Changing trends and outcomes associated with the adoption of minimally invasive pancreatic surgeries: A single institution experience with 150 consecutive procedures in Southeast Asia

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Abstract

Background: Minimally invasive pancreatic surgeries (MIPS) are increasingly adopted worldwide. However, it remains uncertain if these reported experiences are reproducible throughout the world today. This study examines the safety and evolution of MIPS at a single institution in Southeast Asia.

Methods: This is a retrospective review of 150 consecutive patients who underwent MIPS between 2006 and 2018 of which 135 cases (90%) were performed since 2012. To determine the evolution of MIPS, the study population was stratified into 3 equal groups of 50 patients. Comparison was also made between pancreatoduodenectomies (PD), distal pancreatectomies (DP) and other pancreatic surgeries.

Results: One hundred and fifty patients underwent MIPS (103 laparoscopic, 45 robotic and 2 hand-assisted). Forty-three patients underwent PD, 93 DP and 14 other MIPS. There were 21 (14.0%) open conversions. There was an exponential increase in caseload over the study period. Comparison across the 3 time periods demonstrated that patients were significantly more likely to have a higher American Society of Anesthesiologists score, older, undergo PD and a longer operation time. The conversion rate decreased from 28% to 0% and increased again to 14% across the 3 time periods. Comparison between the various types of MIPS demonstrated that patients who underwent PD were significantly older, more likely to have symptomatic tumours, had longer surgery time, increased blood loss, increased frequency of extended pancreatectomies, increased frequency of hybrid procedures, longer post-operative stay, increased post-operative morbidity rate and increased post-operative major morbidity rate.

Conclusion: The case volume of MIPS increased rapidly at our institution over the study period. Furthermore, although the indications for MIPS expanded to include more complex procedures in higher risk patients, there was no change in key perioperative outcomes.

Keywords: Laparoscopic pancreas, laparoscopic pancreatectomy, minimally invasive pancreatectomy, robotic pancreas, robotic pancreatectomy

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INTRODUCTION

Over the past 10–15 years, minimally invasive pancreatic surgery (MIPS) has been increasingly adopted worldwide.\(^1,2\) Although MIPS was first performed over 2 decades ago,\(^3\) its initial adoption was not surprisingly slow due to its technical complexity.\(^3,4\) In recent years, improved knowledge and standardisation of MIPS techniques in addition to rapid advancements in the development of minimally invasive surgical device technology such as the introduction of improved high-definition laparoscopes and new advanced energy devices have allowed more surgeons throughout the world to perform MIPS.\(^5,6\) Hence, the indications of MIPS have expanded as surgeons gained increasing experience with MIPS\(^6\) from less complicated distal pancreatectomies (DP)\(^7,8\) and enucleations\(^9\) to more complicated procedures such as central pancreatectomies\(^10\) and pancreatoduodenectomies (PD)\(^11,12\) including even extended pancreatic resections requiring vascular resections.\(^13\)

Nonetheless, despite increasing numbers of surgeons adopting MIPS today, the most common approach for pancreatic surgery remains the conventional open approach and many surgeons remain sceptical about MIPS. This is despite evidence from numerous case–control retrospective studies\(^14,15\) including several recent randomised control trials in both DP\(^16\) and PD\(^17,18\) demonstrating the advantages of MIPS over traditional open surgery, especially in terms of its superior short-term post-operative outcomes. Today, the main concerns raised by opponents of MIPS are its universal reproducibility and applicability due to the reportedly long and steep learning curve required to learn and achieve proficiency.\(^19,20\) This is especially so with MIPD which is already a highly complicated procedure with a high morbidity rate even when performed via the open approach. Several studies have reported that MIPD is associated with an increased morbidity, especially in the learning phase\(^18,19\) and should be limited to high-volume institutions.\(^15,21\) Robotic pancreatic surgery (RPS) has been proposed as an alternative approach to conventional laparoscopy as its advantages such as improved dexterity and stability have been shown to potentially improve selected outcomes such as decreasing open conversion rate\(^22\) and anastomotic complications, especially during the learning phase.\(^22\)

To date, although large studies have been published to study the development of MIPS from North America, Europe and North Asia,\(^1,23–25\) questions remain if these experiences can be reproduced in other parts of the world today. Hence, the main objective of the present study was to report our modern-day experience with the first 150 consecutive MIPS performed between 2006 and 2018 to study any changing trends in the indications and perioperative outcomes associated with our adoption of MIPS. Of note, 135 (90%) were performed after 2012. This, to the best of our knowledge, is the first series reporting the evolution of MIPS from Southeast Asia.

