Recent Developments in Surgery
Minimally Invasive Approaches for Patients Requiring Pancreaticoduodenectomy

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Over the past decade, minimally invasive surgery has been introduced as a means to allow manipulation of delicate tissues with outstanding visualization of the surgical field. The purpose of this article is to review the available literature regarding early postoperative outcomes and the technical challenges of minimally invasive pancreaticoduodenectomy, including robotic techniques. Herein, we provide a retrospective review of all published studies in the English literature in which a minimally invasive pancreaticoduodenectomy was performed. The reported advantages of minimally invasive pancreaticoduodenectomy include better visualization, faster recovery time, and decreased length of hospital stay. In cases of robotic approaches, some of the proposed advantages include increased dexterity and a superior ergonomic position for the operating surgeon. To our knowledge, few studies have reported results comparable to open techniques in oncologic outcomes with regard to the number of lymph nodes resected and clear margins obtained. An increasing number of pancreatic resections are being performed using minimally invasive approaches. It remains to be determined if the benefits of this technique outweigh its longer operative times and higher costs.

A pancreaticoduodenectomy (PD) has been universally accepted as the only chance for cure for patients with cancerous tumors on the head of the pancreas, distal common bile duct tumors, and periampullary malignant tumors. Since first described by Alessandro Codivilla in 1898 and later popularized by Whipple et al in 1935, significant improvements have been achieved in the preoperative, intraoperative, and postoperative management of patients with pancreatic cancers, resulting in decreased morbidity and mortality rates when surgical procedures are performed at high-volume institutions. These advances have allowed surgeons to explore less invasive alternative techniques with the intention of obtaining faster recovery times while maintaining sound oncologic outcomes. Over the last several years, the introduction of minimally invasive techniques and robotic systems to the field of surgical oncology has allowed for improved visualization of the surgical field with precise manipulation of delicate tissues. For patients with pancreatic cancer, this is of paramount importance because an increasing number of patients undergo neoadjuvant therapy prior to surgical resection, which makes the distinction of normal dissection planes challenging. To date, only a handful of institutions have retrospectively reported their experience with laparoscopic and robotic PD (Table), with conflicting results. With this background, the purpose of our study is to review the current data available on minimally invasive PD.

First Reports of Laparoscopic PD
Laparoscopic PD was first reported in 1994 by Gagner and Pomp in a young patient with chronic pancreatitis from pancreas divisum. Since then, a growing number of surgeons have published their early experience with these procedures. These early studies mainly focused on the feasibility of the technique and on early postoperative outcomes. In general, early data show outcomes similar to those with open techniques, with faster recovery times as evidenced by shorter intensive care unit and overall hospital stays. A recent review by Gumbs et al published in 2011 found 27 articles comprising 285 cases of laparoscopic PD, including 13% of hand-assisted cases. In this extensive review, the rate of conversion to an open approach was 9%, with a weighted average length of stay of 12 days and a morbidity rate of 48%. Based on these findings, Gumbs et al concluded that laparoscopic pancreatic head resections are not only feasible but also safe, with low mortality rates and acceptable complication rates. The authors further emphasized the lack of long-term follow-up data and the relatively small number of studies comparing minimally invasive techniques with open techniques.

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Asburn and Stauffer\textsuperscript{11} recently published the largest complications between the 2 groups.\textsuperscript{15} To our knowledge, significant differences in the occurrence of postoperative complications in the laparoscopy-assisted PD group compared with the open PD group. Furthermore, these investigators found no significant rate of early postoperative morbidity or mortality. As expected, operative times were significantly longer for laparoscopic cases, with a mean (SD) time per case of 541 (88) minutes (9 hours).

