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ORIGINAL ARTICLE

Treatment of intraductal papillary mucinous neoplasms, neuroendocrine and periampullary pancreatic tumors using robotic surgery: a safe and feasible technique

Antonio Luiz de Vasconcellos Macedo · Vladimir Schraibman · Samuel Okazaki · Fernando Concilio Mauro · Marina Gabrielle Epstein · Suzan Menasce Goldman · Suzana A. S. Lustosa · Delcio Matos

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Abstract In the last few years, robotic surgery has started to take its place in pancreatic surgery. Robotic surgery provides advantages such as enhanced visualisation and freedom of dissection within a confined space and also allows economical surgery. The aim of this study was to evaluate the feasibility, safety and short-term outcome of the robotic approach using the da Vinci robotic system in pancreatic/peripancreatic tumors other than pancreatic carcinomas. Fifteen patients with eight intraductal papillary mucinous neoplasms, four pancreatic neuroendocrine and three periampulary tumors were included in this initial series. Seven left pancreatectomies, five pancreatoduodenectomies and two total pancreatectomies were performed at Albert Einstein Hospital, São Paulo, Brazil. The mean operating room time for all the procedures was 503 min (315–775 min). Blood transfusion was necessary in one patient (3 units). The mean length of stay for all patients was 16 days (5–52 days). Large series of robotic pancreatic surgery should be described and the decision as to its routine use will come from cumulative experience. This surgical system allows difficult procedures to be performed more easily, effectively and precisely.

Keywords Pancreatic tumor · Robotic surgery · Duodenopancreatectomy

A. L. de Vasconcellos Macedo · V. Schraibman (✉) · S. Okazaki · F. C. Mauro · M. G. Epstein
Department of General, Gastric and Minimally Invasive Surgery, Albert Einstein Hospital, Rua Monte Aprazível, 149/61A, São Paulo, SP 04513-030, Brazil
e-mail: vschraibman@hotmail.com

V. Schraibman · S. Okazaki · F. C. Mauro · S. A. S. Lustosa · D. Matos
Department of GI Surgery, Federal University of Sao Paulo (UNIFESP_EPM), São Paulo, SP, Brazil

S. M. Goldman
Department of Diagnostic Imaging, Federal University of Sao Paulo (UNIFESP_EPM), São Paulo, SP, Brazil

Introduction

The incidence of pancreatic cysts has been reported to be increasing rapidly, because of either an increasing incidence of cystic neoplasms or improved detection and recognition of these lesions. The most significant recent change in the diagnosis and treatment of pancreatic cystic neoplasms is the recognition of intraductal papillary mucinous neoplasm (IPMN) as a distinct pathologic entity; IPMNs have become the second most common cause of pancreatic resections in many large centers [1]. Many authors advocate surgical resection for all the symptomatic cysts, not only for the relief of symptoms but also because of the higher potential for malignancy in this subset of patients [1]. In contrast, incidental pancreatic cysts, despite their lower risk of malignancy, cannot be ignored because many investigators have demonstrated that a significant proportion of these could be either malignant or premalignant [1–3].

Neuroendocrine pancreatic tumors (PNT) are the most prevalent abdominal endocrine neoplasms. PNTs comprise a rare group of neoplasms with complex patterns of behavior requiring detailed specialist management (e.g., insulin, gastrin, glucagon, vasoactive intestinal peptide, corticotropin) that can cause distinct clinical syndromes [1–3], and surgery remains the only curative modality currently available for resectable PNTs [2]. However, most pancreatic neuroendocrine tumors are nonfunctional, and they are generally hard to diagnose until symptoms develop from a mass effect or from metastatic disease. In most cases the patient is asymptomatic and the tumor is noted incidentally on routine abdominal imaging.

Periampulary tumors, other than pancreatic adenocarcinomas, may be treated less aggressively and comprise lesions from different etiologies. They should be treated according to their histologic presentation, varying from local resection to a major duodenopancreatectomy.

