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Robotic Surgery for Benign Duodenal Tumors

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Abstract

Introduction—Benign duodenal and periampullary tumors are uncommon lesions requiring careful attention to their complex anatomic relationships with the major and minor papillae as well

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as the gastric outlet during surgical intervention. While endoscopy is less morbid than open resection, many lesions are not amenable to endoscopic removal. Robotic surgery offers technical advantages above traditional laparoscopy, and we demonstrate the safety and feasibility of this approach for a variety of duodenal lesions.

Methods—We performed a retrospective review of all robotic duodenal resections between April 2010 and December 2013 from two institutions. Demographic, clinicopathologic, and operative details were recorded with special attention to the post-operative course.

Results—Twenty-six patients underwent robotic duodenal resection for a variety of diagnoses. The majority (88 %) were symptomatic at presentation. Nine patients underwent transduodenal ampullectomy, seven patients underwent duodenal resection, six patients underwent transduodenal resection of a mass, and four patients underwent segmental duodenal resection. Median operative time was 4 h with a median estimated blood loss of 50 cm³ and no conversions to an open operation. The rate of major Clavien-Dindo grades 3–4 complications was 15 % at post-operative days 30 and 90 without mortality. Final pathology demonstrated a median tumor size of 2.9 cm with a final histologic diagnoses of adenoma ($n=13$), neuroendocrine tumor ($n=6$), gastrointestinal stromal tumor (GIST) ($n=2$), lipoma ($n=2$), Brunner's gland hamartoma ($n=1$), leiomyoma ($n=1$), and gangliocytic paraganglioma ($n=1$).

Conclusion—Robotic duodenal resection is safe and feasible for benign and premalignant duodenal tumors not amenable to endoscopic resection.

Keywords

Operative surgical procedure; Robotics; Duodenal neoplasm; Ampulla; Hepatopancreatic

Introduction

Benign duodenal and periampullary tumors are rare lesions with potentially complex anatomic relationships to the major and minor papillae as well as the gastric outlet. Current management strategies include endoscopic resection (endoscopic mucosal resection or papillectomy) as well as a variety of open surgical techniques (duodenal sleeve resection, transduodenal ampullary resection including radical pancreaticoduodenectomy) requiring laparotomy with its associated morbidity.¹⁻⁴ The safety and feasibility of endoscopic resection is firmly established and may be the preferred method when the risk of malignancy, anatomic location, and local expertise allow.⁵⁻¹⁰ Larger lesions, and particularly those in the periampullary location, may require multiple endoscopic procedures with a correspondingly higher incidence of bleeding and perforation as well as frequent post-resection endoscopic surveillance.^{5, 8, 11-22}

A safe minimally invasive approach to duodenal resection and reconstruction addresses the shortcomings of both the endoscopic and open surgical techniques without adding significant morbidity or compromising outcome. Despite the widespread introduction of laparoscopic techniques into surgical practice over the last two decades, few series of laparoscopic resection for benign duodenal tumors have been reported.²³⁻³⁰ Delayed adoption may reflect technical shortcomings of laparoscopic surgery for reconstructing the ampulla and closing the duodenum. Robot-assisted surgery, with computer-enhanced

dexterity and three-dimensional visualization,³¹ is a promising technique to bridge the gap between the endoscopic and surgical approaches to duodenal resection. We report a multi-institutional series of 26 robotic resections for benign and low-grade tumors of the duodenum and periampullary region. The series demonstrates the feasibility, safety, and versatility of this platform for minimally invasive duodenal resections. Robot-assisted surgery provides a minimally invasive alternative when an endoscopic approach is believed to be inadequate and open surgery unnecessarily morbid.