Theoretical Advantages of Robotic-Assisted PD

It is generally accepted that the use of robotic systems provides improved visualization with 3-dimensional imaging and improved movement of instrumentation in limited spaces and ensures better ergonomics for the operating surgeon\textsuperscript{46} (Box). These observations arose from a series of retrospective studies describing the first experiences using robotics for PD. Giulianotti and colleagues\textsuperscript{7} reported in 2010 the first series of 50 patients who underwent robotic-assisted PD in Italy and the United States. In this retrospective study, the median operative time was 421 minutes (range, 240-660 minutes), with a median blood loss of 394 mL (range, 80-1500 mL). The length of stay significantly varied depending on the location. In the Italian group, the mean length of stay was 28.7 days, whereas in the US group, the mean length of stay was 12.5 days. In this series,\textsuperscript{7} 6 patients had a grade A fistula postoperatively, 5 patients had a grade B fistula postoperatively, and 1 patient had a grade C fistula postoperatively. More recently, in a single-institution retrospective review, Zureikat and colleagues\textsuperscript{17} reported on 24 patients who underwent a robotic-assisted nonpylorus-preserving PD at the University of Pittsburgh in Pennsylvania. The median operative time in this study\textsuperscript{17} was 512 minutes (range, 327-848 minutes), with a median blood loss of 320 cm\textsuperscript{3} (range, 50-1000 cm\textsuperscript{3}) and a median length of stay of 9 days (range, 4-87 days). The overall pancreatic fistula rate was 27% (n = 8). Clavien grade III and grade IV complications occurred in 7 patients (23%), whereas Clavien grade I and grade II complications occurred in 27% of patients.

Table. Current Studies Available on Robotic-Assisted Pancreaticoduodenectomy

<table>
<thead>
<tr>
<th>Source, y</th>
<th>Patients, No.</th>
<th>Operative Times, min</th>
<th>Estimated Blood Loss, mL</th>
<th>Length of Stay, d</th>
<th>Pathology Data</th>
<th>Leak Rate, %</th>
<th>Complication Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giulianotti et al,\textsuperscript{7} 2001\textsuperscript{a}</td>
<td>50</td>
<td>421 (240-660)</td>
<td>394 (80-1500)</td>
<td>22 (5-85)</td>
<td>Positive margin rate of 0% in Italy and 21% in US; 21 and 15 mean lymph nodes harvested in Italy and US, respectively</td>
<td>31.3</td>
<td>Did not discriminate among complications based on surgical approach</td>
</tr>
<tr>
<td>Zureikat et al,\textsuperscript{a} 2011</td>
<td>30</td>
<td>512 (327-848)</td>
<td>320 (50-1000)</td>
<td>9 (4-87)</td>
<td>Not available</td>
<td>27</td>
<td>27 (Clavien grade I and grade II), 23 (Clavien grade III and grade IV)</td>
</tr>
<tr>
<td>Zhou et al,\textsuperscript{a} 2011</td>
<td>8</td>
<td>718 (186)</td>
<td>153 (43)</td>
<td>16.4 (4.1)</td>
<td>R0 resection rate of 100%</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Chalikonda et al,\textsuperscript{a} 2012</td>
<td>30</td>
<td>476 (363-727)</td>
<td>485 (50-3500)</td>
<td>9.79</td>
<td>Mean tumor diameter of 2.9 cm</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>Buchs et al,\textsuperscript{a} 2010\textsuperscript{b}</td>
<td>42</td>
<td>Older, 420 (62); younger, 443.8 (9)</td>
<td>Older, 388 (282); younger, 390 (379)</td>
<td>Older, 14.3 (8.3); younger, 11.2 (4.8)</td>
<td>Not available</td>
<td>19.5</td>
<td>39</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Patients were from Italy and the United States (US).

\textsuperscript{b} Comparing 2 groups of patients undergoing robotic-assisted pancreaticoduodenectomy (patients <70 years vs patients $\geq$70 years).