METHODS

The first 150 consecutive patients who underwent MIPS at our institution between 2006 and 2018 were identified from our prospectively maintained pancreatic surgery database. This study was approved by our institution review board. Patient data were collected from the patients’ clinical, radiological and pathological records. Clinical data were collected from our institution computerised clinical database (Sunrise Clinical Manager version 5.8, Eclipsys Corporation, Atlanta, Georgia), and operative data were obtained from another computerised surgical database (OTM 10, IBM, Armonk, New York). The study cohort was stratified into 3 consecutive study groups of 50 patients to study the evolution of MIPS. We first adopted MIPS in 2006 at our institution, but it was only since 2011 that 2 surgeons (Goh and Chan) decided to systematically adopt minimally invasive hepatopancreatobiliary surgery including MIPS.\(^7,26–28\) The decision to perform MIPS was determined by an individual surgeon’s preference after discussion and obtaining informed consent from the patient. This was not based on a standardised institution protocol.

Various approaches were adopted for MIPS as we progressed along our learning curve including the totally laparoscopic approach (lipopolysaccharide [LPS]), hand-assisted laparoscopic, robotic-assisted laparoscopic (RPS) and hybrid laparoscopic/robotic-assisted with open reconstruction depending on an individual surgeon’s experience and preference. Detailed description of our surgical techniques have been reported in our prior studies.\(^7,28,29\)

Definitions

We adopted the definition of an extended pancreatectomy according to that proposed by the international study group whereby any pancreatectomy with adjacent organ not normally part of the resection (e.g. liver, stomach or colon) or major vascular resection was considered an extended resection.\(^30\) Post-operative morbidity was reported according to the Clavien–Dindo classification,\(^1\) up to 90 days after surgery including any readmissions. 30-day, 90-day and in-hospital mortalities were recorded.
Pancreatic fistulas were graded according to the latest 2016 International Society of Grading of pancreatic fistula.[32] Drain fluid amylase was collected routinely on post-operative day 3 when drains were present, and a value of more than 3 times the concentration of the upper limit of serum amylase or a value more than 300 IU/L associated with a clinically symptomatic condition was considered a pancreatic fistula. Patients who had their surgical drains for more than 21 days or required endoscopic or percutaneous intervention were considered to have Grade B fistulas. Grade C pancreatic fistulas were fistulas which required repeat surgical exploration, resulted in organ failure or resulted in mortality. Purely asymptomatic fistulas which were previously defined as a Grade A fistula were no longer considered as a pancreatic fistula or morbidity but were instead classified as a biochemical leak.

In this study, open conversion was defined as any operation where an open incision was made prematurely to complete the procedure. For hybrid MIPS, where a planned short midline incision was made for the reconstruction phase after completion of the resection phase, open conversion was defined as when an open incision was made during the resection phase of the procedure.[39]

The computer program Statistical Package for Social Sciences for Windows, version 21.0 (SPSS Inc., Chicago, IL., USA) was used to perform all statistical analyses. Univariate analyses comparing trends across the 3 groups over time were conducted using the Jonckheere–Terpstra test for continuous variables and Mantel–Haenszel tests for categorical variables. Comparison between PD, DP and other procedures were performed using Chi-squared tests and the Kruskal–Wallis test as appropriate. All tests were 2-tailed and P < 0.05 was considered as statistically significant.

RESULTS

The baseline demographics and outcomes of these 150 patients are summarised in Table 1. One hundred and three (68.7%) were performed laparoscopically, 45 (30.0%) were performed with robotic assistance and 2 (1.3%) were hand-assisted. Twenty (14.7%) procedures were hybrid procedures whereby reconstruction was performed via a mini-laparotomy incision. The procedures performed included 93 DP, 43 PD/total pancreatectomies and other pancreatic surgeries (not performance status) including 8 enucleations, 3 palliative triple bypasses for advanced periampullary tumours, 1 completion pancreateosplenectomy for recurrent tumour after previous open pancreateoduodenectomy, 1 Puestow procedure and 1 cystgastrostomy for pseudocyst.