Neuroendocrine pancreatic tumors, periampulary tumors and IPMNs have a significantly better prognosis than the typical ductal pancreatic adenocarcinoma [1]. Surgical management varies with tumor type, location, and size. Benign PNTs may be treated with enucleation. However, malignant PNTs and premalignant cysts should be managed with either a Whipple resection or distal pancreatectomy, depending on the location of the tumor, with local lymph node resection [3] whenever indicated.

Laparoscopic pancreatic surgery was first reported in 1994 by Gagner and Pomp [4] and Cushieri [5] for patients with chronic pancreatitis; since then many have reported their experience, and we notice a progressively increasing number of laparoscopic pancreatic surgeries being performed and taking the place of classical laparotomy. In the last few years, robotic surgery has started to take its place in pancreatic surgery' Giulianotti et al. [6] reported 134 patients who underwent robotic-assisted surgery for different pancreatic pathologies. All procedures were performed using the da Vinci robotic system, with remarkable results.

The available evidence shows that robotic surgery still offers only limited advantages with respect to short-term outcomes. However, the clinical outcomes should be interpreted with caution. The robotic technique benefits over traditional laparoscopy because the system allows surgeons to perform complex and difficult procedures more easily, effectively and precisely.

Objective

The aim of this study was to evaluate the feasibility, safety and short-term outcome of the robotic approach using the da Vinci robotic system in a series of pancreatic/peripancreatic tumors (neurendocrine, IPMNs and periampulary) other than pancreatic carcinomas.

Materials and methods

From March 2009 to July 2010, a total of 15 patients were operated on using the robotic technique at Albert Einstein Hospital due to the presence of pancreatic lesions (Table 1).

Surgical technique

Either a left pancreatectomy with or without spleen preservation or a pancreaticoduodenectomy is performed

Table 1 Patient age, gender, pre-operative diagnosis and proposed procedure

Patient	Gender	Age	Pre-operative diagnosis	Proposed procedure
P.G.	Female	63	Pancreatic/duodenal GIST	Pancreatoduodenectomy
E.S.B.	Female	56	IPMN in head of pancreas	Pancreatoduodenectomy
R.N.A.	Male	64	Glucagonoma	Pancreatoduodenectomy
P.T.A.	Male	55	Glucoganoma	Distal pancreatectomy
L.V.M.	Female	43	IPMN in the body of pancreas	Distal pancreatectomy
L.H.M.K.	Female	56	Ampullary adenocarcinoma	Pancreatoduodenectomy
R.P.Z.	Female	47	IPMN in the body of pancreas	Distal pancreatectomy
N.M.P.M.L.	Female	62	Insulinoma in the body of the pancreas (previous failed laparoscopic approach)	Distal pancreatectomy
S.M.M.	Female	62	IPMN in the head of pancreas	Pancreatoduodenectomy
P.R.B.	Male	59	IPMN in the body of pancreas	Distal pancreatectomy
A.A.R.	Male	86	Duodenal adenocarcinoma	Pancreatoduodenectomy
O.D.C.B.I	Female	46	IPMN in the body of pancreas	Distal pancreatectomy
U.A.	Male	73	IPMN involving all pancreas	Total pancreatectomy
J.M.S.	Male	51	Carcinoid tumor	Total pancreatectomy
M.P.M.	Male	52	IPMN in the body of pancreas	Distal pancreatectomy with splenectomy

Intraoperative ultrasound was performed in all patients when left pancreatectomy was indicated. *GIST* gastrointestinal stromal tumor, *IPMN* intraductal papillary mucinous neoplasm according to the location and size of the lesion. The procedure always begins with an exploratory laparoscopy.

The pancreaticoduodenectomy (PD) technique

The patient is placed in the classic French position with a light reverse Trendelenburg tilted to the left side. The robotic system is positioned at the head of the patient, coming slightly from the right shoulder. The assistant surgeon is positioned between the legs of the patient or at the left side (depending on belly size). The operation begins with a diagnostic laparoscopy using a 12-mm bladeless trocar placed in the umbilical scar. The trocars are then set up in an curve with the concavity towards the head (Fig. 1).

