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Editorial Board Member of *World Journal of Gastrointestinal Oncology*, Claudio Luchini, MD, PhD, Associate Professor, Department of Diagnostics and Public Health, University and Hospital Trust Verona, Verona 37134, Italy. claudio.luchini@katamail.com

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## Retrospective Study

**Robotic resection of duodenal gastrointestinal stromal tumour:  
Preliminary experience from a single centre**

Zhi-Peng Zhou, Xiang-Long Tan, Zhi-Ming Zhao, Yuan-Xing Gao, Yu-Yao Song, Yu-Ze Jia, Cheng-Gang Li

**ORCID number:** Zhi-Peng Zhou 0000-0001-8881-1972; Xiang-Long Tan 0000-0003-2185-2416; Zhi-Ming Zhao 0000-0003-2374-0856; Yuan-Xing Gao 0000-0001-6094-9793; Yu-Yao Song 0000-0002-9048-0591; Yu-Ze Jia 0000-0003-2473-7907; Cheng-Gang Li 0000-0001-7990-1300.

**Author contributions:** Zhou ZP and Tan XL contributed equally to this work, and are considered co-first authors; Zhou ZP and Tan XL analyzed 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 article for important intellectual content.

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**Zhi-Peng Zhou, Xiang-Long Tan, Zhi-Ming Zhao, Yuan-Xing Gao, Yu-Yao Song, Yu-Ze Jia, Cheng-Gang Li,** Department of Hepato-Pancreato-Biliary Surgery, Chinese PLA General Hospital, Beijing 100853, China

**Corresponding author:** Cheng-Gang Li, MD, PhD, Associate Professor, Department of Hepato-Pancreato-Biliary Surgery, Chinese PLA General Hospital, No. 28 Fuxing Road, Beijing 100853, China. [lcheng301@126.com](mailto:lcheng301@126.com)

**Abstract****BACKGROUND**

Experience in minimally invasive surgery in the treatment of duodenal gastrointestinal stromal tumors (DGISTs) is accumulating, but there is no consensus on the choice of surgical method.

**AIM**

To summarize the technique and feasibility of robotic resection of DGISTs.

**METHODS**

The perioperative and demographic outcomes of a consecutive series of patients who underwent robotic resection and open resection of DGISTs between May 1, 2010 and May 1, 2020 were retrospectively analyzed. The patients were divided into the open surgery group and the robotic surgery group. Pancreatoduodenectomy (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**

Of the 28 patients included, 19 were male and 9 were female aged  $51.3 \pm 13.1$  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 ( $P >$

additional data are available.

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0.05). OT and EBL in the robotic group were significantly different to 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 ( $P > 0.05$ ).

### CONCLUSION

Robotic resection is safe and feasible for patients with DGISTs, and its therapeutic effect is equivalent to open surgery.

**Key Words:** Gastrointestinal stromal tumor; Duodenum; Pancreaticoduodenectomy; Limited resection; Robotic resection

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**Core Tip:** Minimally invasive surgery for the treatment of duodenal gastrointestinal stromal tumors (DGISTs) has made rapid progress. More and more cases of DGISTs treated by robotic surgery have been reported. The results of this study suggest that robotic resection of DGISTs is safe and effective, and can be carried out in experienced medical centres.

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## INTRODUCTION

Duodenal gastrointestinal stromal tumors (DGISTs) are independent undifferentiated mesenchymal tumours, and account for only 2% to 5% of all gastrointestinal stromal tumours[1-5]. Surgical resection is the most effective treatment for DGISTs[6,7]. Nevertheless, due to the special location of the duodenum at 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 surgical technique[8].

Resection methods for DGISTs include limited resection and pancreaticoduodenectomy (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 the treatment for DGISTs 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 purpose of this study was to analyze and compare the effect of robotic resection and open surgery in the treatment of DGISTs. This study also provides a reference for scientific and reasonable selection of the surgical treatment for DGISTs.

## MATERIALS AND METHODS

### Patients

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

**Selection of the patients**

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 surgery.

**Perioperative data**

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

POPC included postoperative pancreatic fistula, delayed gastric emptying (DGE), postoperative haemorrhage and bacteraemia. All complications were documented clearly and graded according to the International Study Group for Pancreatic Surgery grading system[12]. The recurrence risk assessment system for primary DGISTs after complete resection was according to the modified National Institutes of Health 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, United States). 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 the DGIST during surgery.