Major morbidity (Clavien–Dindo Grade III–V) occurred in 29 patients (20.7%) including 9 (6.0%) reoperations. Post-operative pancreatic fistula occurred in 30 (20.0%) of patients, of which 4 (2.7%) were Grade C. Nineteen fistulas (12.9%) were more than Clavien–Dindo Grade II requiring percutaneous drainage or reoperation. There was no 30-day mortality, 3 (2.0%) in-hospital mortalities and 4 (2.7%) 90-day mortalities. The 4 90-day mortalities included 2 patients who demised after laparoscopic distal pancreatectomy; 1 after developing myocardial infarction and intracerebral haemorrhage and another in a post-renal transplant patient who developed nosocomial pneumonia after laparoscopic distal pancreatectomy combined with gastric wedge resection and extended right hemicolecotomy for synchronous pancreatic intraductal papillary mucinous neoplasm, gastric gastrointestinal stromal tumour and colorectal carcinoma. Two patients demised after laparoscopic PD; 1 from irreversible anoxic brain injury after developing early respiratory failure immediately post-extubation after reoperation for pancreatic ascites and another from early systemic recurrence of cancer after discharge from hospital.

Changing trends and outcomes of minimally invasive pancreatic surgery over the study period

The changing trends and outcomes associated with the adoption of MIPS across the 3 study groups are summarised in Table 1. The case volume of MIPS performed over time increased from an average of about 1 case every 2 months in the 1st 50 cases to over 3 cases a month in the most recent 50 cases. Since 2012, there was a rapid exponential increase in MIPS cases performed. Of note, 135 of the 150 cases (90%) were performed over the past 7 years. Comparison across the 3 groups demonstrated that patients were significantly more likely to be of older age, had a higher American Society of Anesthesiologists (ASA) score, undergo PD and a longer operation time. The open conversion rate decreased from 28% to 0% and increased again to 14% across the 3 time periods. There was no significant difference in other perioperative outcomes such as major post-operative morbidity, mortality and length of hospital stay.

Comparison between distal pancreatectomies, pancreateoduodenectomies and other performance status

Comparison between the 3 groups demonstrated that patients who underwent PD were significantly older, more likely to have symptomatic tumours, longer operation time, increased blood loss, increased frequency of extended pancreatectomies, increased frequency of hybrid procedures, longer post-operative stay, increased post-operative morbidity rate and increased post-operative...
Table 1: Comparison between the clinicopathologic features and perioperative outcomes of patients across the 3 patient groups