Comparison of Techniques: Laparoscopic vs Open PD

With the increasing number of surgeons rapidly gaining experience in complex laparoscopic pancreatic techniques, the first reports of comparative studies have recently been published.\textsuperscript{9,11,15} In a retrospective review of 51 consecutive patients who underwent either an open or a laparoscopic PD, Kuroki and colleagues\textsuperscript{15} found decreased blood loss in the laparoscopy-assisted PD group compared with the open PD group. Furthermore, these investigators found no significant differences in the occurrence of postoperative complications between the 2 groups.\textsuperscript{15} To our knowledge, Asburn and Stauffer\textsuperscript{11} recently published the largest comparative study of more than 260 patients, 53 of whom underwent a laparoscopic PD. Intraoperative and postoperative factors in favor of a laparoscopic approach included decreased blood loss, shorter lengths of hospital stay and intensive care unit stay, transfusion requirements, and greater number of lymph nodes retrieved at the time of the operation. Importantly, no differences were noted in the rate of early postoperative morbidity or mortality. As expected, operative times were significantly longer for laparoscopic cases, with a mean (SD) time per case of 541 (88) minutes (9 hours).
Other investigators have compared robotic-assisted PD with open PD. Zhou et al\(^\text{18}\) reported on 16 patients who had no significant difference in negative margin rates but had lower rates of blood loss, lower complications rates, and decreased lengths of stay with robotic-assisted PD. The low number of patients in this study\(^\text{18}\) prohibits any meaningful statistical analysis. A larger study by Chalikonda and colleagues\(^\text{9}\) compared 30 patients undergoing robotic-assisted PD with 30 patients undergoing open PD; both groups had similar demographic characteristics and surgical indications. Operative times were significantly longer in the robotic-assisted group, but their overall blood loss was lower. The mean lengths of stay were significantly different between groups (9.79 days for the robotic-assisted group vs 13.26 days for the open group; \(P = .04\)). Based on these limited data, both studies\(^\text{8,9}\) concluded that robotic-assisted PD might be associated with faster recovery times but longer operative times.

With regard to immediate oncologic outcomes, Zeh et al\(^\text{18}\) reported on 50 consecutive patients who underwent a robotic-assisted PD (36 underwent a classic PD, and 14 underwent a pylorus-preserving PD). The median tumor size was 2.5 cm, with a mean (SD) of 17 (7) lymph nodes retrieved. For these patients, the overall margin-negative (R0) resection rate was 89%. Importantly, 11 of the 15 patients who met the criteria for adjuvant therapy were treated at a mean follow-up of 11.5 weeks postoperatively.

### Current Limitations

The main limitations of robotic procedures are related to the high costs associated with the purchase of the robotic system and disposable equipment\(^\text{8,9}\) and the steep learning curve associated with the technique. To date, studies comparing the cost-effectiveness of robotic-assisted PD or minimally invasive PD with the cost-effectiveness of open PD have not been conducted.

As with other complex operations, there is a lack of data regarding the recommended number of procedures a surgeon should perform before attempting robotic-assisted PD. Undoubtedly, prior extensive experience in hepatopancreatobiliary surgery is mandatory, and training in minimally invasive PD is typically recommended. Proctored testing tailored to the curriculum is often required by credentialing departments before establishing a new program.\(^\text{20}\)

### Conclusions

Minimally invasive techniques provide some benefits to patients requiring a PD. The robotic systems currently available are not hindered by some of the limitations that plague laparoscopic techniques, such as a limited range of motion, a 2-dimensional visualization of the surgical field, and poor ergonomics for surgeons. For example, the ability of the system to compensate for natural tremors may allow for a more precise technique when a delicate anastomosis is constructed.\(^\text{10}\) However, it is intriguing that the available data on minimally invasive techniques have failed to demonstrate improvements in outcomes, such as leak rates and conversion rates, compared with the outcomes associated with laparoscopic techniques. The need for a longer learning curve might serve to explain some of these issues.

Currently, data on oncologic outcomes have been limited to a few retrospective reports, and there is a lack of literature investigating the financial implications of this approach. The need for cost-effective approaches that could potentially provide similar or better early and late results is essential in times of financial difficulties. Although shorter hospital stays are certainly appealing, based on currently available data, the faster recovery times associated with minimally invasive approaches have not resulted in adjuvant chemotherapy being initiated sooner. From the perspective of general surgery residents, it is imperative to understand that only after rigorous unbiased examination could minimally invasive PD potentially become a valid tool in the armamentarium of surgeons for treating pancreatic cancer.

### REFERENCES


