A narrative review of minimally invasive pancreatic surgery: from pipedreams to pancreatoduodenectomies

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Background and Objective: Minimally invasive surgery (MIS) has become a standard approach to surgical disease of the abdomen. However, minimally invasive pancreatic surgery (MIPS) has been more difficult to establish, given the characteristic complexities of pancreatic operations. There are furthermore ongoing questions regarding the best clinical scenarios in which to use minimally invasive approaches. The history is complex and the field continues to evolve. This review follows the historical path of MIPS in pancreatic surgery and furthermore examines current points of controversy.

Methods: A review of the literature was undertaken to identify landmark papers along the development of MIPS as well as historical reviews.

Key Content and Findings: This review examines the history of MIS and MIPS, with an emphasis on the role that laparoscopy and robotic surgery have played in the ability to perform pancreatic surgery through an MIS approach. An examination of the state-of-the-art is included, reviewing past successes and ongoing challenges.

Conclusions: MIPS has seen significant improvements since its inception, and there are signs that progress will continue well into the future. Areas of controversy persist, but the field has continued to push the boundaries of what is feasible and beneficial to patients undergoing pancreatic resections.

Keywords: Minimally invasive pancreatic surgery (MIPS); minimally invasive pancreatic resection; laparoscopic pancreatectomy; robotic pancreatectomy

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Introduction

The introduction of minimally invasive surgery (MIS) techniques has revolutionized the field of surgery. Many of the most common abdominal surgical procedures are now performed in a MIS approach as part of the standard of care (1). Well-established benefits across multiple surgical subspecialties often include shorter length-of-stay, decreased post-operative pain, and lower incidence of perioperative complications (2,3). Laparoscopic surgery has been the most widely adopted MIS approach in abdominal surgery. Further technologic advances have given rise to robotic-assisted approaches, which are becoming increasingly prevalent.

Adoption of MIS techniques in the field of pancreatic surgery has been slower than in other fields, owing to the complexity of these procedures and historically high risk of morbidity and mortality. However, in recent decades there has been an increasing trend towards minimally invasive pancreatic surgery (MIPS), with some procedures being performed preferentially through a laparoscopic or robotic approach (4). In this article the authors present an overview

Table 1 Search strategy

Items	specification
Date of search	21 September 2022
Databases and other sources searched	PubMed, reference lists were screened for relevant publications
Search terms	((((Minimally invasive) OR (Laparoscopic)) OR (Robotic)) OR (Robotic-assisted)) AND (((((Pancreatectomy) OR (Pancreatoduodenectomy)) OR (Whipple)) OR (Distal pancreatectomy)) OR (Left-sided pancreatectomy))
Timeframe	1990–2022
Inclusion criteria	Articles in English reporting outcomes after and history of minimally-invasive pancreatic resections
Exclusion criteria	Low reliability articles were excluded
Selection	Asbun D and Lluis N conducted the search. All authors agreed with the literature selection

of the history of MIPS as well as a perspective on the state of the art. The focus will be on MIS distal pancreatectomies and MIS pancreatoduodenectomies, which are the most commonly performed procedures in this realm. There are important new studies which have been recently published, and this review will incorporate those findings along with other well-established reports. The review is of a wide scope and as such will be limited in its ability to explain granular points within landmark studies. However, the important conclusions will be underscored, with an emphasis on the points that have helped propel forward minimally invasive approaches to pancreatic surgery. We present this article in accordance with the Narrative Review reporting checklist (available at https://dmr.amegroups.com/article/view/10.21037/dmr-22-73/rc).

Methods

A search of scientific literature was undertaken to identify landmark publications that made significant contributions to the development of MIPS. Additional historical reviews were also included. See *Table 1* for details on the search strategy.