|                          | Total          | Group 1          | Group 2          | Group 3          | P     |
|--------------------------|----------------|------------------|------------------|------------------|-------|
| n                        | 150            | 50               | 50               | 50               | NA    |
| Time interval, months    |                |                  |                  |                  |       |
| Median age, years (range)| 62 (18-85)     | 57 (20-78)       | 61 (18-79)       | 66.5 (34-85)     | 0.002 |
| Male, n (%)              | 77 (51.5)      | 72 (54.0)        | 71 (44.0)        | 72 (50.0)        | 0.842 |
| BMI                       | 22.9 (12.6-40.5)| 24.0 (13.6-35.9)| 22.6 (12.6-32.3) | 22.8 (16.4-40.5) | 0.177 |
| Symptomatic, n (%)       | 70 (46.7)      | 22 (44.0)        | 23 (46.0)        | 25 (50.0)        | 0.549 |
| Laparoscopic, n (%)      | 103 (68.7)     | 39 (78.0)        | 32 (64.0)        | 32 (64.0)        | 0.081 |
| Hand assisted, n (%)     | 2 (1.3)        | 2 (4.0)          | 0                | 0                |       |
| Robotic assisted, n (%)  | 45 (30.0)      | 9 (18.0)         | 18 (36.0)        | 18 (36.0)        |       |
| Lap assisted (hybrid), n (%) | 22 (14.7) | 1 (2.0)          | 17 (34.0)        | 4 (8.0)          | 0.398 |
| Previous abdominal surgery, n (%) | 38 (25.3) | 13 (26.0)        | 10 (20.0)        | 15 (30.0)        | 0.647 |
| ASA score, n (%)         | 123 (53.3)     | 45 (18.4)        | 45 (18.4)        | 45 (18.4)        |       |
| n                        | 255 (100)      | 90 (35.1)        | 90 (35.1)        | 75 (30.0)        |       |
| Median tumour size, cm (range) | 25.0 (0-14.0) | 25.0 (0-7.5)     | 27.5 (0-14.0)    | 25.0 (9-0)       | 0.742 |
| Type of pancreatic surgery, n (%) | 90 (35.1) | 30 (33.3)        | 30 (33.3)        | 30 (40.0)        |       |
| Distal pancreatectomy    | 93 (62.0)      | 44 (88.0)        | 28 (56.0)        | 21 (42.0)        | <0.001 |
| Pancreatoduodenectomy    | 43 (28.7)      | 3 (6.0)          | 18 (36.0)        | 22 (44.0)        |       |
| Others                   | 14 (9.3)       | 3 (6.0)          | 4 (8.0)          | 7 (14.0)         |       |
| Extended pancreatectomy  | 10 (6.7)       | 1 (2.0)          | 5 (10.0)         | 4 (8.0)          | 0.231 |
| Concomitant surgery       | 9 (6.0)        | 3 (6.0)          | 0                | 6 (12.0)         | 0.208 |
| Median operation time, min (range) | 330 (45-930) | 307 (45-685)    | 352.5 (75-930)   | 397.5 (115-805)  | 0.044 |
| Intraoperative blood transfusion, n (%) | 19 (12.7)      | 6 (12.0)        | 7 (14.0)         | 6 (12.0)         | 1.000 |
| Median estimated blood loss, ml (range) | 200 (0-4000) | 175 (0-2000)    | 200 (0-1700)     | 225 (0-4000)     | 0.668 |
| Open conversion, n (%)   | 21 (14.0)      | 14 (28.0)        | 0                | 7 (14.0)         | 0.044 |
| Completed MIS            | 107 (71.3)     | 35 (70.0)        | 33 (66.0)        | 39 (78.0)        | 0.378 |
| Median post-operative hospitalisation, days (range) | 7 (1-73)      | 6 (3-73)         | 7 (3-69)         | 7 (1-50)         | 0.151 |
| Readmission, n (%)       | 30 (20.0)      | 10 (20.0)        | 6 (12.0)         | 14 (28.0)        | 0.319 |
| Post-operative morbidity, n (%) | 65 (43.3)      | 22 (44.0)        | 17 (34.0)        | 26 (52.0)        | 0.421 |
| Major morbidity (> Grade 2), n (%) | 29 (20.7) | 9 (18.0)         | 11 (22.4)        | 9 (22.0)         | 0.630 |
| Reoperation, n (%)       | 9 (6.0)        | 1 (2.0)          | 3 (6.0)          | 5 (10.0)         | 0.093 |
| Pancreatic fistula, n (%) | 30 (20.0)      | 11 (22.0)        | 8 (16.0)         | 11 (22.0)        | 1.000 |
| Grade B                  | 26 (17.3)      | 11 (22.0)        | 7 (14.0)         | 8 (16.0)         |       |
| Grade C                  | 4 (2.7)        | 0                | 1 (2.0)          | 3 (6.0)          |       |
| Grade 3/> fistula, n (%) | 19 (12.8)      | 9 (18.4)         | 5 (10.0)         | 5 (10.0)         | 0.229 |
| Post-operative bleeding, n (%) | 2 (1.3)        | 0                | 1 (2.0)          | 1 (2.0)          | 0.385 |
| Mortality                |                |                  |                  |                  |       |
| 30-day, n (%)            | 0              | 0                | 0                | 0                |       |
| In-hospital, n (%)       | 3 (2.0)        | 1 (2.0)          | 2 (4.0)          | 0                | 0.477 |
| 90-day, n (%)            | 4 (2.7)        | 1 (2.0)          | 2 (4.0)          | 1 (2.0)          | 1.000 |

BMI: Body mass index, ASA: American Society of Anesthesiologists, MIS: Minimally invasive surgery, NA: Not available

major morbidity rate [Table 2]. Patients who underwent DP had a significantly larger tumour size and patients who underwent enucleation had a significantly higher ASA score.