Methods

We performed a retrospective review of all robotic duodenal resections between April 2010 and December 2013 at the University of Pittsburgh and Beth Israel Deaconess Medical Center after receipt of Institutional Review Board approval and execution of a data use agreement. Demographic information and preoperative clinical characteristics were analyzed, including symptoms, Charlson Comorbidity Index,³² preoperative imaging, and findings on endoscopic ultrasound. Operative details included the American Society of Anesthesiologists performance score, duration of operation, estimated blood loss, use of pancreatic or biliary stents, and surgical drainage. Operations performed were classified as (1) ampullectomy, (2) transduodenal excision of mass, (3) partial duodenal resection with excision of mass, or (4) segmental duodenal resection (or a sleeve duodenectomy). Postoperative complications were evaluated at 30 and 90 days and scored by the Clavien-Dindo scale.³³

Indications for the robot-assisted approach evolved during this series based on accumulated technical experience, with the surgical alternative being pancreaticoduodenectomy through either a robot-assisted or open approach reflecting standard endosonographic criteria and patient choice.

Operative Technique

Positioning and Trocar Placement—The patient is placed supine on a split-leg operating table with the right arm padded and tucked. Appropriate monitoring devices are placed as well as a nasogastric tube and a Foley catheter. The peritoneal cavity is accessed in the left upper quadrant in the mid-clavicular line using a 5-mm optical separator, and the abdomen is insufflated to 15 mmHg with CO₂. Subsequent trocars are placed in the configuration for pancreaticoduodenectomy, including a 12-mm camera trocar to the right and superior to the umbilicus, two 5-mm trocars in the right upper quadrant, one 5-mm trocar in the right lower quadrant, and a 12-mm trocar in the left lower quadrant (Fig. 1). Using a combination of blunt dissection and electrocautery, a Kocher maneuver is performed to mobilize the duodenum and right colon. Complete mobilization of the duodenum out of the retroperitoneum from the ligament of Treitz to the foramen of Winslow and medial to the root of the SMA from the aorta is crucial to allow for safe and tension-free repair of the duodenum. Following complete Kocher maneuver, the robot is docked over the patient's head with two arms on the right.

Transduodenal Ampullectomy—After the duodenum is mobilized from the ligament of Treitz to the foramen of Winslow, two sponge pads are placed in the retroperitoneum to

elevate the duodenum. A longitudinal duodenotomy is made with electrocautery scissors after the identification of the ampulla by intraoperative ultrasound facilitated either by preoperative stent placement or passage of a 4-French biliary catheter through the cystic duct following cholecystectomy. A transfixing suture is placed through the ampulla and the stent to facilitate exposure of the ampulla through the duodenotomy. Two stay sutures are placed on opposite walls of the duodenum and retracted using the weight of bulldog clamps. Ampullectomy is performed by first incising the mucosa 0.5–1 cm circumferentially around the lesion with the cautery scissors and then dissecting in the submucosal plane until the bile duct is reached (Fig. 2a). Hemostasis is achieved by brief application of cautery to the penetrating submucosal vessels. The bile duct is marked with a 5-0 PDS suture on its superior edge. Continuing the dissection clockwise from the 12 o'clock to 6 o'clock position, the pancreatic duct is identified after incising the bile duct (usually at the 6 o'clock position). A 7-French Hobbs stent is placed in the pancreatic duct for subsequent reconstruction. The dissection is completed in the submucosal plane, and the specimen is retrieved through the left lower quadrant trocar using an Endocatch® bag. We do not routinely perform frozen section analysis for lesions that have been completely grossly excised. Patients are counseled before the procedure of the potential need for pancreaticoduodenectomy in the event that invasive cancer is identified.

The mucosa of the duodenum is re-approximated to the mucosa of the bile duct using 5-0 Vicryl sutures beginning at 12 o'clock and continuing in a clockwise fashion. Several sutures are also placed in the septum between the pancreatic and bile ducts to ensure these ducts remain patent and connected. A 5- or 7-French Hobbs stent can be placed in the bile duct at this time. The duodenum is closed transversely in two layers using 4-0 V-Loc® suture with a Connell stitch followed by seromuscular closure. An omental patch is placed over the closure. We do not routinely place drains in these operations.

Transduodenal Excision of Mass

Following duodenal mobilization, two stay sutures are placed in the superior and inferior ends of the duodenum and a longitudinal (pyloro)duodenotomy is made. Wide local resection of the lesion(s) is performed, and the surgical margins are evaluated by frozen section as indicated. The pyloroduodenotomy is repaired transversely in two layers (Fig. 2b). Esophagogastroduodenoscopy is performed as needed to assess for leak.