Historical context: laparoscopic surgery

Most surgeons have come across the adage, "Eat when you can, sleep when you can, and don't mess with the pancreas" (or a variation thereof). This reflects surgeons' long-standing view that the pancreas is an unforgiving organ when diseased, especially with pathology necessitating surgical intervention. The pancreas is difficult to access surgically, as it lays in the retroperitoneum behind the stomach and flanked by other organs including the duodenum, spleen, liver, colon, kidneys, and adrenal glands. It is intimately related to many critical vascular structures, including the celiac axis and its branches, the superior mesenteric artery, the portal vein and its tributaries, a complex nervous plexus, and the porta hepatis. Surgical intervention often involves careful dissection away from these structures, which is made more difficult by many disease processes, including pancreatitis, neoplasia and associated desmoplastic reaction, and chronic inflammation from nearby organs. Furthermore, the physiology of the pancreas adds an extra layer of complexity. It produces digestive enzymes that can leak from cut or fractured pancreatic parenchyma, as well as from anastomoses involving the pancreatic duct. These enzymes can incite tissue damage when exposed to surrounding structures and serve as the catalyst for many postoperative complications.

Despite these difficulties, MIS approaches to the pancreas have been progressing for more than a century. In 1911 Bernheim published a report of intraperitoneal insufflation and inspection (termed "organoscopy") using a cystoscope in a patient with suspected pancreatic cancer (5). This general technique of abdominal inspection had been described in preceding years in a seminal publication by Jacobaeus (6) and separately by Kelling (7). Bernheim's organoscopy served to rule out peritoneal spread or other signs of metastasis prior to laparotomy for pancreatic resection. Despite the intentional use of laparoscopy in a patient with pancreatic pathology, in Bernheim's view, "obviously, a structure lying as deeply as the pancreas could not be inspected". Significant advances in the field did not appear until 1972, when Meyer-Burg reported laparoscopy as a method to biopsy the pancreas (8). Larger case series promoting the technique soon followed (9,10).

Semm performed the first appendectomy through a completely laparoscopic approach in 1980 (11), and in 1985 Mühe performed the first laparoscopic cholecystectomy (12). Although both Semm and Mühe initially received significant criticism and resistance from the medical community, their operations mark the beginning of a groundbreaking era of MIS. By the 1990's, the "laparoscopic revolution" was well underway, with laparoscopic techniques being used for herniorrhaphy, gastric operations, colonic resections, adrenalectomies, and other abdominal operations (1).

In 1994, the first reports of laparoscopic pancreatic resection were published. Gagner and Pomp described a pancreaticoduodenectomy done laparoscopically in a patient with chronic pancreatitis (13). One month later, Cuschieri published his experience with a variety of laparoscopic procedures, including laparoscopic PD (LPD), laparoscopic distal pancreatectomy (LDP), and laparoscopic partial resection for insulinoma (14).

The enthusiasm of these and other early laparoscopic pancreatic surgeons was tempered by the difficulty of the operations and associated complications. In 1997 Gagner and Pomp published a series of 23 patients undergoing MIPS titled, "*Laparoscopic Pancreatic Resection: Is It Worthwhile?*". They reported a 40% rate of conversion to open surgery in LPD patients, and 36% for patients undergoing LDP or pancreatic enucleation (15). They concluded that there was no discernible benefit to LPD, although lesser resections showed a decrease in hospitalization and thus may offer an advantage. This sentiment was echoed by others in the field at the time (16).

Continued enthusiasm and improved outcomes with laparoscopy

Despite the initial caution, surgeons continued to explore the role of MIS in pancreatic surgery. As experience grew, reported outcomes began to improve. In 2005, Mabrut *et al.* reported outcomes from a retrospective multicenter cohort of 127 patients who had undergone a variety of laparoscopic pancreatic resections, including pancreatic enucleations, distal pancreatectomy (DP), and PD (17). There was a 14% rate of conversion to open, 31% rate of pancreatic-related complications, and no deaths. These outcomes were deemed acceptable when compared to standards established for open pancreatectomies. Similarly, in 2007 Palanivelu *et al.* published favorable outcomes after nearly a decade of LDP, and in 2009 published their 10-year experience with LPD (18,19). Morbidity, mortality, hospital length of stay (LOS), and oncologic outcomes such as R0 resection and local recurrence rates were all well within accepted norms.