This setup is very important in order to avoid collisions, ease the exposure, and ensure security in case of bleeding. Three or four arms can be used according to the surgeon's demand. Liver exposure comes from the right 5-mm trocar. The assistant can use either the lower 12-mm trocar or the left flank 5-mm trocar. The right pararectal trocar can be used for the optics, alternating with the umbilical trocar according to need.

After exposure of the pancreatic head, a laparoscopic ultrasonography is performed by the assistant in order to confirm the lesion and its local relationships. Vascular and irreversible steps of the surgery are initiated immediately afterwards.

As in laparoscopic surgery, the following steps are performed:

- Kocher maneuver
- Duodenum exposure and superior mesenteric vein (SMV) identification at the root of the mesenterium with its dissection under the pancreatic trajectory
- Hepatic hilum dissection with identification of the hepatic artery, common bile duct transection and gastroduodenal artery ligation after temporal clamping to confirm liver blood flow

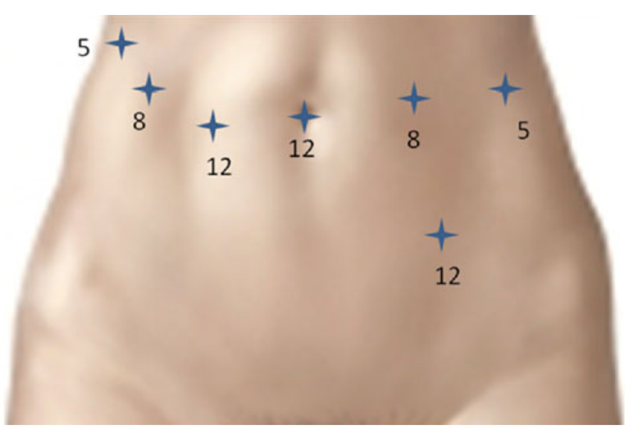

Fig. 1 Size (mm) and position of the trocars

- Transection of the duodenum or stomach depending on the tumor location using an Echelon stapler (Ethicon Endo-Surgery, Cincinnati, OH, USA), blue or green load
- Lymphadenectomy of the celiac trunk is performed whenever needed
- Jejunum division distal to the ligament of Treitz with a 45-mm Echelon blue load with seamguard
- Pancreas division using Echelon, blue or green load
- Dissection of the uncinate process
- Reconstruction: biliary reconstruction is made with continous PDS 4 or 5.0 sutures in the posterior layer and simple sutures in the anterior layer; pancreatic reconstruction is made with the posterior wall of the stomach with 4 or 5.0 prolene or the jejunal limb with 4 or 5.0 PDS according to local anatomy and pancreatic tissue; gastrojejunal reconstruction is made with 2.0 prolene in the same jejunal loop
- The specimen is extracted through a 15 mm endobag through a small Pfannenstiel incision. One or two drains are systematically placed at the end of the procedure.

The distal pancreatectomy technique

Trocars are placed as in Fig. 1. After the exploratory laparoscopy, a laparoscopic ultasonography is performed in order to define the exact tumor position. Dissection begins in the inferior border of the pancreas, detaching it from the mesocolon. After tumor location, the pancreas is transected with at least 3 cm margin. When needed, the SMV is identified and a Penrose drain passed; the pancreas is transected with an Echelon green load. The splenic artery and vein are ligated in this order (spleen resection cases). In cases with spleen preservation, the small branches to the pancreas are carefully dissected and ligated until the last attachments to the spleen. A 15-mm endobag is placed through a small Pfannenstiel incision and the piece is retrieved. One drain is placed near the pancreatic stump.

Results

The mean operating room time for all the procedures was 503 min (315–775 min). Blood transfusion was necessary in only one patient (3 units). The mean length of stay was 16 days (5–52 days) for all patients (Table 2).

Total conversion rate was 6.7%, in one case due to difficulty in exposing the biliodigestive anastomosis.