All patients were followed up for 1 mo after discharge and then at 6-mo 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].

**Statistical analysis**

Continuous data are presented as the mean  $\pm$  SD. The Student's *t*-test was used to compare normally distributed variables between groups, whereas the Mann-Whitney *U* test was used for non-normally distributed variables. Categorical data were compared using the chi-squared test. Overall survival (OS) was estimated using the Kaplan-Meier method, and a comparison of OS between subgroups was analyzed 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, United States).

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**RESULTS**

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**Patient characteristics**

Table 1 shows the characteristics of the 19 male and 9 female patients with a mean age of 51 years. The most common tumour site was the descending section of the duodenum (16, 57%) followed by the horizontal section (9, 32%), the bulb section (2, 7%), and the ascending section (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 received imatinib after surgery, and 4 patients had postoperative recurrence and metastasis. All the tumours were DGISTs on final histopathological examination, and were R0 resected.

Table 1 Patient demographics

Clinicopathologic features	Value (%)
Mean age (range), yr	51.3 ± 13.1 (30-84)
Sex, male/female	
Male	19 (68)
Female	9 (32)
Tumor location	
Bulb	2 (7)
Descending section	16 (57)
Horizontal section	9 (32)
Ascending section	1 (4)
Surgical technique	
Open surgery	13 (46)
Robotic surgery	15 (54)
Types of resection	
Limited resection	17 (61)
PD	11 (39)
Tumor size (cm)	
≤ 2	2 (7)
2-5	17 (61)
5-10	7 (25)
> 10	2 (7)
Risk assessment (NIH 2008)	
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)

NIH: National Institutes of Health.

### Perioperative outcomes

Of the 28 patients, 13 underwent open surgery, and 15 underwent robotic surgery. No significant differences in age, sex, tumour size, operation mode, PHS, tumour mitosis, incidence of POPC, risk classification, postoperative targeted drug therapy or postoperative recurrence were observed between the two groups ( $P > 0.05$ ) (Table 2). OT and EBL in the robotic surgery group were significantly different compared with those in the open surgery group ( $P < 0.05$ ). Complications included POPE in 9 cases, DGE in 5 cases and abdominal haemorrhage in 2 cases, and all the patients were cured

**Table 2 Comparison of patients in the open surgery group and robotic surgery group (n = 28)**

	No. of patients		P value
	Open	Robotic	
Total patients	13	15	
Age			0.718
≥ 50 yr	8	8	
< 50 yr	5	7	
Sex			0.689
Male	8	11	
Female	5	4	
Tumor size			0.255
< 5 cm	5	10	
≥ 5 cm	8	5	
Surgical technique			0.700
Limited resection	7	10	
PD	6	5	
OT (min)			0.029
mean ± SD 1	207.7 ± 63.1	156.0 ± 55.4	
EBL (mL)			0.01
mean ± SD 1	340.0 ± 401.8	62.3 ± 34.9	
PHS (d)			0.294
mean ± SD 1	16 ± 9.4	15.7 ± 13.4	
Mitotic count (/50 HPF)			1.000
≤ 5	12	14	
> 5	1	1	
Risk assessment			0.072
Low	6	13	
Medium	4	1	
High	3	1	
POPC			1.000
Yes	7	7	
No	6	8	
Postoperative targeted therapy			1.000
Yes	4	5	
No	9	10	
Recurrence/metastasis			0.311
Yes	3	1	
No	10	14	

PD: Pancreatoduodenectomy; OT: Operation time; EBL: Estimated blood loss; PHS: Postoperative hospital stay; HPF: High-power fields; POPC: Postoperative complications.

after conservative treatment.

### **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 segment 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. As shown in [Figure 1](#), the surgeons performed duodenal dissection, tumour resection, duodenal repair and duodenojejunostomy 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 in 5 patients was medium grade, and was high grade in another 4 patients. All 9 patients were treated with imatinib, and 4 patients developed 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 these tumours were resected ([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 ( $P > 0.05$ ).