Segmental Duodenal Resection (Sleeve Resection)—After duodenal mobilization, the location of the lesion is identified with respect to the ampulla. This can be performed by preoperative endoscopy to place a tattoo or clip, with intraoperative endoscopy or ultrasound as required. The precise location of the ampulla is confirmed by transcystic catheterization of the common bile duct following cholecystectomy (Fig. 2c). After confirming that the ampulla is not involved, the duodenum is divided distal or proximal to the lesion using an EndoGIA stapling device, and LigaSure® is used to divide the duodenal mesentery and small perforating branches from the head of the pancreas. The duodenum is then resected using an EndoGIA stapling device with frozen sections as indicated to confirm complete excision. A side-to-side duodenojejunostomy is performed in two layers (Fig. 2d).

Post-operative Management

We do not routinely place surgical drains. A nasogastric (NG) tube is left in place overnight and then removed. Patients have their diet advanced as tolerated. If they fail to tolerate a diet, then a 24-h trial of NG decompression is initiated to determine whether a high-protein liquid diet or total parenteral nutrition (TPN) will be required while awaiting resolution of edema. In this series, only one patient required TPN (for nutritional supplementation in addition to a regular diet), and one patient required reinsertion of an NG tube.

Results

Indications and Outcomes

Twenty-six patients underwent robotic resection for benign duodenal lesions including suspected adenoma ($n=13$), neuroendocrine tumor ($n=6$), gastrointestinal stromal tumor (GIST) ($n=3$), lipoma ($n=2$), and mass without specific diagnosis ($n=2$). The precise anatomic location of these lesions is shown in Fig. 3. Median age of the cohort was 64.5 years (range 35–81 years), and 50 % of patients were male (13). Ninety-two percent of patients were Caucasian and 8 % were African-American. Median preoperative age-adjusted Charlson Comorbidity Index (CCI) was 3 with median body mass index 29.2 (range 18.1–47.2). Most patients (18, 69 %) had an American Society of Anesthesiologists (ASA) performance status of III or IV (1, 3.8 %), while seven patients (27 %) were classified ASA I.

The majority (23, 88 %) of patients were symptomatic and/or being followed for known Barrett's esophagus or duodenal lesions at the time of presentation. Patients with symptoms presented with one or more of the following: abdominal pain or worsening gastrointestinal reflux (8, 30.7 %), gastric outlet obstruction (4, 11.5 %), upper gastrointestinal bleeding or anemia (10, 38.5 %), unintentional weight loss (3, 11.5 %), liver function abnormalities/jaundice (2, 7.6 %), pancreatitis (2, 7.6 %), and dysphagia (1, 3.8 %). Median preoperative albumin was 3.9 g/dL and hemoglobin was 14 g/dL. Nearly all patients had a preoperative CT scan (88 %), half of which demonstrated a measurable lesion with a median diameter of 2.1 cm (0.3–5.1 cm). Eighteen patients (69 %) underwent EUS with a median lesion size of 2.5 cm (0.3–4 cm) (Table 1). Preoperative imaging showed dilated common bile ducts in two patients and dilated pancreatic ducts in two patients.

Nine patients (35 %) underwent transduodenal ampullectomy, during which temporary pancreatic duct stents were placed in eight (89 %) patients with common bile duct stents in six (67 %). Six patients underwent transduodenal excision of a mass, seven underwent partial duodenal resection, and four required segmental duodenectomy with one concurrent distal gastrectomy. Median operative time was 240 min (range 99–437 min). There were no conversions to an open operation. Median estimated blood loss was 50 cm³, and no patients required intraoperative transfusion.

Final pathology demonstrated a median tumor size of 2.9 cm (0.7–6.5 cm) with histologic diagnoses of adenoma ($n=13$, one with focal high-grade dysplasia), neuroendocrine tumor ($n=6$), GIST ($n=2$), lipoma ($n=2$), Brunner's gland hamartoma ($n=1$), leiomyoma ($n=1$), and gangliocytic paraganglioma ($n=1$). The margin status of each histologic subtype is shown in

Table 3. Three patients (25 %) with adenoma had positive margins. None of these occurred at the bile duct margin, and none were grossly evident at the time of surgery despite magnified vision. There was a single patient with adenoma and high-grade dysplasia and negative margins. One patient with a Brunner's gland hamartoma had a positive margin, a benign entity of no clinical significance. No patients with neuroendocrine tumor or GIST had positive margins.