**DISCUSSION**

MIPS was first reported more than 2 decades ago by Gagner et al. Since then, several large series from throughout the world including North America, North Asia and Europe reporting on MIPD and MIDP have been published. However, to date, the adoption and development of MIPS in other parts of the world such as Southeast Asia has not been well-described. Furthermore, although MIPS is increasingly performed by more surgeons worldwide there remains limited large single studies reporting on the contemporary development of MIPS.

In this present modern-day study, we demonstrated that as our institution gained more experience with MIPS, the case volume increased exponentially as we expanded our indications to perform increasingly more complicated pancreatic surgeries such as PD in higher risk patients (older age with a higher ASA score) with no difference in post-operative outcomes such as post-operative morbidity, major morbidity and hospital stay but at the expense of a longer operative duration.

Examination of open conversion rates demonstrated a decrease in unplanned open conversion rates from 28%
Table 2: Comparison between the clinicopathologic features and perioperative outcomes of patients by resection type

|                          | Total | DP  | PD  | Others | P    |
|--------------------------|-------|-----|-----|--------|------|
| n                        | 150   | 93  | 43  | 14     |      |
| Median age, years (range)| 62 (18-85) | 61 (19-85) | 67 (24-82) | 56.5 (18-82) | 0.025 |
| Male, n (%)              | 77 (51.3) | 41 (44.1) | 29 (67.4) | 7 (50.0) | 0.106 |
| BMI                      | 22.9 (12.6-40.5) | 23.1 (12.6-35.9) | 22.7 (14.5-35.1) | 22.1 (13.6-40.5) | 0.262 |
| Symptomatic, n (%)       | 70 (46.7) | 30 (32.3) | 34 (79.1) | 6 (42.9) | <0.001 |
| Laparoscopic, n (%)      | 103 (66.7) | 67 (72.0) | 28 (65.1) | 8 (57.1) | 0.495 |
| Hand assisted, n (%)     | 2 (1.3)  | 2 (2.2)  | 0 (0)    | 0 (0)    |      |
| Robotic, n (%)           | 45 (30.0) | 24 (25.8) | 15 (34.9) | 6 (42.9) |      |
| Hybrid (open reconstruction), n (%) | 22 (14.7) | 0 (0)    | 21 (48.8) | 1 (7.1) | <0.001 |
| Previous abdominal surgery, n (%) | 38 (25.3) | 25 (26.9) | 8 (18.6) | 5 (35.7) | 0.378 |
| ASA score, n (%)         | 1      | 23 (15.3) | 15 (16.1) | 3 (7.0) | 5 (35.7) | 0.009 |
| 2                       | 100 (66.7) | 66 (71.0) | 30 (69.8) | 4 (28.6) |      |
| 3                       | 27 (18.0) | 12 (12.9) | 10 (23.3) | 5 (35.7) |      |
| Median tumour size, cm (range) | 25.0 (0-14.0) | 3.0 (0-14.0) | 2.5 (1.0-7.0) | 1.5 (0-3.6) | <0.001 |
| Extended pancreatectomy, n (%) | 10 (6.7)  | 3 (3.2)  | 7 (16.3) | 0 (0)    | 0.010 |
| Concomitant procedure, n (%) | 9 (6.0)  | 6 (6.5)  | 2 (4.7)  | 1 (7.1)  | 0.903 |
| Median operation time, min (range) | 330 (45-930) | 285 (85-775) | 595 (360-930) | 245 (45-500) | <0.001 |
| Intraoperative blood transfusion, n (%) | 19 (12.7) | 10 (10.8) | 9 (20.9) | 0 (0)    | 0.082 |
| Median estimated blood loss, ml (range) | 200 (0-4000) | 150 (25-2000) | 400 (50-4000) | 50 (0-350) | <0.001 |
| Open conversion, n (%)   | 21 (14.0) | 12 (12.9) | 8 (18.6) | 1 (7.1)  | 0.497 |
| Completed MIS, n (%)     | 107 (71.3) | 87 (81.7) | 14 (32.6) | 12 (85.7) | <0.001 |
| Median post-operative hospitalisation, days (range) | 7 (1-73)  | 6 (3-73)  | 11 (5-62) | 6 (1-29)  | <0.001 |
| Readmission, n (%)       | 30 (20.0) | 19 (20.4) | 10 (23.3) | 1 (7.1)  | 0.419 |
| Post-operative morbidity, n (%) | 65 (43.3) | 30 (32.3) | 29 (67.4) | 6 (42.9) | 0.001 |
| Major morbidity (> Grade 2), n (%) | 29 (20.7) | 15 (16.7) | 13 (35.1) | 7 (7.7)  | 0.031 |
| Reoperation, n (%)       | 9 (6.0)  | 2 (2.2)  | 7 (16.3) | 0 (0)    | 0.003 |
| Pancreatic fistula, n (%) | Total   | 30 (20.0) | 19 (20.4) | 8 (18.6) | 3 (21.4) | 0.960 |
| Grade B                  |         |         |       |        |      |
| Grade C                  |         |         |       |        |      |
| Grade 3/4 fistula, n (%) | 19 (12.8) | 14 (15.2) | 5 (11.9) | 0 (0)    | 0.278 |
| Post-operative bleeding, n (%) | 2 (1.3)  | 0 (0)    | 2 (4.7)  | 0 (0)    | 0.080 |
| Mortality                |         |         |       |        |      |
| 30-day, n (%)            | 0 (0)   | 0 (0)   | 0 (0)   | 0 (0)   | NA    |
| In-hospital, n (%)       | 3 (2.0) | 2 (2.2)  | 1 (2.3)  | 0 (0)    | 0.852 |
| 90-day, n (%)            | 4 (2.7) | 2 (2.2)  | 2 (4.7)  | 0 (0)    | 0.568 |

