Changing trends and outcomes associated with the adoption of minimally-invasive pancreato-biliary surgery: Contemporary experience of a ‘self-taught’ early adopter in Southeast Asia

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Abstract

Background: Minimally-invasive pancreato-biliary surgery (MIPBS) is increasingly reported worldwide. This study examines the changing trends, safety and outcomes associated with the adoption of MIPBS based on a contemporary experience of an early adopter in Southeast Asia.

Methods: Retrospective review of 114 consecutive patients who underwent MIPBS by a single surgeon over 86 months from 2011. The study population was stratified into three equal groups of 38 patients. Comparison was also performed between minimally-invasive pancreato surgery (MIPS) and minimally-invasive biliary surgery (MIBS).

Results: There were 70 MIPS and 44 MIBS. Sixty-three cases (55.3%) were performed using robotic assistance and fourteen (12.3%) were hybrid procedures with open reconstruction. Forty-four (38.6%) procedures were performed for malignancy. There were 8 (7.0%) open conversions and median operation time was 335 (range, 60–930) min. There were nine extended pancreatectomies including seven involving vascular reconstructions. Major morbidity (>Grade 2) occurred in 20 (17.5%) patients including 6 (5.3%) reoperations and there was no mortality. Comparison across the three groups demonstrated that with increasing experience, there was a significant trend in a higher proportion of higher ASA score patients, increasing frequency of procedures requiring anastomosis and increasing the use of robotic assistance without significant difference in key perioperative outcomes such as open conversion rate, morbidity and hospital stay. Comparison between MIPS and MIBS demonstrated that MIPS was associated with significantly longer operation time, increased blood loss, increased transfusion rate, longer hospital stay, increased readmission rate and increased morbidity.

Conclusion: MIPBS can be safely adopted today with a low open conversion rate.

Keywords: Hepaticojejunostomy, laparoscopic biliary, laparoscopic pancreas, pancreatectomy, robotic

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INTRODUCTION

The adoption of minimally-invasive pancreatic and biliary surgery (MIPBS) is increasing rapidly throughout the world today. However, MIPBS remains a highly complicated and technically demanding procedure and large series of minimally-invasive pancreatic surgery (MIPS) and minimally-invasive biliary surgery (MIBS) remain limited to a few early adopting and pioneering expert centres from North America, Europe, and certain parts of Asia including North Asia and the Indian subcontinent.

At present, there are only a few studies from Southeast Asia on MIPBS which were mainly published from our centre. Despite many single-centre studies on MIPBS published to date, contemporary studies reporting on a single surgeon's experience adopting MIPBS remain limited.

The present study examines the changing trends, safety and outcomes associated with the adoption of MIPBS based on the experience of an early adopter in Southeast Asia. To the best of our knowledge, this is the first such study to date in the literature.

METHODS

All patients who underwent MIPBS by a single surgeon at Singapore General Hospital over 86 months between 2011 and 2019 were identified from a prospectively maintained surgical database. This study was approved by our Institution Review Board and conforms to the provisions of the Declaration of Helsinki in 1995 (as revised in Brazil 2013). One hundred and fourteen patients were identified. All data were obtained from the patients’ clinical, radiological and pathological records. These were obtained from two prospective computerised clinical databases (Sunrise Clinical Manager version 5.8, Eclipsys Corporation, Atlanta, Georgia and OTM 10, IBM, Armonk, New York). Only cases whereby the surgeon was the principal operator who performed the majority of the procedure or critical portions of the procedure were included. As this was a university-affiliated teaching hospital; in many of the cases, parts of the operation were performed by surgical trainees or fellows under supervision. The surgeon had no prior experience or formal fellowship training in MIPBS before the study period. However, he had a large experience with open hepatopancreatobiliary (HPB) and transplant surgery having performed over 600 cases before the study period, having completed 2 fellowships in abdominal organ (liver, kidney and pancreas) transplant and HPB surgical oncology. He had also gained experience with other minimally-invasive surgery (MIS) procedures such as cholecystectomies, appendectomies and donor nephrectomies.

The choice between robotic and laparoscopic approach was dependent on the surgeon's and patient’s preference and the final approach was determined after a detailed discussion with the patient emphasising the advantages and limitations of both approaches. Cost and availability of the robotic platform were a major factor in deciding on its use.