Post-operative Course

Median hospital length of stay was 6 days (3–43 days). All patients were discharged on a regular diet except one, who required caloric support with total parenteral nutrition due to delayed gastric emptying. There were three 30-day (11.5 %) and two 90-day (7.7 %) readmissions.

Complications were scored according to the Clavien-Dindo classification (Table 2).³³ Fifty percent of patients experienced no complications, whereas 35 % had minor grade I/II events. Fifteen percent of patients experienced major complications (Clavien-Dindo grades 3–4) at the 30- and 90-day post-operative time points (Table 3). The grade IIIA complications were intra-abdominal abscesses requiring image-guided drainage. The grade IIIB complication occurred in a patient who underwent concomitant distal gastrectomy and developed a clinically evident leak with sepsis requiring both interventional radiologic guided drainage and reoperation. The grade IVA complication was intra-abdominal hemorrhage on postoperative day 1, requiring reoperation and oversewing of small perforating vessels from the pancreas followed by respiratory failure requiring intensive care unit management. Other complications of grade II or less included wound infection ($n=3$), atrial fibrillation ($n=2$), urinary tract infection ($n=1$), delayed gastric emptying ($n=1$), and pneumonia ($n=1$). There were no pancreatic fistulas.

Discussion

This multicenter cohort study of robot-assisted duodenal resection demonstrates the feasibility and safety of the described surgical technique for a variety of symptomatic benign and premalignant pathologies with a median size of nearly 3 cm. Median blood loss was minimal with median operative time of 4 h and no conversions to an open operation. Despite the complexity of the associated reconstructions, morbidity greater than or equal to Clavien-Dindo grade III was acceptable (15 %) with a single clinically evident duodenal leak requiring reoperation. Median hospital stay was less than 1 week, and all patients tolerated a regular diet upon discharge.

Although open surgical resection is the classic treatment for benign ampullary and nonampullary neoplasms, the morbidity of this approach remains significant. Local resection for ampullary neoplasms has less morbidity than pancreaticoduodenectomy in exchange for higher rates of recurrence and the need for ongoing endoscopic surveillance.^{34–38} The largest series comparing pancreaticoduodenectomy to ampullectomy demonstrated complication rates of 52.2 versus 33.3 %.³ Despite causing less severe morbidity than pancreaticoduodenectomy, complications following open transduodenal ampullectomy are still significant, with complications including delayed gastric emptying, wound infection,

and pancreatitis occurring in 48 % of 28 patients of one series.³⁷ In multiple small series, complications following local ampullary resection range from 10 to 29 %.^{36, 38, 39} The morbidity of open resection for nonampullary neoplasms is less significant than that of ampullectomy, but rates are still as high as 50 %.³⁹ In this report, only 15 % of the patients experienced serious side effects as measured by Clavien-Dindo classification. However, it should be noted that the Clavien-Dindo classification system has been reported to underestimate the true value of minimally invasive surgical procedures.⁴⁰ Recently, Clavien has revised his scoring system to allow a more granular view of complications.⁴¹

The morbidity of open treatment for duodenal lesions has stimulated endoscopic alternatives for ampullary and nonampullary duodenal lesions. Two main techniques have been described: endoscopic submucosal dissection (ESD) and endoscopic mucosal resection (EMR). Both techniques can cause major complications including perforation and bleeding. Despite enhanced rates of en bloc resection, the risk of perforation during ESD for nonampullary adenomas is reported to be as high as 35.7 %.⁷ The significance of post-ESD perforation is magnified further by the difficulty of recognizing iatrogenic perforation in the duodenum compared to other hollow viscus.^{7, 42} The EMR technique is used more widely due to its reduced perforation rate but still carries its own complications. Several small case series of EMR for nonampullary lesions describe perforation rates from 0 to 4.3 % including one fatal event.^{5, 12, 14, 43} Bleeding rates following endoscopic excision range from 5 to 8.8 %, ^{5, 13, 15} with rates of intra-procedural bleeding as high as 14–29 %.^{12, 14} Hemicircumferential lesions may exhibit intra-procedural bleeding in as many as 60 % of cases.¹⁶ For ampullary lesions, perforation (though rare) and bleeding are reported complications in addition to post-procedure pancreatitis in 4.9–19 % of patients,^{8, 17–21} causing subsequent papillary stenosis and cholangitis.⁶

