Robotic Resection of Duodenal Gastrointestinal Stromal Tumour: Preliminary Experience from a Single Centre

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Research

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Abstract

Background: The experience of minimally invasive surgery in the treatment of duodenal gastrointestinal stromal tumours (DGISTs) is accumulating, but there is no consensus on the choice of surgical method. The purpose of this study is to summarize the technique and feasibility of robotic resection of DGIST.

Methods: The demographics and perioperative outcomes of a consecutive series of patients who underwent robotic resection and open resection of DGIST between May 1, 2010 and May 1, 2020 were retrospectively analysed. Patients were divided into an open surgery group and a robotic surgery group. Pancreaticoduodenectomy (PD) or limited resection was performed based on the location of the tumour and the distance between the tumour and duodenal papilla. Age, sex, tumour location, tumour size, operation time (OT), estimated blood loss (EBL), postoperative hospital stay (PHS), tumour mitosis, postoperative risk classification, postoperative recurrence and recurrence-free survival were compared between the two groups.

Results: Among the 28 patients, there were 19 males and 9 females aged 51.3± 13.1 years. Limited resection was performed in 17 patients, and PD was performed in 11 patients. Eleven patients underwent open surgery, and 17 patients underwent robotic surgery. Two patients in the robotic surgery group underwent conversion to open surgery. All the tumours were R0 resected, and there was no significant difference in age, sex, tumour size, operation mode, PHS, tumour mitosis, incidence of postoperative complications, risk classification, postoperative targeted drug therapy or postoperative recurrence between the two groups (p>0.05). OT and EBL in the robotic group were significantly different from those in the open surgery group (p<0.05). All the patients survived during the follow-up period, and 4 patients had recurrence and metastasis. No significant difference in recurrence-free survival was noted between the open surgery group and the robotic surgery group (p>0.05).

Conclusions: Robotic resection is safe and feasible for patients with duodenal gastrointestinal stromal tumours, and its therapeutic effect is equivalent to open surgery.

Introduction

Duodenal gastrointestinal stromal tumours (DGISTs) are independent undifferentiated mesenchymal tumours, and they only account for 2–5% of all gastrointestinal stromal tumours [1–5]. Surgical resection is the most effective treatment for DGIST [6, 7]. However, due to the special location of the duodenum, which is the junction of the biliary tract, pancreas and gastrointestinal tract, and its complex anatomical and physiological functions, there is no consensus on the choice of operation mode [8].

The resection methods of DGIST include limited resection and pancreatoduodenectomy (PD), which should be determined according to the location of the tumour, the relationship between the tumour and the duodenal papilla, and whether the tumour invades the surrounding tissues. The indications for minimally invasive surgery, such as laparoscopic and robotic resection, have been expanding in treatment
for DGIST in recent years [9, 10]. Laparoscopic or robotic resection can be performed according to the location and size of the tumour in an experienced medical centre.

The primary purpose of resection is to achieve minimal complications and avoid complicated operations or multiple organ resections [11]. Our surgical team has performed more than 4000 robotic hepatopancreatobiliary procedures in the past ten years. The objective of this study was to analyse and compare the effect of robotic resection and open surgery in the treatment of DGIST. This study also provides a reference for scientific and reasonable selection of surgical treatment for DGIST.

**Patients And Methods**

**Patients**

The clinical data of 28 consecutive patients who underwent surgical resection of DGIST between May 1, 2010 and May 1, 2020 were retrospectively analysed. The patients were divided into an open surgery group and a robotic surgery group. This study was approved by the Institutional Review Board of Chinese PLA General Hospital.

**Patient Selection**

The inclusion criteria were as follows: (1) single or multiple tumours limited to the duodenum, (2) R0 resection confirmed by postoperative pathology, and (3) no general medical conditions that contraindicated anaesthesia and surgery. The exclusion criteria were (1) liver or other abdominal organ metastasis, (2) invasion of the portal vein or portal vein tumour thrombus, and (3) targeted therapy before surgery.

**Preoperative Evaluation**

Duodenal endoscopic ultrasonography and contrast-enhanced computed tomography (CT) scans were performed as routine diagnostic procedures before the operations.

**Perioperative Data**

Baseline demographics and perioperative and pathology data were obtained from the electronic medical records. Clinical outcomes, including operative time (OT), estimated blood loss (EBL), postoperative complications (POPC), and postoperative hospital stay (PHS), were analysed retrospectively.