Postoperative complications were: two pancreatic fistulas (percutaneous drainage of fluid collection in one case, late laparoscopic drainage in the other); two

Table 2 Results in terms of age, type of surgery, operating time, final diagnosis, length of stay, surgery duration, immediate complications or need for blood transfusion, late complications and need for conversion

No.	Age	Type of surgery	Operating time + intraoperative ultrasound (min)	Final diagnosis	Length of stay (days)	Immediate complications or blood transfusion (BT)	Late complications	Need for conversion
1	63	Duodenectomy	360	Duodenal GIST	6	No	–	No
2	56	Pancreatoduodenectomy	790	IPMN	23	No	Percutaneous drainage of fluid collection	No
3	64	Pancreatoduodenectomy	435	Glucagonoma	17	No	–	No
4	55	Distal pancreatectomy w/o splenectomy	480	Glucagonoma	7	No	Abdominal hemorrhage (splenic artery stenting) Pancreatic fistula (late laparoscopic drainage)	No
5	43	Distal pancreatectomy with splenectomy	345	IPMN	7	No	–	No
6	56	Pancreatoduodenectomy	630	Ampullary adenocarcinoma	52	BT (3 units)	Abdominal hemorrhage (laparotomy) first PO day	No
7	47	Distal pancreatectomy with splenectomy	315	IPMN	5	No	–	No
8	62	Distal pancreatectomy w/o splenectomy	530	Insulinoma	5	No	–	No
9	62	Pancreatoduodenectomy	775	IPMN	12	No		Conversion: difficulties in exposing biliodigestive anastomosis
10	59	Distal pancreatectomy with splenectomy	555	IPMN	16	No	–	No
11	86	Pancreatoduodenectomy	570	Duodenal adenocarcinoma	25	No	Billiary fistula after abdominal drain removal eighth PO day	No
12	46	Distal pancreatectomy with splenectomy	385	IPMN	5	No	–	No
13	73	Total pancreatectomy with splenectomy	775	IPMN	32	No	–	No
14	51	Total pancreatectomy with splenectomy	755	Carcinoid tumor	7	No	–	No
15	52	Distal pancreatectomy with splenectomy	255	IPMN	7	No	–	No

GIST gastrointestinal stromal tumor, *IPMN* intraductal papillary mucinous neoplasm, *PO* postoperative

abdominal hemorrhages (the respective proceedings were re-laparotomy on the first postoperative day in one case and placement of a splenic artery stent in the other); and one biliary fistula after abdominal drain removal on the eighth postoperative day, clinically treated (Tables 3 and 4).

Discussion

Pancreatic surgery, since its inception, has been one of the most complex and demanding surgeries among the abdominal procedures. Since the introduction of laparoscopic surgery in the late 1980s, Gagner and Pomp [4] and

Table 3 Type of surgery performed, surgery duration, mean length of stay and number of patients

Operation	Surgery duration (min)	Mean length of stay (days)	No. of patients	%
Pancreatoduodenectomy	640 (435–790)	25.8 (12–52)	5	33.5
Distal pancreatectomy w/o Splenectomy	505 (480–530)	6 (5–7)	2	13.1
Distal pancreatectomy with splenectomy	371 (255–555)	8 (5–16)	5	33.5
Total pancreatectomy with Splenectomy	765 (755–775)	19.5 (7–32)	2	13.1
Duodenectomy	240	3	1	6.7
Total			15	100

Table 4 Results according to histopathology

Histopathology	No. of patients	%
IPMN	8	53.4
Glucoganoma	2	13.1
Insulinoma	1	6.7
Carcinoid tumor	1	6.7
Duodenal GIST (duodenectomy)	1	6.7
Duonenal adenocarcinoma	1	6.7
Ampullary adenocarcinoma	1	6.7
Total	15	100

GIST gastrointestinal stromal tumor, *IPMN* intraductal papillary mucinous neoplasm

Cushieri [5] described the first laparoscopic pylorus-preserving pancreatoduodenectomy in 1994.

In 1996, Gagner et al. [7] reported his experience with laparoscopic resection of islet cell tumors, although the experience worldwide is still modest and most reports are based in personal case series with short-term outcomes.

