open (681 mL) and laparoscopic (667 mL; $P = .17$). Notably, the robotic group demonstrated a 74-minute mean increase in operative time (includes approximately 25 minutes of docking and undocking of the robot) over the laparoscopic group ($P = .01$).

In regard to postoperative outcomes (Table III), a reduction in mean length of stay was noted in the robotic group (3.8 days) when compared with open (7.7 days) or laparoscopic (6.4 days) groups ($P = .04$). No 30-day mortality occurred in any group, and the perioperative morbidity (including superficial surgical site infection) was similar at 18%, 33%, and 18%, in ODP, LDP, and RDP, respectively ($P = .4$). Of note, no documented pancreatic fistulae were found in the robotic group. Four and 2 documented pancreatic fistulae were found in the ODP and LDP groups, respectively. The remaining major morbidity included 2 intra-abdominal abscesses requiring drain placement in the open group, acute renal failure, and a postoperative hemorrhage from a splenic artery pseudoaneurysm in the laparoscopic group. In the robotic group, 1 patient developed a pulmonary embolism and another developed significant bilateral pulmonary effusions.

The operative costs associated with each approach demonstrate significant differences. Operative cost, including anesthesia, intraoperative pharmacy, blood bank, and equipment was higher in the robotic group ($4,898) compared with open ($3,510) and laparoscopic ($3,072; $P = .04$; Fig 2). Additionally, when the amortized cost (adjusted) of the robotic device and associated maintenance is considered, the operative cost rises to $6,214 ($P = .01$). Alternatively, total costs demonstrated no difference between the 3 approaches with $15,521, $12,900, and $10,588 in ODP, LDP, and RDP, respectively ($P = .4$). This pattern is maintained even when including the adjusted cost of the robotic approach ($P = .4$).

**DISCUSSION**

As surgical technique evolves in response to new developments and advancements in technology, one of the most critical elements is to determine the efficacy, safety, and feasibility of these novel approaches to previously accepted procedures. Ten years into their introduction, investigators

| Table I. Patient demographics, indications, and pathology |  |
|-------------|-------------|-------------|-------------|
|             | Open        | Laparoscopic| Robotic  |
| n           | 22          | 18          | 17          |
| Age (years) | 59.0        | 59.0        | 64.0        | $P = .08$ |
| Sex (% male)| 45.0        | 50.0        | 35.0        | $P = .5$  |
| ASA score   | 2.9         | 2.9         | 2.8         | $P = .23$ |
| Indication  |             |             |             |
| Adenocarcina | 11 (50)     | 2 (11)      | 0 (0)       | $P = .49^*$|
| NET         | 4 (18)      | 5 (28)      | 5 (29)      |
| IPMN        | 4 (18)      | 2 (11)      | 6 (35)      |
| MCN         | 2 (9)       | 3 (17)      | 3 (18)      |
| SCA         | 0 (0)       | 2 (11)      | 1 (6)       |
| Other       | 1 (5)       | 3 (17)      | 2 (12)      |
| Mean specimen length (SEM) (cm) | 10 (+/-5) | 9 (+/-4) | 9 (+/-4) | $P = .87$ |
| Mean lesion size (cm) |             |             |             |
| Radiographic (SEM) | 5 (+/-4) | 3 (+/-1) | 2 (+/-1) | $P = .01$ |
| Pathologic (SEM) | 6 (+/-4) | 4 (+/-3) | 2 (+/-1) | $P = .06$ |

*Denotes statistical comparison between robotic and laparoscopic groups only.
continue to expand the use of robotic surgery. In this series, we sought to compare RDP with conventional open and laparoscopic techniques. These data suggest that RDP is a feasible approach and can be performed in a comparably safe, efficacious, and cost-effective manner.

Although this analysis is retrospective of 3 different approaches, the groups analyzed were similar with regard to age, sex, and preoperative morbidity (based on ASA score). Additionally, no significant differences were observed in the length of operative specimen, although the size of the specimen alone may not fully represent the difficulty of the operation. Lesions were larger in the open group (based on radiology and pathology), but only a small difference was noted in the lesion size between laparoscopic and robotic cases. With regard to indication, the laparoscopic and robotic groups showed no significant difference in this analysis. These factors allow for reasonable comparison, certainly between the 2 minimally invasive groups.