Definitions

In this study, all types of pancreatic surgeries were included such as pancreatoduodenectomies, distal/subtotal pancreatectomies and other pancreatic surgeries such as pancreaticojejunostomy, enucleation and resections for tumours adherent to the pancreas. Only major biliary surgeries were included in this study which included choledochoectomies, hepaticechojejunoanastomoses, surgical resection for suspected gallbladder cancer and hilar lymph node dissection. Selected surgeries for complicated gallstone disease were also included such as surgery for Mirizzi Syndrome, cholecystoenteric fistula and transcholedochal bile duct exploration as a salvage procedure for choledocholithiasis after failed endoscopic retrograde cholangiopancreatography. Other procedures for gallstone disease such as difficult cholecystectomy for cholecytitis and transcytic bile duct exploration for choledocholithiasis were excluded.

Hybrid procedures were defined as those whereby the resection phase was performed entirely by MIS (laparoscopically/robotically), but the reconstruction phase such as the closure of fistula, bilioenteric or pancreateoenteric anastomoses were performed through a mini-laparotomy incision. Exceptions were in selected cases of Roux-en-Y hepaticojejunoanastomoses and pancreatoduodenectomies whereby the jejunojejunoanastomoses or the duodeno-/gastro-jejunoanastomoses were constructed extracorporeally through the specimen extraction site. These were still considered totally MIS and not hybrid procedures.

All procedures whereby the robot was docked to assist in surgery were defined as robotic-assisted procedures. All procedures whereby the pre-operative plan was for MIPBS but the procedure had to be completed prematurely through an open incision were defined as an open conversion. The operative techniques and approaches adopted have been described in previous studies. Post-operative complications and mortality were classified according to the Clavien-Dindo grading system and were recorded up to 30-day postoperatively.
Pancreatic fistulas were defined and graded according to the 2016 International Society of Grading of Pancreatic fistula.\textsuperscript{[21]} Drain fluid amylase was routinely collected on post-operative day 3 and a value more than three times the concentration of the upper limit of serum amylase or a value more than 300 IU/L associated with a clinically relevant condition was considered a clinically relevant pancreatic fistula. Grade B pancreatic fistula included patients who had surgical drains kept in place for more than 21 days or required endoscopic or percutaneous placement of new drainage tubes. Grade C pancreatic fistulas were fistulas which required reoperation, resulted in organ failure or mortality. The international study group definition was used to define an extended pancreatectomy whereby any pancreatectomy with adjacent organ not normally part of the resection (such as liver, stomach or colon) or vascular resection was considered an extended resection.\textsuperscript{[22]}

In order to determine the changing trends of MIPBS adopted by the surgeon, the 114 patients were divided into three equal groups of 38 patients: Group 1: Case 1–38, Group 2: Case 39–76 and Group 3: Case 76–114. The comparison was done between these three groups. In addition, we also compared the baseline characteristics and outcomes of MIPS versus MIBS.

Table 1: Comparison between the clinicopathologic features and perioperative outcomes of the 114 patients across the three patient groups