The ongoing development of surgical technologies helped make MIPS safer and more feasible. For example, the use of reinforced staple lines during LDP, first described in 2007 by Jimenez *et al.* (20) and separately by Thaker *et al.* (21), was presented as a way to decrease the rate of postoperative pancreatic fistulas. The same spirit of innovation driving the use of laparoscopy continued to encourage the development of adjunct technologies aimed at facilitating and improving MIPS. Technologies that developed in response to the widespread use of laparoscopic surgery—such as intraoperative ultrasound, higher definition cameras, and a variety of surgical energy devices—have been pivotal in the ability to perform MIS pancreatic resections.

Naturally, investigations began to compare open pancreatic surgery to MIPS, showing some benefits of MIPS. In 2012, Asbun *et al.* compared patients undergoing open PD to LPD during a 6-year period (22). There was significantly longer mean operating time for LPD (401 *vs.* 541 min, P=0.001), but also significantly less intraoperative blood loss (195 *vs.* 1,032 mL, P<0.001), less mean packed red blood cell transfusion (0.64 *vs.* 4.7, P<0.001), and shorter mean hospital LOS (8 *vs.* 12.4 days, P<0.001) in the laparoscopic cohort. Morbidity and mortality were similar.

Croome *et al.* in 2014 compared 214 patients who had undergone open PD to 108 who had undergone LPD (23). Patients who underwent LPD had no significant difference in major complications, oncologic outcomes such as node- or margin-negative status, or baseline patient characteristics. However, the LPD cohort had a shorter median LOS (6 *vs.* 9 days, P<0.001) and had less delay or inability to undergo adjuvant chemotherapy (12% *vs.* 5%, P=0.04), with longer progression-free survival (P=0.02).

An 11-country European multinational retrospective comparison of minimally invasive DP to open DP was published in 2017 (24). This propensity-score matched study evaluated both robotic and LDP in the MIS DP arm. Median blood loss (200 *vs.* 300 mL, P=0.001) and hospital stay (8 *vs.* 9 days, P<0.001) were lower after MIS DP, and MIS DP had higher R0 resection rate (67% *vs.* 58%, P=0.019). However, lymph node retrieval (14 *vs.* 22, P<0.001) was lower after MIS DP. High grade complications, 90-day mortality, and median overall survival were similar between the two cohorts. The authors acknowledge apparent benefits to MIS DP but echoed

Table 2 Published randomized controlled trials evaluating laparoscopic pancreatoduodenectomy

Author (study name)	Year	Design	Comparison	Primary outcome	n	Outcomes
Palanivelu (PLOT) (31)	2017	Single-center, open-label, RCT	Lap *vs.* open	LOS	32 lap *vs.* 32 open	• LOS (days), median [range]: lap 7 [5–52] *vs.* open 13 [6–30], P=0.001 • Similar overall complications and mortality
Poves (PADULAP) (32)	2018	Single-center, open-label, RCT	Lap *vs.* open	LOS	34 lap *vs.* 32 open	• LOS (days), median [range]: lap 13.5 [5–54] *vs.* open 17 [6–150], P=0.024 • Clavien-Dindo grade complications ≥3: lap 5 *vs.* open 11, P=0.04 • Similar oncological standards
van Hilst (LEOPARD-2) (33)	2019	Multicenter, patient-blinded, phases 2/3, RCT	Lap *vs.* open	Safety (phase 2), functional recovery (phase 3)	50 lap *vs.* 49 open	• Complication-related mortality: lap 10% *vs.* open 2%, P=0.2 • Terminated early
Wang (MITG-P-CPAM) (34)	2021	Multicenter, open-label, RCT	Lap *vs.* open	LOS	297 lap *vs.* 297 open	• LOS (days), median [95% CI]: lap 15 [14–16] *vs.* open 16 [15–17], P=0.02 • Similar short-term morbidity and mortality

RCT, randomized control trial; Lap, laparoscopic; LOS, length of stay.

growing calls for randomized trials.