Notably, in the operating room, the robotic approach demonstrated a lower conversion-to-open rate (only 1 case) than its laparoscopic counterpart, though 1 conversion to purely laparoscopic was performed and a trend toward reductions in estimated blood loss. These benefits came at the expense of a greater than 1-hour increase in overall operative time. Given that the robot requires approximately 30 minutes to dock and undock and that instrument exchange is more time consuming compared with conventional laparoscopy, the actual time spent performing the operation is similar between all 3 groups. Interestingly, the conventional laparoscopic group actually demonstrated a shorter operative time than the open approach. These effects highlight the importance of a learning curve in adopting a new approach. In this case, prior to performing any robotic assisted surgery, the surgeon participated in a training workshop using the robotic system on both inanimate and animate models. This workshop was followed by proctored and then independent robotic cholecystectomies. The entire initial experience and learning curve for the robotic approach to distal pancreatectomy is included in this analysis. Importantly, all these variables rely on a comfort level with both open and laparoscopic approaches for this operation.

One of the most interesting findings is the differences observed in rates of splenectomy and, when the spleen is preserved, the ability to use a vessel-preserving technique. Although salvage of the spleen has attracted considerable attention because of suggested short- and long-term immunologic benefits, it is unclear whether preservation of the splenic artery and vein adds any short- or long-term benefit. Some authors have suggested reductions in postoperative thrombocytosis and a risk of hemorrhage associated with the vessel sparing approach. Others have suggested that

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**Table II. Intraoperative results**

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>Laparoscopic</th>
<th>Robotic</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive margins (%)</td>
<td>2 (18)</td>
<td>0</td>
<td>0</td>
<td>.48*</td>
</tr>
<tr>
<td>Lymph nodes obtained (n)</td>
<td>14</td>
<td>11</td>
<td>5</td>
<td>.06</td>
</tr>
<tr>
<td>Spleen preservation (%)</td>
<td>3 (14)</td>
<td>5 (28)</td>
<td>11 (65)</td>
<td>.04*</td>
</tr>
<tr>
<td>Splenic artery and vein preserved (%)</td>
<td>2 (9)</td>
<td>3 (18)</td>
<td>11 (65)</td>
<td>.006*</td>
</tr>
<tr>
<td>Conversion rate (%)</td>
<td>n/a</td>
<td>2 (11)</td>
<td>2 (12)**</td>
<td>.99*</td>
</tr>
<tr>
<td>Mean blood loss (mL)</td>
<td>681 (50–3,300)</td>
<td>667 (50–7,000)</td>
<td>279 (20–1,200)</td>
<td>.17</td>
</tr>
<tr>
<td>Mean operative time (min)</td>
<td>234 (136–437)</td>
<td>224 (100–346)</td>
<td>298 (191–418)</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Denotes statistical comparison between robotic and laparoscopic groups only.

**Spleen and Splenic Vessel Preservation**

![Spleen and Splenic Vessel Preservation](image)

Fig 1. Rates of spleen and splenic artery and vein preservation (Kimura technique) comparing each approach. *Statistical significance noted at \( P < .05 \).
this process only increases operative time and intraoperative blood loss.\textsuperscript{26} Our data do not support this, however. In either case, the robotic approach clearly allows for the surgeon to select either technique and to preserve the spleen in benign and preneoplastic lesions of the pancreatic tail. The lack of pancreatic adenocarcinoma cases in the robotic arm prevents comparisons for invasive cancer. When looking at the overall number of lymph nodes harvested, a trend toward a reduced number of lymph nodes was observed in robotic cases. This effect is most likely, in part, a result of the reduced rate of pancreatosplenectomy in robotic cases, with the spleen containing a significant number of the regional lymph nodes.

All of these approaches were similar with regard to measures of safety. No 30-day mortality occurred in any group, and no significant differences in morbidity. Expected morbidity for distal pancreatectomy has been reported between 32--57%.\textsuperscript{27} The morbidity is lower in this series, although we have excluded pancreatic resections related to pancreatitis. Interestingly, no clinical pancreatic fistulas were noted in the robotic group, although this finding was not a significant difference. Four (18\%) and 2 (11\%) pancreatic fistulae were found in the open and laparoscopic groups, respectively. Previously published rates of pancreatic fistula vary between 10--50\% for left pancreatectomy.\textsuperscript{28,30}

Little doubt exists based on these data that the use of a robotic system increases direct operative costs. This is even more apparent when the initial purchase and maintenance of the robotic system is included as an amortized cost, adding more than $1,300 per case. Importantly, the laparoscopic equipment and suite are used during the robotic procedure as well, and consequently, no amortized costs were included in the laparoscopic group. The surprising finding of similar overall costs associated with hospital stay is based largely in the significant reduction in mean postoperative length of stay compared with both laparoscopic and open groups. Although the overall morbidity was not decreased in these groups, a reduction in the rate of major morbidity such as clinically significant pancreatic fistula could explain this difference. Another possible explanation is that manipulation and torque of the transabdominal ports is reduced significantly in the RDP group as a result of the ability to reticulate the instruments within the patient. This ability may reduce repeated trauma to the abdominal wall. Robotic approaches to other procedures, such as radical prostatectomy, could not demonstrate an overall cost benefit. The difference may be a result of the short overall length of stay (1--2 days) and of the lower morbidity for that procedure compared with distal pancreatectomy.\textsuperscript{22}