POPC included postoperative pancreatic fistula (POPF), delayed gastric emptying (DGE), postoperative haemorrhage and bacteraemia. All complications were documented clearly and graded according to the International Study Group for Pancreatic Surgery (ISGPS) grading system [12]. The recurrence risk
assessment system for primary DGIST after complete resection is according to the modified National Institutes of Health (NIH) classification system (2008) [13].

Surgical Technique And Follow-up

All robotic operations in this study were performed by a single team of surgeons using the Da Vinci Si Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). PD or limited resection was performed based on the location of the tumour and the distance between the tumour and duodenal papilla. The anastomotic method of pancreaticojejunostomy and choledochojejunostomy used in open or robotic PD (RPD) surgery was the same. Five ports were placed in the robotic resection. After docking, dissection and mobilization of the duodenum were performed using a coagulation hook or an ultrasonic scalpel. Intraoperative ultrasound was used to locate the tumour and determine the boundary of DGIST in operations.

All patients were followed up 1 month after discharge and then at 6-month intervals thereafter. According to the results of the postoperative recurrence risk assessment, moderate- to high-grade patients were recommended to take imatinib (Novartis Pharma Schweiz AG, Switzerland) at 400 mg/d for 3 years [14].

Statistics

Continuous data are presented as the mean ± SD. Student’s t-test was used to compare normally distributed variables between groups, whereas the Mann–Whitney U test was used for nonnormally distributed variables. Categorical data were compared using the chi-squared test. OS was estimated using the Kaplan-Meier method, and comparison of OS between subgroups was analysed using the log-rank test. A P-value < 0.05 was considered statistically significant. All analyses were performed using IBM SPSS statistical software, version 20 (SPSS, Chicago, IL, USA).

Results

Patient characteristics

Table 1 presents detailed characteristics of the 28 patients, including 19 men and 9 women with a mean age of 51 years. The most common tumour site was in the descending part of the duodenum (16, 57%) followed by the horizontal part (9, 32%), the bulb part (2, 7%), and the ascending part (1, 4%). Limited resection was performed in 17 patients, and PD was performed in 11 patients. Eleven patients underwent open surgery, and 17 patients underwent robotic surgery. Two patients in the robotic surgery group underwent conversion to open surgery. Nine patients took imatinib after the operation, and 4 patients had postoperative recurrence and metastasis. All the tumours were duodenal gastrointestinal stromal tumours on final histopathological examination, and all of them were R0 resected.
Table 1 Patients demographics

| Clinicopathologic features          | Value (%)             |
|-------------------------------------|-----------------------|
| Mean age (range), yr                | 51.3 ± 13.1 (30-84)   |
| Sex, M/F                            |                       |
| Male                                | 19 (68%)              |
| Female                              | 9 (32%)               |
| Tumour location                     |                       |
| Bulb                                | 2 (7%)                |
| Descending part                     | 16 (57%)              |
| Horizontal part                     | 9 (32%)               |
| Ascending part                      | 1 (4%)                |
| Operation mode                      |                       |
| Open surgery                        | 13 (46%)              |
| Robotic surgery                     | 15 (54%)              |
| Types of resection                  |                       |
| Limited resection                   | 17 (61%)              |
| PD                                  | 11 (39%)              |
| Tumour size (cm)                    |                       |
| ≤2                                  | 2 (7%)                |
| 2–5                                 | 17 (61%)              |
| 5–10                                | 7 (25%)               |
| >10                                 | 2 (7%)                |
| Risk assessment (NIH 2003)          |                       |
| Low                                 | 19 (68%)              |
| Medium                              | 5 (18%)               |
| High                                | 4 (14%)               |
| Resection margin status             |                       |
| R0                                  | 28 (100%)             |
| R1                                  | 0                     |
| Postoperative targeted drug therapy |                       |
| Yes                                 | 9 (32%)               |
| No                                  | 19 (68%)              |
| Postoperative recurrence and metastasis |                 |
| Yes                                 | 4 (14%)               |
| No                                  | 24 (86%)              |

Abbreviations: PD pancreaticoduodenectomy

Perioperative Outcomes

Among the 28 patients, 13 received open surgery, and 15 received robotic surgery. Table 2 reveals no significant difference in age, sex, tumour size, operation mode, PHS, tumour mitosis, incidence of POPC, risk classification, postoperative targeted drug therapy or postoperative recurrence between the two groups (p > 0.05). OT and EBL in the robotic surgery group were significantly different compared with that in the open surgery group (p < 0.05). The complications included POPE in 9 cases, DGE in 5 cases and abdominal haemorrhage in 2 cases, and all the patients were cured after conservative treatment.
Table 2  
Comparison of patients in the open surgery group and robotic surgery group (n = 28)