|                                      | Total  | Group 1 | Group 2 | Group 3 | P   |
|--------------------------------------|--------|---------|---------|---------|-----|
| n                                    | 114    | 38      | 38      | 38      |     |
| Median age (range), years            | 63 (18-96) | 59 (21-79) | 60.5 (18-82) | 66.5 (28-96) | 0.107 |
| Male, n (%)                          | 63 (55.3) | 20 (52.6) | 23 (60.5) | 29 (52.6) | 1.000 |
| Robotic-assisted, n (%)              | 63 (55.3) | 15 (39.5) | 21 (55.3) | 27 (77.1) | 0.006 |
| Hybrid, n (%)                        | 14 (12.3) | 4 (10.5) | 9 (23.7) | 1 (2.6) | 0.297 |
| Symptomatic, n (%)                   | 39 (44.8) | 15 (37.7) | 21 (57.7) | 12 (37.5) | 0.134 |
| Previous abdominal surgery, n (%)    | 29 (25.4) | 6 (15.8) | 10 (26.3) | 13 (34.2) | 0.066 |
| Ancreatic surgery, n (%)             | 70 (61.4) | 20 (52.6) | 24 (63.2) | 26 (68.4) | 0.355 |
| Biliary surgery, n (%)               | 44 (38.6) | 18 (47.4) | 14 (36.8) | 12 (31.6) |     |
| ASA score, n (%)                     | 1(16.7) | 8 (21.1) | 9 (23.7) | 2 (5.3) | 0.042 |
|                                     | 2(61.4) | 24 (63.2) | 21 (55.3) | 25 (65.8) |     |
|                                     | 3(21.9) | 6 (15.8) | 8 (21.1) | 11 (28.9) |     |
| Malignant neoplasm, n (%)            | 44 (38.6) | 10 (26.3) | 18 (47.4) | 16 (42.1) | 0.159 |
| Anastomosis, n (%)                   | 32 (28.1) | 3 (7.9) | 12 (31.6) | 17 (44.7) | 0.001 |
| Vascular reconstruction, n (%)       | 7 (6.1) | 0 | 3 (7.9) | 4 (10.5) | 0.057 |
| Median tumour size, mm (range)       | 20 (0-140) | 25 (0-140) | 20 (0-130) | 20 (0-90) | 0.131 |
| Concomitant surgery other than cholecystectomy, n (%) | 20 (22.5) | 5 (18.5) | 5 (16.7) | 10 (31.3) | 0.228 |
| Open conversion, n (%)               | 8 (7.0) | 6 (15.8) | 0 | 2 (5.3) | 0.074 |
| Median operation time (range), min   | 335 (60-930) | 350 (135-775) | 320 (85-930) | 352.5 (60-805) | 0.670 |
| Intraoperative blood transfusion, n (%) | 14 (12.3) | 6 (15.8) | 4 (10.5) | 4 (10.5) | 0.486 |
| Median estimated blood loss (range), ml | 100 (0-4000) | 100 (0-2000) | 100 (0-1700) | 100 (0-4000) | 0.736 |
| Median post-operative hospitalisation (range), days | 6 (1-73) | 7 (2-73) | 5 (1-69) | 6 (1-50) | 0.626 |
| Post-operative morbidity, n (%)      | 39 (34.2) | 11 (28.9) | 11 (28.9) | 17 (44.7) | 0.149 |
| Major morbidity (≥ Grade 2), n (%)   | 20 (17.5) | 5 (13.2) | 8 (21.1) | 7 (18.4) | 0.548 |
| Reoperation, n (%)                   | 6 (5.3) | 1 (2.6) | 2 (5.3) | 3 (7.9) | 0.306 |
| Readmission, n (%)                   | 12 (10.6) | 3 (8.1) | 2 (5.3) | 7 (18.4) | 0.146 |
| Mortality                            | 0 | 0 | 0 | NA |     |

ASA: American Society of Anesthesiologists; NA: Not available

All statistical analyses were conducted using the computer programme Statistical Package for Social Sciences for Windows, version 21.0 (SPSS Inc., Chicago, IL, USA). Univariate analyses comparing trends across the three groups over time were performed using the Jonckheere-Terpstra test for continuous variables and Mantel-Haenszel test for categorical variables. Statistical analyses were performed using the Mann-Whitney U test and Chi-squared tests as appropriate. All tests were two-sided and \( P < 0.05 \) was considered statistically significant.

RESULTS

The baseline demographics and perioperative outcomes of the 114 patients who underwent MIPBS are summarised in Table 1. The types of MIPBS are summarised in Table 2. Sixty-three cases (55.3\%) were performed with robotic assistance. Forty-four (86.7\%) had histologically proven malignancy and 29 (25.4\%) had previous abdominal surgery. There were 8 (7.0\%) open conversions. There were 20 (17.5\%) major morbidities (≥ grade 2) and no 30-day mortalities.

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This is summarised in Table 1. Comparison across the three groups demonstrated that patients who underwent MIPBS...
were significantly more likely to have a higher ASA score, undergo robotic-assisted surgery and undergo procedures requiring the performance of an anastomosis. There was no significant difference in outcomes across the three groups.

**Comparison between minimally-invasive pancreatic surgery and minimally-invasive biliary surgery**

Comparison between MIPS and MIBS demonstrated MIPS was associated with significantly increased frequency of vascular reconstruction, larger tumour size, longer operation time, increased frequency of blood transfusion, increased estimated blood loss, longer post-operative stay, increased readmission rate, increased post-operative morbidity and increased major morbidity [Table 3].

**DISCUSSION**

Today, although conventional laparoscopic surgery has become the gold standard for straightforward cholecystectomies with reported open conversion rates of $<5\%$,[23,24] its use for more complicated biliary operations such as bile duct stones, biliary strictures, Mirizzi syndrome, gallbladder malignancy, biliary malignancies and even severe cholecystitis remain more limited and is associated with relatively high open conversion rates of up to $40\%$.[25,26] Similarly, although MIPS is increasingly adopted worldwide,[27,28] the most common approach for PS remains the conventional open approach, and many surgeons remain skeptical about MIPS.[29] The main concerns raised today by opponents of MIPS are its reproducibility and universal applicability due to the long and steep learning curve reportedly required to learn MIPS and to achieve proficiency.[30,31] This is especially so with pancreatoduodenectomy which is a highly complicated procedure with a high morbidity rate even through the traditional open approach. Hence, not surprisingly today most surgeons still elect to perform MIPBS through the traditional open approach.