These findings added to more preliminary series with similar results (25-27). Several meta-analyses and systematic reviews conducted in the mid and late 2010's revealed similar perioperative benefits for both LDP and LPD. This is especially seen in relation to decreased LOS, less blood transfusion, and equivalent oncologic outcomes without increased morbidity or mortality in the laparoscopic approach (28-30).

Randomized controlled trials (RCTs) on laparoscopic pancreatectomies

In recent years, several important RCTs have been conducted to evaluate the impact of a laparoscopic approach to pancreatic resections. The earliest of these compared laparoscopic to open PDs (*Table 2*), with subsequent ones comparing MIS and open approaches to DP (*Table 3*).

Pancreaticoduodenectomies: laparoscopic vs. open

The 2017 PLOT trial designed by Palanivelu *et al.* randomized patients to LPD or open PD (31). They recruited 32 patients in each arm, all of them diagnosed with a resectable pancreatic head/ampulla cancer. Operations were performed by one of two senior surgeons, who had performed over 25 of each laparoscopic and open PD, and who had extensive experience with other advanced laparoscopic procedures. Median LOS was shorter for the laparoscopic group than for the open group (7 *vs.* 13 days, P=0.001), and intraoperative blood loss was less (401 *vs.* 250 mL, P<0.001). Operative time was longer for laparoscopic than open PD (359 *vs.* 320 min, P=0.041). Morbidity, mortality, R0 resection rate, and mean lymph nodes retrieved were similar between the two groups.

Similarly, PADULAP trial published in 2018 by Poves *et al.* randomized 66 patients scheduled to undergo PD into a laparoscopic (34 patients) and an open group (32 patients) (32). The patients were treated for both malignant and benign diseases. LPDs were performed by one surgeon who had performed over 20 LPDs and was obtaining similar or better results compared to open. Open PD were performed by one of two surgeons. As with the PLOT trial, when comparing laparoscopic to open PD, median LOS was shorter (13.5 *vs.* 17 days, P=0.024) and median operating times were longer (486 *vs.* 365 min, P=0.0001). There were significantly less Clavien-Dindo grade ≥3 complications in the laparoscopic cohort (5 *vs.* 11 patients, P=0.04), although this significance did not extend to pancreas-specific complications. Margin status, lymph nodes received, and 90-day mortality were similar between the two groups. The PLOT and PADULAP trials solidified LPD as a safe option in experienced hands, and offered some benefits compared to open PD.

Table 3 Published randomized controlled trials evaluating minimally invasive distal pancreatectomy

Author (study name)	Year	Design	Comparison	Primary outcome	n	Outcomes
de Rooij (LEOPARD) (35)	2019	Multi-center, patient blinded, RCT	MIS *vs.* open	TFR	51 MIS *vs.* 57 open	• TFR (days), median [IQR]: MIS 4 [3–6] *vs.* open 6 [5–8], P<0.001 • Conversion rate 8% • Estimated blood loss (mL): MIS 150 *vs.* open 400, P<0.001 • Operative time (min): MIS 217 *vs.* open 179, P=0.005 • Clavien-Dindo complications grade ≥3: MIS 25% *vs.* open 38%, P=0.21 • Delayed gastric emptying grade B/C: lap 6% *vs.* open 20%, P=0.04 • Clinically relevant pancreatic fistula: lap 39% *vs.* open 23%, P=0.07 • Quality of life (days 3–30): favors laparoscopic • 90-day mortality: lap 0% *vs.* 2%, NS
Björnsson (36)	2020	Single-center, open label, RCT	Lap *vs.* open	LOS	29 lap *vs.* 29 open	• LOS (days), median [IQR]: lap 5 [4–5] *vs.* open 6 [5–7], P=0.002 • TFR (days), median [IQR]: lap 4 [2–6] *vs.* open 6 [4–7], P=0.007 • Operative time (120 min) was similar • Estimated blood loss (mL): lap 50 *vs.* open 100, P=0.018

RCT, randomized control trial; MIS, minimally invasive surgery; Lap, laparoscopic; TFR, time to functional recovery; LOS, length of stay; IQR, interquartile range; NS, not significant.