DP: Distal pancreatectomies, PD: Pancreatoduodenectomies, BMI: Body mass index, ASA: American Society of Anesthesiologists, NA: Not available

In addition, it is imperative to note that there was no significant difference in other important perioperative outcomes such as the rate of blood transfusions, length of stay, complication rate and mortality over the study period. These findings support the hypothesis that when adopted gradually in a step-wise manner, MIPS can be safely adopted. Our findings are concordant with the current worldwide trend whereby MIPS is being increasingly adopted in more and more centres worldwide, further confirming its reproducibility.

Comparison between the various types of MIPS demonstrated not surprisingly that MIPD was associated with the longest operation time, increased blood loss, highest morbidity rate, highest major morbidity rate and longest hospital stay. MIPD is well recognised as a highly complicated procedure, and its routine adoption remains controversial today. Although 2 recent single-centre prospective randomised control trials suggested superiority of laparoscopic PD, a third...
multicenter trial from the Netherlands, the LEOPARD-2 study[37] reported higher mortality of laparoscopic versus open PD and had to be terminated prematurely. MIPD not only requires a highly complicated resection phase but also involves a technically demanding reconstruction phase. In particular, it requires the creation of secure biliointestinal and pancreatointestinal anastomoses.[29,38] Several investigators[18,19] have rightly raised concerns about the potential increase in complications and even mortality, especially during the early learning curve of MIPD. Hence, some investigators have proposed adopting hybrid MIPD with open reconstruction to bridge the large gap between the traditional open and totally management information system.[29] In our early experience, we similarly adopted the hybrid approach in most PD cases which enabled us to perform these complicated procedures safely. Some surgeons have proposed performing robotic PD especially during the reconstruction phase as the superior dexterity of the robot has been shown to be especially useful for the creation of the complex pancreatointestinal anastomosis in MIPD.[22,24,28,29] However, studies on robotic PD remain limited to low level retrospective studies,[29] and further studies are needed to determine its utility.

CONCLUSION

This modern-day single-centre study demonstrates that MIPs can be safely adopted today. This study provides further evidence supporting the adoption of MIPs in other expert centres worldwide. Over the study period, the case volume of MIPs rapidly increased at our centre. Although we expanded the indications of MIPs to include more complex surgeries in older/sicker patients, there was no significant change in the main perioperative outcomes.

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Conflicts of interest

There are no conflicts of interest.

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