It is important to note the limitations of this series. The first significant limitation is the noticeable differences in indications for operative procedures in the 3 groups. Though these differences did not reach statistical significance between the laparoscopic and robotic groups, clearly a bias

Table III. Postoperative outcome and costs

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>Laparoscopic</th>
<th>Robotic</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of stay (d)</td>
<td>8 (3–25)</td>
<td>6 (3–34)</td>
<td>4 (2–6)</td>
<td>.04</td>
</tr>
<tr>
<td>Morbidity (%)</td>
<td>4 (18)</td>
<td>6 (33)</td>
<td>3 (18)</td>
<td>.4</td>
</tr>
<tr>
<td>30-day mortality (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>Associated cost (USD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operative</td>
<td>3,510</td>
<td>3,072</td>
<td>4,898</td>
<td>.04</td>
</tr>
<tr>
<td>Operative (adjusted)</td>
<td></td>
<td></td>
<td>6,214</td>
<td></td>
</tr>
<tr>
<td>Hospital stay</td>
<td>12,011</td>
<td>9,828</td>
<td>5,690</td>
<td>.01</td>
</tr>
<tr>
<td>Total</td>
<td>15,521</td>
<td>12,900</td>
<td>10,588</td>
<td>.26</td>
</tr>
<tr>
<td>Total (adjusted)</td>
<td></td>
<td></td>
<td>11,904</td>
<td>.41</td>
</tr>
</tbody>
</table>

![Fig 2. Direct operative costs and overall cost of hospital stay compared by approach. All figures presented in U.S. Dollars (USD). * Statistical significance noted at P < .05.](image-url)
was directed toward invasive cancer in the open group. As no cases were performed for adenocarcinoma in the robotic group, the rate of spleen preservation clearly will be lower, but even when cases for adenocarcinoma are excluded from analysis, the rate of splenectomy in the robotic group is lower than either open or laparoscopic. Another difference with regard to indication was that in the open and laparoscopic groups, several patients underwent operations for complicated pancreatitis. This situation was not the case in the RDP group; therefore, these cases were excluded from further analysis. The time period of 1 year limits the number of cases available for comparison even at a high-volume institution. The small number of cases in the LDP and RDP groups may hinder the analysis of any differences and must be taken into account. Additionally, these patients were not randomized with regard to their operative approach. Surgeon referral patterns, preferences, and anticipated difficulty of operative dissection could have each introduced bias into the selection of approach. Dramatic reductions were observed in the length of hospital stay in the robotic group. Although this result is encouraging, it must be tempered by the lack of patient or nurse blinding and the retrospective nature of this analysis. In addition, patients in the laparoscopic and open groups who experienced significant postoperative morbidity significantly lengthened the postoperative stay and may skew the mean values for these groups upward for both length of stay and overall cost. Finally, several of these cases are performed for oncologic purposes. Although we examine some pathologic factors associated with adequate oncologic resection (margins, lymphadenectomy, etc), this series is not structured to form any conclusion with regard to the longer term oncologic validity of any given approach.

These findings support the use of a robotic minimally invasive approach in selected cases for resection of the distal pancreas. Given these results, further prospective analysis to determine the efficacy of these approaches would provide further insight into the future role of robotic and laparoscopic pancreatic surgery. Additionally, endpoints including a reduction in narcotic use, earlier return to work, and longer term oncologic outcomes should be evaluated.

In conclusion, safety and cost effectiveness are 2 of the practical burdens associated with the introduction of surgical innovation. This study examines an initial experience with RDP compared with concurrent conventional laparoscopic and open approaches. Differences in the spectrum of disease limit comparisons with the open group. Nonetheless, these data suggest that direct hospital costs are comparable between all groups. They also suggest a shorter length of hospital stay in patients undergoing robotic versus conventional laparoscopic or open approaches. Finally, these data indicate a higher spleen and splenic vessel preservation rate with a robotic approach at the expense of increased operative time. In summary, a robotic approach to distal pancreatectomy is safe and cost effective in selected cases.