Major limitations of the endoscopic approach include the inability to completely excise lesions involving more than one third of the duodenal circumference. Guidelines from the American Society for Gastrointestinal Endoscopy suggest that lesions affecting more than 33 % of the circumference of the duodenum should be referred for surgical evaluation.⁴⁴ While it is technically feasible to resect lesions occupying a large portion of the duodenal circumference, lesion size is the only risk factor not only associated with uncontrolled bleeding^{13, 16} but also increases the rate of incomplete resection and recurrence. In one study, complete resection rate was achieved in only 45.5 % of lesions occupying between one quarter and one half of the duodenal circumference compared to 94.7 % for tumors occupying less than one-third the diameter of the duodenum.⁴⁵ In a separate series, remnant tissue was discovered in 23.8 % of cases (all of which were excised piecemeal).⁴³ Recurrence rates in the literature range from 0 % over an 11-month median follow-up⁵ to rates as high as 20 to 37.5 % for nonampullary lesions^{13, 15, 22} and from 2 to 33 % in ampullary lesions.^{17–21} The final limitation of the endoscopic technique is the inability to excise lesions invading beyond the muscularis propria due to the risk of perforation.⁹

The limitations of endoscopic therapy, combined with the morbidity of open surgical management, make minimally invasive resection of duodenal lesions that do not require pancreaticoduodenectomy ideal. To date, experience with minimally invasive duodenal surgery is limited to single case reports and small series,^{23, 25, 26, 28, 30, 46} in addition to a

series of ten duodenal sleeve resections for a variety of benign and malignant diagnoses demonstrating a complication rate of 10 %.²⁷ The robotic platform offers several potential advantages specific to duodenal and ampullary lesions. Operations in this anatomic location often require extremes of instrument articulation as well as precision during reconstruction of the biliary and pancreatic orifices as well as duodenal anastomoses. The robotic platform offers greatly increased degrees of freedom in wrist articulation compared to laparoscopy, three-dimensional and magnification views unmatched by the laparoscopic view, and stabilization via computer-aided reduction in operator tremor. These advantages are particularly beneficial in duodenal resection where laparoscopy lacks precision and flexibility.

This study has several limitations despite its multicenter construct. The cohort is small and highly selected due to the relative infancy of this procedure and rarity of the diagnosis. There are few case series in the literature to serve as historical controls, whether open or laparoscopic. The applicability of robotic resection is effectively limited to centers with a high volume of duodenal resections as robotic surgery has both a steep learning curve and high cost of implementation relative to the low frequency with which these lesions are encountered.³

Conclusion

We conclude that robotic ampullectomy, local excision, and sleeve resection are feasible and safe for duodenal lesions not amenable to endoscopic resection. Robotic technology confers several technical advantages that facilitate complex resection and reconstruction during periampullary procedures.

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References

1. Neoptolemos JP, Russell RC, Bramhall S, Theis B. Low mortality following resection for pancreatic and periampullary tumours in 1026 patients: UK survey of specialist pancreatic units. UK Pancreatic Cancer Group. *Br J Surg.* 1997; 84:1370–1376. [PubMed: 9361591]
2. Nordlinger B, Jeppsson B, el-Khoury W, et al. Tumours of Oddi: diagnosis and surgical treatment. *HPB Surg.* 1992; 5:123–131. discussion 131–123. [PubMed: 1351739]
3. Winter JM, Cameron JL, Olin K, et al. Clinicopathologic analysis of ampullary neoplasms in 450 patients: implications for surgical strategy and long-term prognosis. *J Gastrointest Surg.* 2010; 14:379–387. [PubMed: 19911239]
4. Yan JQ, Peng CH, Yang WP, et al. Surgical management of benign duodenal tumours. *ANZ J Surg.* 2010; 80:526–530. [PubMed: 20795967]