Different conclusions were presented by van Hilst *et al.* in results from the 2019 LEOPARD-2 trial (33). LEOPARD-2 was a patient-blinded phase II/III RCT comparing laparoscopic and open PD across four centers in the Netherlands. A total of 99 patients with malignant and benign pancreatic diseases were randomized and underwent either laparoscopic (50 patients) or open (49 patients) PD. The surgeons participating had performed over 50 advanced laparoscopic procedures and at least 20 LPD (and overall, over 50 open and lap PD), and had undergone a training program specific for LPD. The trial was terminated before reaching full accrual due to unexpectedly high mortality in the laparoscopic group: 5 (10%) of LDP patients, compared to 1 (2%) of patients in the open group [risk ratio (RR) 4.90, 95% CI: 0.59–40.44, P=0.20]. Other outcomes evaluated were not statistically significant, although some—including median time to functional recovery, high-grade complications, and grade B/C pancreatic fistulas (37)—trended higher in the LPD group. The higher mortality in this investigation gave rise to concern over the wide-spread adoptability of MIPS.

The most recent and largest RCT on this topic was published by Wang *et al.* in 2021 (34). This RCT was conducted across 14 centers in China. Patients with benign or malignant disease were randomized to undergo either open PD or LPD by experienced surgeons who had each performed over 100 LPD. At time of the modified intention-to-treat analysis, each cohort contained 297 patients. The median hospital LOS was significantly shorter for patients who underwent LPD than for open PD (15.0 *vs.* 16.0 days, P=0.02). There was no significant difference between 90-day mortality, serious postoperative complications, or comprehensive complication index score.

The above data overall suggest a benefit to LPD, particularly in relation to hospital LOS. The conflicting results of the LEOPARD-2 trial are considered by some to be due to inexperience of some of the pancreatic surgeons with LPD. Although not formally established, the number of LPD a surgeon needs to complete before overcoming the learning curve is usually considered to be at least 40 LPD, although some studies suggest this number should be higher (38,39). Only surgeons from the largest and most recent of the above-mentioned RCTs met this criterion. It is thus clear that the procedure is technically challenging, and the learning curve may take years to surpass before a clear benefit to LPD over open PD is established.

Distal pancreatectomies: laparoscopic vs. open

There are two important RCTs that have been conducted to compare outcomes of patients with benign or malignant tumors of the left pancreas undergoing either a MIS or open approach to DP. A double-blinded RCT involving 14 centers in The Netherlands (LEOPARD) compared outcomes after MIS or open DP in patients with benign or malignant lesions (35). Five out of 47 patients in the MIS arm underwent robotic-assisted procedures, and the others LDP. MIS achieved a shorter functional recovery time than the open approach (*Table 3*). In addition, patients undergoing MIS experienced less intraoperative blood loss (at the expense of longer duration of surgery), less delayed gastric emptying, and better quality of life during the first month than patients undergoing the open approach. A secondary analysis of data from the LEOPARD trial found that both approaches achieved similar outcomes in terms of total medical cost, as well as cosmetic satisfaction and disease-specific quality of life one year after surgery (40). A detailed analysis indicated that MIS was more cost-effective.

A Swedish single-center, open label RCT also compared outcomes after open or LDP, including patients with benign and malignant lesions (36). The authors reported that the laparoscopic approach resulted in less intraoperative blood loss, shorter functional recovery time, and shorter hospital LOS than the open approach. Both approaches were similar in terms of operative time and postoperative complications.