REFERENCES


DISCUSSION
Dr Gerard Aranha (Maywood, IL): When a new technique is being introduced, which is in this case robotic distal pancreatectomy, and compared to the standard, which is open, more than just the question of cost arise. One is safety, and you’ve shown that it is safe. There’s low mortality. The second would be, is the procedure appropriate for the disease at hand? I think what you showed, and you said that, that for small benign lesions where one wishes to save the spleen, this procedure may be indicated, but you have not shown that for cancer of the pancreas, that the procedure is appropriate. And would you agree with that assessment? Three, you claim a zero percent recurrence in fistula rate with the robotic group. Did you have differences in the closure of the stump between the 3 groups, the open, the laparoscopic and the robotic? And of your robotic group patients, how many were readmitted to have abscesses drained?

Dr Joshua Waters (Indianapolis, IN): Thank you, Dr Aranha, and thank you for the insightful questions. I think the first question is very important, and I tried to make it as prominent as I could in the presentation that we clearly did not do any of these operations in the robotic group and actually very few of the operations in the laparoscopic group for known pancreatic adenocarcinoma. I would not extend these results to be applied to those patients until further investigation is done with regard to potentially prospective examination of laparoscopic versus open distal pancreatectomy for the indication of adenocarcinoma. I think once you’ve established that a minimally invasive approach is adequate in terms of lymphadenectomy, the ability to obtain a negative radial or tangential margin, then I think potentially those results could be extended to the robotic approach as a similar minimally invasive approach.

Your second question is with regard to the fistula rate and the management of the pancreatic stump in these patients. So I think it’s an important question, especially when you look at the indications for operation in the robotic group as these were mostly cystic lesions of the pancreas and pancreatitis was excluded. So we’re dealing, generally, with very soft pancreatic gland in these cases. In general, in the robotic group, the stump was managed using a linear cutter stapler, most often using some type of stapler buttress device, similar to the Segguard. What I will say is in a number of cases, the gland was either too thick or too firm, and it had to be divided using an energy device and oversewn. But there was a lot of variability in all 3 of the groups in the way the stump is managed. And I think the literature is equivocal, at least to date, with regard to how to manage the pancreatic stump during distal pancreatectomy and what effect that may have on fistula rates. But I agree. I think maybe creating a more homogeneous group in the way the pancreatic stump is dealt with would allow us to better address this question.

Your third question was regarding readmission of patients for potential delayed pancreatic fistulas or other
In the robotic group, 2 patients were readmitted. One of these was readmitted early in the postoperative period or early following discharge for periumbilical cellulitis requiring the umbilical wound to be opened. The second patient was admitted much later, actually after 14 days, for left upper quadrant pain and was found to have a fluid collection in the splenic bed. This patient actually underwent a splenectomy. It was 1 of the few splenectomies in the robotic group. The fluid collection that was drained was found to be amylase poor and culture negative. So we did not find any pancreatic fistula in this group, to address that question.

Dr Mark Talamonti (Evanston, IL): You report on your initial experience with robotic distal pancreatectomy and compare the clinical outcomes and direct costs for your first 17 patients relative to very similar patients done during the same time period with open and traditional laparoscopic techniques at a high-volume surgery program. Your data demonstrate that robotic distal pancreatectomy can be performed safely and efficiently with comparable morbidity and mortality rates and improved rates of splenic preservation and decreased rates of pancreatic fistulas and blood loss. So the answer to your question in the title of your paper is, can robotic distal pancreatectomy be performed cost effectively? And I think the answer is yes.

Nonetheless, I do have several questions for you. The rate of splenic preservation is 2–4 times higher with robotic distal pancreatectomy and a note was made in your manuscript of the ability to preserve the splenic vessels in every case using the robot. While the advantages of splenic preservation do not need to be repeated here, why do the authors feel that the preservation of the vessels offers any advantage? Isn’t this really a seduction of the technology, to try and preserve the vessels, when they may not even be necessary to preserve the spleen? Were there any cases of splenic infarction or abscess in the open distal pancreatectomies and the laparoscopic distal pancreatectomies when the vessels were divided? Do you think your operative times would be similar if the time spent trying to preserve the vessels was eliminated? This leads to my second question. There was a bit of a disturbing trend in the reduced lymph node count in the robotic distal pancreatectomies with an average lymph node harvest of only 5 nodes relative to 14 and 11 in the open and laparoscopic patients. In your presentation in the manuscript, you postulate that this difference may be due to a higher rate of splenic preservation and retention of nodes in the splenic hilum. I would argue, however, that it may be due to your perseverance and persistence in preserving the splenic vessels and a lesser regional lymphadenectomy along the splenic artery and celiac nodes. Can you tell us if you believe there’s any difference in the ability to perform a complete regional lymph node dissection with the robot? And if so, would you have any recommendations, as Dr Aranha said, whether or not you would be reluctant to use this in cancer patients?