5. Min YW, Min BH, Kim ER, et al. Efficacy and safety of endoscopic treatment for nonampullary sporadic duodenal adenomas. *Dig Dis Sci*. 2013; 58:2926–2932. [PubMed: 23695872]
6. Patel R, Varadarajulu S, Wilcox CM. Endoscopic ampullectomy: techniques and outcomes. *J Clin Gastroenterol*. 2012; 46:8–15. [PubMed: 22064552]
7. Jung JH, Choi KD, Ahn JY, et al. Endoscopic submucosal dissection for sessile, nonampullary duodenal adenomas. *Endoscopy*. 2013; 45:133–135. [PubMed: 23364841]
8. Jung MK, Cho CM, Park SY, et al. Endoscopic resection of ampullary neoplasms: a single-center experience. *Surg Endosc*. 2009; 23:2568–2574. [PubMed: 19360365]
9. Azih LC, Broussard BL, Phadnis MA, et al. Endoscopic ultrasound evaluation in the surgical treatment of duodenal and peri-ampullary adenomas. *World J Gastroenterol*. 2013; 19:511–515. [PubMed: 23382629]
10. van Heumen BW, Roelofs HM, Te Morsche RH, et al. Celecoxib and tauro-ursodeoxycholic acid co-treatment inhibits cell growth in familial adenomatous polyposis derived LT97 colon adenoma cells. *Exp Cell Res*. 2012; 318:819–827. [PubMed: 22366264]
11. Bourke MJ. Endoscopic resection in the duodenum: current limitations and future directions. *Endoscopy*. 2013; 45:127–132. [PubMed: 23364840]
12. Sohn JW, Jeon SW, Cho CM, et al. Endoscopic resection of duodenal neoplasms: a single-center study. *Surg Endosc*. 2010; 24:3195–3200. [PubMed: 20490557]
13. Basford PJ, George R, Nixon E, et al. Endoscopic resection of sporadic duodenal adenomas: comparison of endoscopic mucosal resection (EMR) with hybrid endoscopic submucosal dissection (ESD) techniques and the risks of late delayed bleeding. *Surg Endosc*. 2014
14. Lepilliez V, Chemaly M, Ponchon T, et al. Endoscopic resection of sporadic duodenal adenomas: an efficient technique with a substantial risk of delayed bleeding. *Endoscopy*. 2008; 40:806–810. [PubMed: 18828076]
15. Abbass R, Rigaux J, Al-Kawas FH. Nonampullary duodenal polyps: characteristics and endoscopic management. *Gastrointest Endosc*. 2010; 71:754–759. [PubMed: 20363416]
16. Fanning SB, Bourke MJ, Williams SJ, et al. Giant laterally spreading tumors of the duodenum: endoscopic resection outcomes, limitations, and caveats. *Gastrointest Endosc*. 2012; 75:805–812. [PubMed: 22305507]
17. Catalano MF, Linder JD, Chak A, et al. Endoscopic management of adenoma of the major duodenal papilla. *Gastrointest Endosc*. 2004; 59:225–232. [PubMed: 14745396]
18. Cheng CL, Sherman S, Fogel EL, et al. Endoscopic snare papillectomy for tumors of the duodenal papillae. *Gastrointest Endosc*. 2004; 60:757–764. [PubMed: 15557951]
19. Bohnacker S, Seitz U, Nguyen D, et al. Endoscopic resection of benign tumors of the duodenal papilla without and with intraductal growth. *Gastrointest Endosc*. 2005; 62:551–560. [PubMed: 16185970]
20. Irani S, Arai A, Ayub K, et al. Papillectomy for ampullary neoplasm: results of a single referral center over a 10-year period. *Gastrointest Endosc*. 2009; 70:923–932. [PubMed: 19608181]
21. Yamao T, Isomoto H, Kohno S, et al. Endoscopic snare papillectomy with biliary and pancreatic stent placement for tumors of the major duodenal papilla. *Surg Endosc*. 2010; 24:119–124. [PubMed: 19517183]
22. van Heumen BW, Mul K, Nagtegaal ID, et al. Management of sporadic duodenal adenomas and the association with colorectal neoplasms: a retrospective cohort study. *J Clin Gastroenterol*. 2012; 46:390–396. [PubMed: 22178960]
23. Honda G, Kurata M, Matsumura H, et al. Laparoscopy-assisted transduodenal papillectomy. *Dig Surg*. 2010; 27:123–126. [PubMed: 20551656]
24. Hadjittofi C, Parisinos CA, Somri M, Matter I. Totally laparoscopic resection of a rare duodenal tumour. *BMJ Case Rep* 2012. 2012
25. Orsenigo E, Di Palo S, Vignali A, Staudacher C. Laparoscopic excision of duodenal schwannoma. *Surg Endosc*. 2007; 21:1454–1456. [PubMed: 17177083]
26. Poves I, Burdio F, Alonso S, et al. Laparoscopic pancreas-sparing subtotal duodenectomy. *JOP*. 2011; 12:62–65. [PubMed: 21206106]