## **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 surgical technique. The size of the tumour varies from patient to patient when the diagnosis is confirmed, and most tumours are located in the descending section of the duodenum [15]. Some 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 examined. It is helpful to provide a reference for the scientific and reasonable selection of surgical methods for the treatment of DGISTs. The principle of the operation is to completely remove the tumour, ensure a 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 as PD involves the removal of multiple organs, and the surgical 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 dissection and tumours with a distance from the nipple less than 2 cm that invade the pancreatic head or are closely related to the superior mesenteric vein and superior artery [14,22].

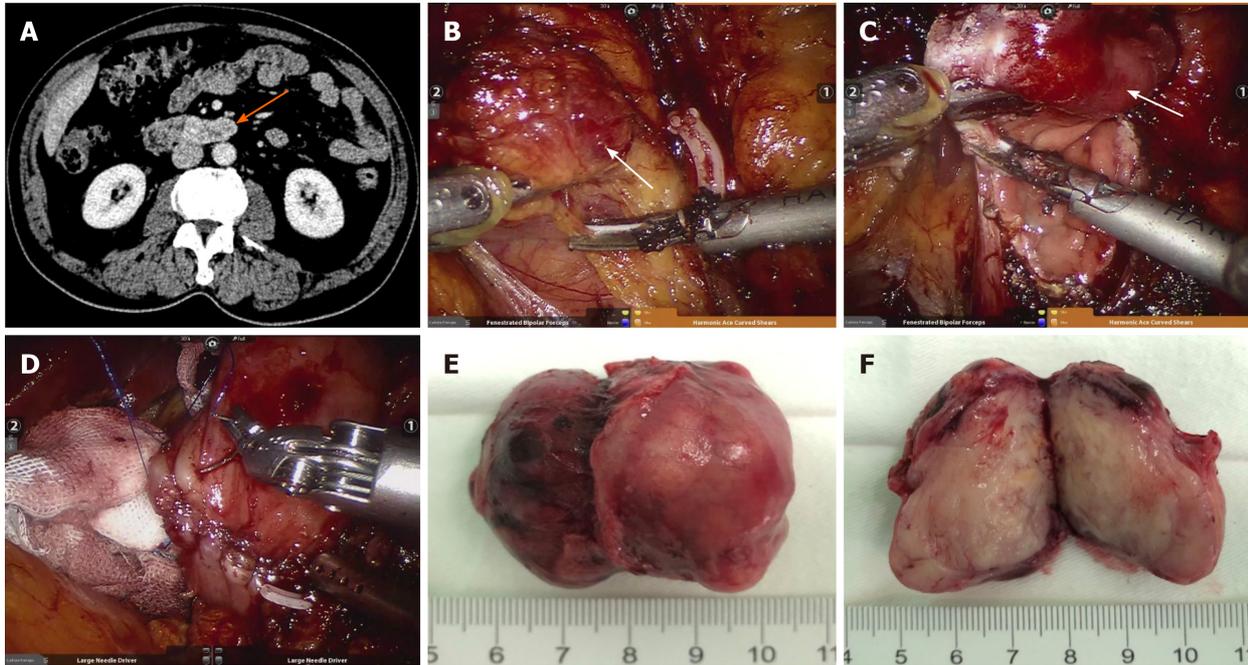
Robotic surgery has more advantages than laparoscopic surgery in duodenal dissection, tumour resection, duodenal repair and duodenojejunostomy. It is easy for surgeons with experience in RPD to dissociate any part of the duodenum. Endoscopic ultrasound is an important method for the diagnosis of GISTs and can confirm the origin and scope of the 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 DGISTs and clarify the lesion site and its invasion to surrounding organs. As duodenoscopy often cannot accurately identify 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 in this study were finally identified and located during robotic resection.

Our results revealed significant differences in the mean OT and intraoperative blood loss between the robotic surgery 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 OT, less intraoperative bleeding and smaller surgical incision. Such robotic operations are recommended to treat DGISTs in medical centres with robotic surgery facilities 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 inflammation and adhesion around the tumour are serious, it is difficult to dissociate the duodenum. In the

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

Patient, No./sex/age, yr	Tumor location	Operation	Recurrent time (mo)	Recurrent location	Risk of disease progression
1/M/75	Descending section	RPD	21	Liver	Medium
2/M/61	Horizontal section	PD	36	Mesocolon	High
3/M/50	Descending section	PD	108	Liver	Medium
4/M/56	Descending section	PD	60	Liver	Medium



**Figure 1** Robotic resection of duodenal gastrointestinal stromal tumor. A: Computed tomography revealed a tumour (arrow) located in the horizontal section of the duodenum; B: Robotic dissection of descending and horizontal segments of the duodenum and tumour exposure (arrow); C: Robotic resection of duodenal gastrointestinal stromal tumor (arrow); D: Robotic suture repair of duodenum; E: The resected specimen; F: Specimen interior.