**Table 2: Types of minimally-invasive pancreato-biliary surgery performed in the 114 patients**

| Type of surgery | n |
|-----------------|---|
| Pancreatic surgery | 70 |
| Pancreatoduodenectomy/total pancreatectomy | 21 |
| Distal pancreatectomy | 38 |
| Enucleation/wedge resection | 7 |
| Other | 4 |
| Biliary surgery | 44 |
| Major liver resection with bile duct resection/HJ | 2 |
| Hepaticojejunostomy including triple bypass | 6 |
| Surgery for Mirizzi Syndrome | 11 |
| Salvage transcholedochal bile duct exploration | 4 |
| Choledochoenteric fistula | 6 |
| Surgical resection for GBC | 13 |
| Others | 2 |

\(^{1}\) Pancreatoduodenectomies with radical cholecystectomies were included here, \(^{2}\) Including 1 resection of retroperitoneal Schwannoma with wedge of pancreas and 1 resection of D3/D4 GIST with wedge of pancreas, \(^{3}\) This included 1 lateral pancreatecojejunostomy, 1 gastric resection for GIST abutting pancreas, 1 left adrenalectomy for tumour abutting abutting, 1 completion pancreateopancreatectomy for recurrent tumour after previous pancreatoduodenectomy, \(^{4}\) This included 1 transcholedochal resection of polyp, 1 hilar lymph node dissection. GBC: Gallbladder cancer; HJ: Hepaticojejunostomy, GIST: Gastrointestinal stromal tumour

**Table 3: Comparison between minimally-invasive pancreatic surgery and minimally-invasive biliary surgery**

|                          | MIPS | MIBS | P   |
|--------------------------|------|------|-----|
| n                        | 70   | 44   |     |
| Median age (range), years| 62.5 (18-85) | 63.5 (29-96) | 0.294 |
| Male, n (%)              | 40 (57.1) | 23 (52.3) | 0.611 |
| Robotic-assisted, n (%)  | 43 (61.4) | 20 (45.5) | 0.122 |
| Hybrid, n (%)            | 10 (14.3) | 4 (9.1) | 0.561 |
| Symptoms, n (%)          | 31 (44.3) | 8 (47.1) | 0.837 |
| Previous abdominal surgery, n (%) | 18 (25.7) | 11 (25.0) | 0.932 |
| ASA score, n (%)         | 1 (15.7) | 8 (18.2) | 0.454 |
| 2                        | 46 (65.7) | 24 (54.5) |     |
| 3                        | 13 (18.6) | 12 (27.3) |     |
| Malignant neoplasm, n (%)| 30 (42.9) | 14 (31.8) | 0.239 |
| Vascular reconstruction, n (%) | 7 (10.0) | 0 | 0.032 |
| Anastomosis, n (%)       | 24 (34.3) | 8 (18.2) | 0.062 |
| Median tumour size, mm (range) | 25 (0-140) | 8 (0-85) | 0.001 |
| Open conversion, n (%)   | 4 (5.7) | 4 (9.1) | 0.709 |
| Median operation time (range), min | 390 (130-930) | 247.5 (60-805) | 0.001 |
| Intraoperative blood transfusion, n (%) | 13 (18.6) | 1 (2.3) | 0.009 |
| Median estimated blood loss (range), mL | 200 (10-4000) | 50 (0-700) | 0.001 |
| Median post-operative hospitalisation (range), days | 7 (2-73) | 5 (1-29) | 0.001 |
| Readmission, n (%)       | 12 (17.1) | 0 | 0.003 |
| Post-operative morbidity, n (%) | 31 (44.3) | 8 (18.2) | 0.005 |
| Major morbidity (> Grade 2), n (%) | 17 (24.3) | 3 (6.8) | 0.022 |
| Reoperation, n (%)       | 5 (7.1) | 1 (2.3) | 0.403 |
| Mortality, n (%)         | 0 | 0 | 1.000 |