27. Stauffer JA, Raimondo M, Woodward TA, et al. Laparoscopic partial sleeve duodenectomy (PSD) for nonampullary duodenal neoplasms: avoiding a whipple by separating the duodenum from the pancreatic head. *Pancreas*. 2013; 42:461–466. [PubMed: 23462322]
28. Ahn KS, Han HS, Yoon YS, et al. Laparoscopic transduodenal ampullectomy for benign ampullary tumors. *J Laparoendosc Adv Surg Tech A*. 2010; 20:59–63. [PubMed: 19792863]
29. Rosen M, Zuccaro G, Brody F. Laparoscopic resection of a periampullary villous adenoma. *Surg Endosc*. 2003; 17:1322–1323. [PubMed: 12799897]
30. Bowers SP, Smith CD. Laparoscopic resection of posterior duodenal bulb carcinoid tumor. *Am Surg*. 2003; 69:792–795. [PubMed: 14509329]
31. Zeh HJ 3rd, Bartlett DL, Moser AJ. Robotic-assisted major pancreatic resection. *Adv Surg*. 2011; 45:323–340. [PubMed: 21954697]
32. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987; 40:373–383. [PubMed: 3558716]
33. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004; 240:205–213. [PubMed: 15273542]
34. Meneghetti AT, Safadi B, Stewart L, Way LW. Local resection of ampullary tumors. *J Gastrointest Surg*. 2005; 9:1300–1306. [PubMed: 16332486]
35. Farnell MB, Sakorafas GH, Sarr MG, et al. Villous tumors of the duodenum: reappraisal of local vs. extended resection. *J Gastrointest Surg*. 2000; 4:13–21. discussion 22–13. [PubMed: 10631358]
36. Clary BM, Tyler DS, Dematos P, et al. Local ampullary resection with careful intraoperative frozen section evaluation for presumed benign ampullary neoplasms. *Surgery*. 2000; 127:628–633. [PubMed: 10840357]
37. Posner S, Colletti L, Knol J, et al. Safety and long-term efficacy of transduodenal excision for tumors of the ampulla of Vater. *Surgery*. 2000; 128:694–701. [PubMed: 11015104]
38. de Castro SM, van Heek NT, Kuhlmann KF, et al. Surgical management of neoplasms of the ampulla of Vater: local resection or pancreatoduodenectomy and prognostic factors for survival. *Surgery*. 2004; 136:994–1002. [PubMed: 15523392]
39. Kemp CD, Russell RT, Sharp KW. Resection of benign duodenal neoplasms. *Am Surg*. 2007; 73:1086–1091. [PubMed: 18092639]
40. Baker MS, Sherman KL, Stocker S, et al. Defining quality for distal pancreatectomy: does the laparoscopic approach protect patients from poor quality outcomes? *J Gastrointest Surg*. 2013; 17:273–280. [PubMed: 23225109]
41. Slankamenac K, Graf R, Barkun J, et al. The comprehensive complication index: a novel continuous scale to measure surgical morbidity. *Ann Surg*. 2013; 258:1–7. [PubMed: 23728278]
42. Honda T, Yamamoto H, Osawa H, et al. Endoscopic submucosal dissection for superficial duodenal neoplasms. *Dig Endosc*. 2009; 21:270–274. [PubMed: 19961529]
43. Alexander S, Bourke MJ, Williams SJ, et al. EMR of large, sessile, sporadic nonampullary duodenal adenomas: technical aspects and long-term outcome (with videos). *Gastrointest Endosc*. 2009; 69:66–73. [PubMed: 18725157]
44. Adler DG, Qureshi W, et al. Standards of Practice C. The role of endoscopy in ampullary and duodenal adenomas. *Gastrointest Endosc*. 2006; 64:849–854. [PubMed: 17140885]
45. Kedia P, Brensinger C, Ginsberg G. Endoscopic predictors of successful endoluminal eradication in sporadic duodenal adenomas and its acute complications. *Gastrointest Endosc*. 2010; 72:1297–1301. [PubMed: 20970793]
46. Marzano E, Ntourakis D, Addeo P, et al. Robotic resection of duodenal adenoma. *Int J Med Robot*. 2011; 7:66–70. [PubMed: 21341365]