|                | Open | Robotic | \( P \)-value |
|----------------|------|---------|---------------|
| **Total patients** | 13   | 15      |               |
| **Age**            |      |         | 0.718         |
| \( \geq 50 \text{yr} \) | 8    | 8       |               |
| \(< 50 \text{yr} \)   | 5    | 7       |               |
| **Sex**            |      |         | 0.689         |
| M                 | 8    | 11      |               |
| F                 | 5    | 4       |               |
| **Tumour size**    |      |         | 0.255         |
| \(< 5 \text{cm} \)   | 5    | 10      |               |
| \( \geq 5 \text{cm} \) | 8    | 5       |               |
| **Operation mode** |      |         | 0.700         |
| Limited resection | 7    | 10      |               |
| PD                | 207.7| 156.0   |               |
| OT (min)          | 63.1 | 55.4    |               |
| **Mean**          |      |         |               |
| **Standard deviation** |      |         |               |
| EBL (ml)          |      |         | 0.01          |
| Mean              | 340.0| 62.3    |               |
| Standard deviation | 401.8| 34.9    |               |
| PHS (days)        |      |         | 0.294         |
| Mean              | 16   | 15.7    |               |
| Standard deviation | 9.4  | 13.4    |               |

*Abbreviations: PD pancreaticoduodenectomy, OT operation time, EBL estimated blood loss, PHS postoperative hospital stay, POPC postoperative complications*
|                              | No. Patients |       | P-value |
|------------------------------|--------------|-------|---------|
|                              | Open  | Robotic |         |
| Mitotic count (/50 HPF)      | 12    | 14     | 1.000   |
| ≤5                           | 1     | 1      | 0.072   |
| > 5                          | 6     | 13     | 1.000   |
| Risk assessment              | 4     | 1      | 1.000   |
| Low                          | 3     | 1      | 0.311   |
| Medium                       | 7     | 7      |         |
| High                         | 6     | 8      |         |
| POPC                         | 4     | 5      |         |
| Yes                          | 9     | 10     |         |
| No                           | 3     | 1      |         |
| Post targeted therapy        | 10    | 14     |         |
| Yes                          |       |        |         |
| No                           |       |        |         |
| Recurrence/metastasis        |       |        |         |
| Yes                          |       |        |         |
| No                           |       |        |         |

Abbreviations: PD pancreaticoduodenectomy, OT operation time, EBL estimated blood loss, PHS postoperative hospital stay, POPC postoperative complications

**Surgical Findings**

In the robotic surgery group, 15 patients completed the operation, and 2 patients were converted to open surgery because the tumour was located at the horizontal segments of the duodenum and the surrounding inflammatory adhesion was too serious. Limited resection was performed in 10 cases, and PD was performed in 5 cases. Figure 1 shows that surgeons performed duodenal dissection, tumour resection, duodenal repair and duodenojejunostomy operations using a robotic surgery system.

**Outcome Of Postoperative Follow-up**

All 28 patients survived during the follow-up period. The postoperative pathology showed that the recurrence risk of 5 patients was medium grade, and another 4 patients was high grade. All 9 patients
were treated with imatinib, and 4 patients had recurrence and metastasis. Among the patients with recurrence and metastasis, liver metastasis occurred in 3 cases, and mesocolon metastasis occurred in 1 case. All of the tumours were resected again (Table 3). Figure 2 shows that there was no significant difference in recurrence-free survival between the open surgery group and the robotic surgery group (p > 0.05).

Table 3 General information of patients with recurrence and metastasis (n=4)

| Patient No./Sex/Age(y) | Tumor location | Operation | Recurrent time (mo) | Recurrent location | Risk of disease progression |
|-------------------------|----------------|-----------|--------------------|--------------------|---------------------------|
| 1/M/75                  | Descending part | RPD       | 21                 | liver              | Medium                    |
| 2/M/61                  | Horizontal part | PD        | 36                 | mesocolon          | High                      |
| 3/M/50                  | Descending part | PD        | 108                | liver              | Medium                    |
| 4/M/56                  | Descending part | PD        | 60                 | liver              | Medium                    |

*Abbreviations: RPD robotic PD, PD pancreaticoduodenectomy*

**Discussion**

The incidence of DGIST is low, and patients are typically asymptomatic. Surgical resection can achieve radical cure, but there is no consensus on the choice of operation mode. The size of the tumour varies from patient to patient when the diagnosis is confirmed, and most tumours are located in the descending part of the duodenum [15]. Some of the tumours are close to the nipple and often invade the whole duodenum and pancreas. All of the above factors affect the choice of surgical method; therefore, the basis for these selections should be explored. It is helpful to provide a reference for the scientific and reasonable selection of surgical methods to treat DGIST. The principle of the operation is to completely remove the tumour, ensure the negative margin and intact capsule, and maintain the original anatomical and physiological function of the duodenum as much as possible [16–19].