ASA: American Society of Anesthesiologists, MIPS: Minimally invasive pancreatic surgery, MIBS: Minimally-invasive biliary surgery
Nonetheless, over the past decade, there have been rapid advancements in surgical technique and surgical technology in the field of minimally-invasive HPB surgery, allowing increasing number of surgeons to perform complicated procedures such as major hepatectomies, pancreatocutemies and biliary operations successfully through the minimally invasive approach.\textsuperscript{[12,14,16,17,32,33]} The learning curve for many of these procedures today has also been reported to be shorter compared to that reported by pioneering surgeons.\textsuperscript{[33,34]}

In the present series, 63 MIPBS cases (55\%) were performed with robotic assistance. In this single surgeon’s practice, robotic technology was used to complement and not serve as a replacement for conventional laparoscopy. In our experience with the superior dexterity and increased range of motion of the EndoWrist, we were able to perform many complex tasks successfully such as fine suturing which is required to reconstruct the difficult anastomoses such as hepaticojejunostomy and pancreaticojejunostomy\textsuperscript{[16,17]} despite this being our early experience. These complex tasks are frequently difficult to perform with the straight and rigid conventional laparoscopic instruments especially in tight, narrow spaces such as the proximal hepatic hilum.\textsuperscript{[35]} Although several authors have demonstrated the feasibility and safety of the use of conventional laparoscopy in performing complex MIPBS procedures such as panceatoduodenectomies, these have been mainly limited to ultra-high volume expert surgeons\textsuperscript{[2,3,6,7,11-19]} and questions remain about the transferability and universal applicability of these results. In our opinion, robotic assistance will allow expansion of an individual surgeon’s MIS repertoire allowing him/her to perform more complex operations successfully through the minimally-invasive approach.

At present, the main obstacle to the widespread use of robotic surgery is the increased cost and its limited accessibility. Due to the high cost of purchasing and to maintain the robot; few centres have more than 1 robot if any and hence only a limited number of surgeons can have regular access to this technology for training. Not surprisingly, with their lack of experience and familiarity with the system, few surgeons are willing to attempt complex procedures such as MIPBS with the system. In our practice, robotic surgery was not subsidised by the public health system and patients had to pay an additional charge averaging about USD 3000–4000 for its use. Its use was also limited by resource constrains and hence, accessibility at our institution as there is only one robotic platform shared among the various surgical disciplines such as urology and gynaecology at our institution.

The present contemporary single-surgeon experience with MIPBS supports the hypothesis that MIPBS can be adopted safely today with a relatively short learning curve. Despite not having formal training in MIPBS, today’s so-called ‘self-taught’ surgeon can learn advanced MIS procedures more easily from numerous education platforms such as conferences, overseas site visits and the internet. Most MIPBS surgical procedures, techniques and steps have also been standardised by pioneers and early adopters. Moreover, with the advancements in MIS equipment technology such as improved laparoscopic cameras and monitors, energy and stapling devices and the availability of the robotic platform, complex MIPBS procedures can be performed more easily by an increasing number of surgeons. Hence, unlike the experiences reported by early pioneering surgeons, the learning curve of the modern-day surgeon is likely to be smoother and less steep.

Nonetheless, it is important to emphasise that the results reported in this study may not be applicable to all surgeons embarking on MIPBS. Several other important confounding factors may have accounted for the shorter learning curve observed in this study. First, the surgeon had prior experience with over 600 open HPB and transplant operations before embarking on MIPBS and less experienced surgeons with a more limited open experience may encounter a steeper learning curve. Second, the surgeon had also gained concurrent laparoscopic experience with about 200 other minimally-invasive liver resections and 100 general surgical procedures such as gastric resections, adrenalectomies and splenectomies during the study. Third, during the period, other surgeons in the department were also adopting and learning MIPBS. Hence, the surgeon also gained further experience when assisting or mentoring these surgeons. Regular case discussion with colleagues also allowed the surgeon to acquire valuable tips and learning experience from each other’s experiences. Finally, it is important to add that the learning curve may even be shorter for surgeons who had prior exposure and formal training in MIPBS.

Finally, in this study, comparison between MIPS and MIBS demonstrated that MIPS was associated with poorer perioperative outcomes such as longer operation time, increased the frequency of blood transfusion, increased estimated blood loss, longer post-operative stay, increased readmission rate, increased post-operative morbidity and increased major morbidity. These findings, suggest that MIPS is technically more complicated and associated with an increased risk compared to MIBS and surgeons should be more cautious when attempting MIPS during their early experience.
CONCLUSION

This contemporary experience of an early adopting surgeon in Southeast Asia confirmed that it can be adopted safely for a wide variety of major MIPBS procedures in carefully selected patients.

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Conflicts of interest
There are no conflicts of interest.

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