These studies demonstrate that MIS DP is feasible, safe, and achieves similar or even better postoperative outcomes than the open approach. RCTs evaluating short- and long-term oncologic outcomes comparing MIS to open DP are lacking, but in many centers LDP has become the standard of care.

Introduction of robotic surgery

The development of robotic-assisted (or, simply, "robotic") surgery has provided another important tool in the surgeon's armamentarium. As with laparoscopic surgery, robotic surgery allows for a minimally invasive approach to surgical operations. Proponents of robotic surgery highlight increased manual dexterity, three-dimensional visualization, and improved surgeon comfort as benefits associated with the robotic platform (41). However, the robotic platform is also associated with higher costs and certain robot-specific technical difficulties, such as loss of haptic feedback, limitations in positioning the patient, and instrumentation that occupies a much larger operating room space. Furthermore, supporting evidence of its benefits is not as robust as it is for laparoscopic operations (42).

The first robotic-assisted pancreatic resection was reported in 2003 by Melvin *et al.*, in a patient with a cystic neuroendocrine tumor who underwent a distal pancreatectomy and splenectomy (43). The patient did well postoperatively. In 2010, Giulianotti *et al.* published a series on 134 patients who had undergone robotic PD, DP, and other pancreatic resections, with rates of complication comparable to open operations (44). By the late 2010's meta-analyses were available of trials comparing robotic pancreatectomies to laparoscopic and open pancreatectomies (45-47). Available studies lacked high-quality, randomized data but demonstrated the safety and feasibility of a robotic-assisted approach.

In 2018, a meta-analysis of fifteen studies including 3,690 patients compared open *vs.* robotic PD or DP (45). In general, robotic surgery had longer operative time. Robotic PD was associated with less blood loss, fewer wound infections, fewer positive margins, and fewer overall complications than open surgery. Both groups were similar in number of lymph nodes harvested, pancreatic fistula rate, delayed gastric emptying, reoperations, length of hospital stays, and mortality. Robotic DP was associated with less blood transfusion, fewer harvested lymph nodes, fewer complications, and shorter hospital stays than open surgery. Both groups were similar in spleen preservation rate, positive margin, pancreatic fistula rate, and mortality. Therefore, the short-term postoperative outcomes of robotic-assisted pancreatic surgery are similar to or better than those of open surgery.

A subsequent meta-analysis the following year of 17 studies including 2,133 patients compared the robotic-assisted approach with the laparoscopic or open approach in DP (47). The robotic approach was associated with a longer operative time, shorter hospital stay, and a higher spleen preservation rate than the laparoscopic approach. It was also associated with a shorter LOS and a lower complication rate when compared to the open approach. This data implies that the robotic approach not only achieves better outcomes than the open approach, but also in these series surpassed outcomes for LDP.

Table 4 Published randomized controlled trials evaluating robotic-assisted pancreatic procedures

Author	Year	Design	Comparison	n	Primary outcome	Outcomes
Chen (48)	2017	Single-center	Central pancreatectomy	50 robotic *vs.* 50 open	LOS	• LOS (days), median: robot 15.6 *vs.* open 21.7, P=0.002 • Operative time (min), median: robot 160 *vs.* open 193, P=0.002 • Operative blood loss (mL): robot 20 *vs.* open 200, P<0.001 • Post-op pancreatic fistula rate: robot 18% *vs.* open 36%, P=0.043
Liu (49)	2021	Single-center	Pancreatojejunal anastomosis in PD	89 single layer *vs.* 93 Blumgart	POPF	• POPF: single layer 6.7% *vs.* Blumgart 11.8%, P<0.001 • Anastomosis time was shorter in single-layer • Operative time, estimated blood loss, LOS, conversion rate, morbidity, reoperation or mortality were similar

PD, pancreatoduodenectomy; Blumgart, modified Blumgart anastomosis; LOS, length of stay; POPF, postoperative pancreatic fistula.