The location of the tumour and the extent of tumour invasion to surrounding tissues determine the specific surgical method. For DGISTs, limited resection should be adopted as much as possible because PD involves the removal of multiple organs, and the operation risk and complication rate are high [20, 21]. According to the guidelines and consensus of experts, limited resection is recommended for tumours with a distance from the nipple greater than 2 cm. PD is recommended for patients with difficulty in tumour dissociation and tumours with a distance from the nipple less than 2 cm that invades the pancreatic head or is closely related to the superior mesenteric vein and superior artery [14, 22].
Robotic surgery has more advantages than laparoscopic surgery in duodenal dissociation, tumour resection, duodenal repair and duodenojejunostomy. It is easy for surgeons with experience in RPD to dissociate any part of the duodenum. Endoscopic ultrasound is an important method for the diagnosis of GIST that can confirm the origin and scope of tumours. Abdominal CT can reveal the tumour location, shape, size, growth mode and its relationship with the gastrointestinal tract [23]. The combination of multiple examinations can improve the diagnostic rate of DGIST and clarify the lesion site and its invasion to surrounding organs. Because duodenoscopy often cannot accurately locate the tumour location during surgery, we routinely use intraoperative ultrasound combined with preoperative imaging examination to determine the tumour location during surgery [24]. All the tumours of patients in this study were finally found and located during robotic resection.

Our results revealed significant differences in the mean operation time and intraoperative blood loss between the robotic group and the open surgery group. These findings suggested that robotic surgery not only has the same therapeutic effect as traditional open surgery but also has the advantages of a shorter operation time, less intraoperative bleeding and smaller surgical incision. Such robotic operations are recommended to treat DGIST in medical centres with robotic surgical conditions and corresponding experience.

Tumour rupture should be avoided as much as possible during DGIST resection because it is a high-risk factor for postoperative recurrence and metastasis [3, 5, 7–11]. Tumours located in the horizontal segment of the duodenum are often closely related to the superior mesenteric vein and superior artery. If the inflammation and adhesion around the tumour are serious, it is difficult to dissociate the duodenum. Therefore, 2 patients who underwent robotic surgery were converted to open surgery in the present study. Avoiding tumour rupture is the most important factor for surgeons to make decisions regarding surgical conversion.

Postoperative DGE, abdominal bleeding, POPE and bacteraemia are common complications in both robotic surgery and open surgery for DGIST. The treatment principle of postoperative complications of the two surgery methods is the same as that of conventional gastrointestinal surgery and PD [6, 16, 17]. Patients with medium and high risk of recurrence were recommended to take imatinib for 3 years to avoid tumour recurrence [14]. In this group of patients, one patient had liver metastasis 2 years after drug withdrawal, and another patient developed liver metastasis 9 years after the operation. This finding indicates whether the oral targeted drug time should be extended after surgery.

The limitation of this study is that the sample size of patients was too small, and a large amount of case data should be accumulated in future research.

Conclusions

In summary, our study suggests that robotic resection of DGISTs is safe and feasible and has the same therapeutic effect as traditional open surgery. Such surgery can be performed in conditional medical
centres, which can reduce surgical trauma, accelerate postoperative rehabilitation, and provide more options for surgical treatment.

**Abbreviations**

DGIST; duodenal gastrointestinal stromal tumour; PD: pancreaticoduodenectomy; OT: operation time; EBL: estimated blood loss; PHS: postoperative hospital stay; CT: computed tomography; POPC: postoperative complications; POPF: postoperative pancreatic fistula; DGE: delayed gastric emptying; ISGPS: International Study Group for Pancreatic Surgery; NIH: National Institutes of Health; RPD: robotic PD; GIST: gastrointestinal stromal tumour

**Declarations**

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**Authors’ contributions**

Zhou ZP and Tan XL contributed equally to this work and should be considered co-first authors. Zhou ZP and Tan XL analysed and interpreted the data and wrote the article. Zhao ZM, Gao YX, Song YY and Jia YZ drafted the work and collected the data. Li CG designed the study and revised the articles for important intellectual content.

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**Availability of data and materials**

The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**

This study was reviewed and approved by the Ethics Committee of the Chinese PLA General Hospital (S2016-098-02).

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.
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