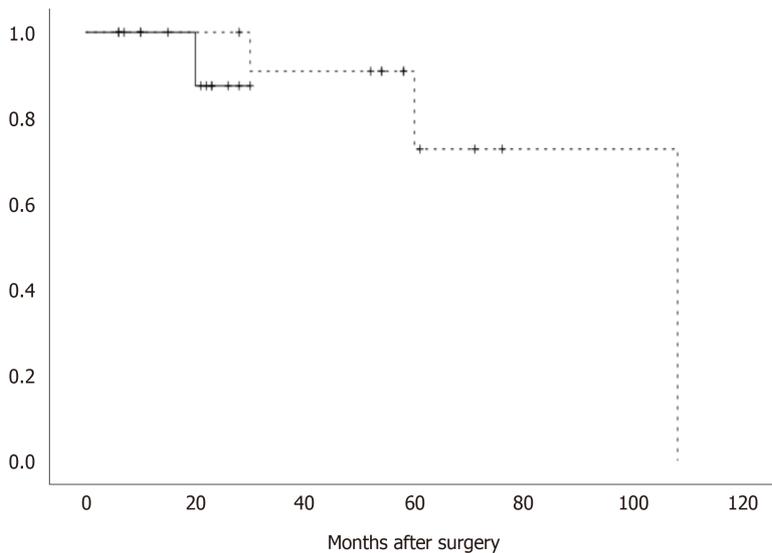
present study, two patients who underwent robotic surgery were converted to open surgery. Avoiding tumour rupture is the most important factor for surgeons making decisions regarding surgical conversion.

Postoperative DGE, abdominal bleeding, POPE and bacteraemia are common complications in both robotic surgery and open surgery for DGISTs. The treatment principle of POPC in the two surgical methods is the same as that of conventional gastrointestinal surgery and PD[6,16,17]. Patients with a 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 surgery. This finding indicates whether the oral targeted drug time should be extended after surgery.

The limitation of this study is that the sample size was too small, and a large amount of case data should be accumulated in future research. 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 suitable medical centres, which can reduce surgical trauma, accelerate postoperative rehabilitation, and provide more options for surgical treatment.

## CONCLUSION

In conclusion, robotic resection is safe and feasible for patients with DGISTs, and its therapeutic effect is equivalent to open surgery.



**Figure 2** Recurrence-free survival in the open surgery group and robotic surgery group. No significant differences in recurrence-free survival were noted between the open surgery group and the robotic surgery group ( $P = 0.358$ ).

## ARTICLE HIGHLIGHTS

### **Research background**

Surgical resection can achieve radical cure of duodenal gastrointestinal stromal tumors (DGISTs); however, there is no consensus on the choice of surgical technique.

### **Research motivation**

The application of robotic surgery in the treatment of DGISTs.

### **Research objectives**

Summarize the experience of a single center treating DGISTs by robotic resection.

### **Research methods**

The perioperative and demographic outcomes of a consecutive series of patients who underwent robotic surgery to treat DGISTs were retrospectively analyzed.

### **Research results**

Of the 28 patients enrolled, 11 patients underwent open surgery, and 17 patients underwent robotic surgery. All the tumours were R0 resected, and there were no significant differences in age, sex, tumour size, operation mode, postoperative hospital stay, tumour mitosis, incidence of postoperative complications, risk classification, postoperative targeted drug therapy or postoperative recurrence between the two groups ( $P > 0.05$ ). Operation time and estimated blood loss in the robotic group were significantly different to those in the open surgery group ( $P < 0.05$ ). No significant difference in recurrence-free survival was noted between the open surgery group and the robotic surgery group ( $P > 0.05$ ).

### **Research conclusions**

Robotic resection is safe and feasible for patients with DGISTs, and its therapeutic effect is equivalent to open surgery.

### **Research perspectives**

Accumulation of experience in the treatment of DGISTs using robotic resection is required.

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