RCTs involving robotic pancreatectomies

Despite the above meta-analyses showing certain superior outcomes with robotic approaches, the studies reviewed were not of the highest quality of evidence. Only two RCTs have been completed to compare outcomes associated with specific robotic pancreatic surgical techniques (*Table 4*). The first RCT compared short-term outcomes of the robotic-assisted approach with the open approach in patients undergoing central pancreatectomy for benign or borderline tumors of the pancreatic neck or body (48). The robotic approach was performed in less operative time and with less blood loss. Patients recovered faster and had shorter hospital LOS and lower postoperative pancreatic fistula rate. The second RCT compared two suturing techniques for pancreatojejunostomy (continuous single layer *vs.* modified Blumgart) in robotic-assisted pancreatoduodenectomy (49,50). Anastomosis time and postoperative pancreatic fistula rate were lower in patients undergoing single-layer anastomosis. Operative time, estimated blood loss, length of hospital stay, conversion rate, morbidity, reoperation, and mortality were similar for both techniques. Although evaluating a specific technique, it is important to note that this second study reported outcomes that are equivalent to or better than what is accepted for open pancreatoduodenectomies.

Even with a paucity of high level evidence to support robotic pancreatectomies, there are indications that pancreatic surgeons are adopting robotic surgery at an increasingly higher rate (42). There are signs of increasing adoption of the robotic platform for MIPS as well as ongoing expansion beyond academic centers (42,51).

Ongoing development and adoption

MIPS has become an important part of the pancreatic surgeon's skillset. Multi-society guidelines have advocated for a MIS approach to pancreatectomies. Perhaps the best example of this lies in the recommendations put forth by the Miami International Evidence-Based Guidelines on Minimally Invasive Pancreas Resection (52), at times simply referred to as the "Miami Guidelines". These clinical practice guidelines arose from a multi-society conference held in Miami, Florida, where over 70 experts from 20 different countries reviewed data and provided guidance on multiple clinical questions in MIPS. Notable recommendations include the preference of minimally invasive DP over open DP, and the acknowledgment that minimally invasive PD is an equivalent operation to open PD.

Despite this growing support from surgical societies, adoption over the decades has been somewhat mixed. An American population-based review was done of all distal pancreatectomies between 1998 to 2009 in the Nationwide Inpatient Sample, constituting a 20% stratified sample of all US hospitals (53). Although now outdated, this study found that even in that early time frame the rate of MIS DP rose from 2.4% to 7.3%. A nationwide study in Norway evaluating use of LDP between 2012 to 2016 showed that the use of LDP had increased to 59%, with LDP achieving better outcomes—such as shorter length of hospital stay, lower rate of splenectomy, and less multivisceral resection—than the open approach (54). This continuing trend is reflected in the results of an international survey completed in 2016 in which 435 surgeons from 50 countries responded to questions about their adoption of MIPS (55). The survey found MIS DP was performed by 79% of surgeons, but MIS PD only 29%. Lack of training was the most frequently cited reason for not performing MIPS.

To this end, several post-graduate MIPS training programs have been developed to provide surgeons with a structured way of gaining confidence to perform more pancreatic resections in an MIS fashion. Well-known examples are two Dutch post-graduate training programs—LAELAPS program for teaching MIS (robotic and laparoscopic) DP (56), the Dutch LAELAPS-2 program for LPD (57)—which have both shown the ability to increase use of MIPS through focused training. Other programs target trainees, such as the University of Pittsburgh Medical Center robotic training program for surgical oncology fellows (58,59). Objective, specialized training will be crucial for the ongoing adoption and development of MIPS.

Conclusions

The MIS approach to pancreatic resections arose early in the development of laparoscopic surgery. However, given inherent complexities in pancreatic surgery, its adoption has not been as widespread as in other types of abdominal operations. Nonetheless, with increasing training and experience, benefits continue to be gleaned from this approach. As techniques are refined and newer technologies arise, MIPS is likely to become the central approach for treating surgical diseases of the pancreas.

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