Dr Joshua Waters (Indianapolis, IN): Your first question regarding the persistence in terms of attempts at vessel preservation in these patients and did we notice any difference in those patients with vessels preserved versus the vessel dividing technique described by Dr Warshaw. So I agree with your assessment that the existing literature regarding vessel preservation and the potential advantages that it can confer is equivocal. We feel that there are a couple of potential theoretical advantages involved in this. In the Japanese literature, Dr Kimura and colleagues have demonstrated that they serially test patients’ platelet levels postoperatively comparing either vessel sparing versus Warshaw technique in patients who have splenic preservation. And what they have noted is that in the group that undergoes division of the vessels and the spleen is relying on the short gastics, those patients peak out with significantly higher levels of postoperative platelets. They relate this to a potential decrease in the splenic blood flow postoperatively, which has been corroborated by some animal studies. Although this hasn’t been borne out in the literature, they suggest potential theoretical increases in thromboembolic events postoperatively, especially in the venous circulation.

With regard to the lymphadenectomy, I agree. When you look at the numbers, the contrast is stark between 14 and 11 versus 5 nodes in the robotic group. And as you noted, we suggested that part of this may be due to the rate of splenectomy in that group and the fact that the spleen has node-bearing tissue. What I would also say is that the difference may be in part factitious, in that in the robotic group, none of these patients was performed for adenocarcinoma, and though it is the responsibility of the surgeon to resect node-bearing tissue, it’s also the responsibility of the pathologist to examine that tissue for nodes.

Dr Vic Velanovich (Detroit, MI): A quick methodological question. Since there was such as a disparity in pathology types, why didn’t you just use a case-controlled type of analysis just to eliminate that and to make it more comparable, so the problems would wash out with the adenocarcinomas in the open group?

Dr Joshua Waters (Indianapolis, IN): I think methodologically that would have been a very excellent way to approach it. We did want to look at our 3 groups in terms of comparison to open laparoscopic and robotic groups and using the open more as a benchmark. What I would say, the true intent of the study was more to compare between the laparoscopic and robotic groups rather than the open, because we do feel that that is a different population of patients, so it’s really fair almost as a benchmark or standard to compare the other 2.

Dr Robert Martin (Louisville, KY): Quickly, methodologically, just because you said that surgical technique was not standardized, but one of your emphasis as splenic preservation, are we to assume that all of the benign laparoscopic distal pancreatectomies were attempted to be spleen salvaged and that these were splenic conversion rates, so to speak? Second question...
is, again, we’ve heard about pathways, obviously, in our trauma patients, and since cost is a big conclusion of your study, were all of the patients postoperatively managed the same way, meaning in regards to a pathway to try and even out the comparison?

Dr Joshua Waters (Indianapolis, IN): First, with regard to attempting splenic salvage. This is clearly a retrospective review, and it’s often difficult to read between the lines when it comes to someone’s planned attempt on whether to do an en-bloc splenectomy. But even in the robotic case, there were certain lesions that although they were not adenocarcinoma, their size or position lent the surgeon toward planning a splenectomy at the start of the operation. I agree. Our best effort was to exclude those adenocarcinomas because they were clearly not going to be spleen preserving, but there are a subset of those patients who remain that may have been planned splenectomy. So the numbers may be slightly closer than they reflect here.

Secondly, with regard to cost in the postoperative management of the patient, I think the algorithm is key, and especially when you’re looking at something retrospectively. The patient knows they had an open operation. The surgeon knows they had an open operation. So from both directions you have a potential for bias in terms of when the patient actually leaves the hospital. I agree. We attempted to make it a contemporary series of 1 year, so that similar postoperative management algorithms would be in place; although I agree, this doesn’t totally remove those potential confounders.

Dr Syed Ahmad (Cincinnati, OH): The question I have is, with regards to the comparison between laparoscopic and robotic, why was there a 2-day difference in hospital stay between those 2 groups? How is the surgery different other than the use of the robot? Were there any other incisions that were utilized in the laparoscopic that weren’t utilized in the robotic? I don’t understand the 2-day difference.

Dr Joshua Waters (Indianapolis, IN): In terms of the 2-day difference, when you look at the preponderance of the cases in either of those groups and if you looked at the range of length of hospital stay, in the robotic group, the longest stay was approximately 6 days. If you look in the laparoscopic group, it was 34 days. If you were to exclude those patients who had significant postoperative morbidity with return to the intensive care unit, I think those 2 cost parameters would converge. So I think that’s important to note.