Fig. 1.

Port placement. Example of typical port placement for robotic duodenal resection. *A* assistant port, *C* camera port, *R* robotic port, *L* liver retractor

Fig. 2.

Robotic duodenal resections. **a** Ampullary reconstruction is seen with catheters in both the common bile duct and pancreatic duct. **b** After either transduodenal resection or ampullectomy, the pyloroduodenotomy or duodenotomy is repaired transversely, in two layers. The first layer utilizes a 4-0 V-Loc Connell stitch (depicted above) followed by a 2-0 silk Lembert layer of sutures. **c** A Fogarty catheter can be used to define the precise location of the ampulla. The image above depicts the catheter balloon as it exits the ampulla in the lumen of the duodenum. **d** Following duodenal sleeve resection, a duodenoduodenostomy (depicted above) or a duodenojejunostomy is performed depending on the location of the resected lesion

Fig. 3.
Anatomic location of lesions. **a** Three patients had lesions in the duodenal bulb, **b** four patients had lesions in D1, **c** seven patients had lesions in the nonampullary region of D2 (either proximal, distal, or on the opposite wall), **d** nine patients had ampullary lesions, and **e** three patients had lesions in D3

Table 1

Preoperative characteristics

Parameter	Value (median)
Age (range)	64.5 (35–81)
BMI (range)	29.2 (18.1–47.2)
Age-adjusted CCI	3 (0–7)
Symptomatic	23 (88 %)
Lesion size: CT scan (range)	2.1 cm (0.3–5.1 cm)
Lesion size: EUS (range)	2.5 cm (0.3–4 cm)

Table 2

Post-operative complications at 90 days graded by Clavien-Dindo scale

Clavien-Dindo complication grade	Value, <i>n</i> (% of all patients)
I	3 (11.5 %)
II	6 (23 %)
IIIa	2 (7.7 %)
IIIb	1 (3.8 %)
IVa	1 (3.8 %)
Complication	Value, <i>n</i> (% of all patients)
Intra-abdominal abscess	3 (11.5 %)
Wound infection	3 (11.5 %)
Atrial fibrillation	2 (7.7 %)
Delayed gastric emptying	1 (3.8 %)
Intra-abdominal hemorrhage	1 (3.8 %)
Pneumonia	1 (3.8 %)
Sepsis	1 (3.8 %)
Urinary tract infection	1 (3.8 %)
Readmission	Value, <i>n</i> (% of all patients)
30-day readmission	3 (11.5 %)
90-day readmission	2 (7.7 %)

Table 3

Margin status by histologic diagnosis

Histologic diagnosis	Positive margins, <i>n</i> (%)
Adenoma	3 (25 %)
Adenoma with high-grade dysplasia	0 (0 %)
Neuroendocrine tumor	0 (0 %)
Gastrointestinal stromal tumor	0 (0 %)
Brunner's gland hamartoma	1 (100 %)
Gangliocytic paraganglioma	0 (0 %)
Leiomyoma, lipoma	Margins not assessed