Assalia and Gagner [8] reviewed laparoscopy of PNTs covering the period January 1966 to October 2003, and found a total of 93 reported cases. The largest surgeon experience from the same institution comprised no more than 10 patients. Insulinoma comprised 87% of all cases. The laparoscopic procedures performed were distal pancreatectomy and enucleation. Another multi-institutional European study comprised 127 patients with PNTs [9], and demonstrated that laparoscopic pancreatic resection is feasible and safe in selected groups of presumed benign pancreatic lesions requiring enucleation procedures or left pancreatic resections. A conflicting aspect of the study was that only four centers (16%) reported more than 10 patients with PNTs.

In our series we had four patients with different PNTs: two glucagonomas, one insulinoma and one carcinoid. Although pancreatic neuroendocrine tumors are often discussed together due to their similar origin, they comprise a heterogeneous group of neoplasms with different characteristics and behaviors. The type of surgery, which varies from a simple enucleation to a total pancreatectomy, is based on tumor location, size, suspicion of invasivity and degree of differentiation, and the relationship with the pancreatic duct. We did not perform any enucleation in our series. Enucleation is normally performed in patients with confirmed benign and small functioning tumors distant to the pancreatic main duct, so the use of intraoperative ultrasound is essential to decide the type of surgery required. We therefore consider the use of intraoperative laparoscopic ultrasonography as an integral part of the robotic and/or laparoscopic pancreatic procedure [10, 11]. The lack of tactile feedback can be a drawback of robotic surgery and may preclude its use to perform a safe operation in PNT and pancreatic cysts, in order to define the safest area (1–2 cm from the tumor) for pancreatic transection. We advocate that laparoscopic ultrasonography should be routinely used to define the exact location of the lesion and, whenever indicated, enucleation, avoiding injuries to the Wirsung or splenic vessels.

In one patient with glucagonoma, his clinical setting of muscle wasting was characteristic. In another patient who underwent partial duodenectomy, a CT scan showed a pancreatic head mass effect. Surgical robotic exploration confirmed a duodenal mass that was locally excised, preserving the pancreatic head. This patient was discharged in the third postoperative day.

On the other hand, minimally invasive pancreaticoduodenectomy remains one of the most advanced and complex abdominal surgeries [12]. Due to the complexity of the pancreatic anatomy, dissection and reconstruction remain very challenging, even to experienced teams.

To date, few series of totally laparoscopic pancreaticoduodenectomies have been reported [13–16]. Many surgeons have adopted critical selection of patients for this operation; however, factors such as age, obesity, previous surgery and clinical status remain a matter of debate in every published paper.

In the last decade there have been few reports on robotic pancreatic surgery. This is due to the complexity of the procedure, the low incidence of the disease and the necessity for an expert team to perform such complex procedures. Giulianotti et al. [17, 18] and Kendrick and Cusati [14] were the pioneers with the largest reported series of robotic pancreatic surgery. Most of the series have no more than 20 cases. Ours is the first large series reported from Latin America.

Differences in duration of the procedure and complications are mainly related to the initial diagnosis and clinical status of the patients in this series. One of our duodenopancreatectomies was performed in a 86-year-old patient, and our surgery duration lowered as we gained experience in using the robot. In the first cases, trocar positioning was not always perfect, duration of surgery was high, and the sense of comfort of the surgeon and assistant was low, but as we did more cases, trocar positioning was mastered, duration of surgery lowered and the sense of comfort for all the team increased, bringing better results.

Surgery duration also varied widely according to the complexity of the cases. Most of our cases were on obese patients; our first duodenopancreatectomy lasted 13 h in a morbidly obese women who developed a pancreatic fistula and stayed in hospital for 52 days with no need for re-operation. Our last duodenopancreatectomy lasted less than 10 h in a 86-year-old man, and he was dismissed on the 25th postoperative day. We also performed a left pancreatectomy for a re-operative case due to unsuccessful previous attempt to enucleate an insulinoma by another team; our approach lasted 530 min. All tissue was fibrosed due to leakage of pancreatic juice in the retrogastric area; the tumor was resected together with the left pancreas and the spleen was preserved. Our apparently high rate of early and late complications (35%) is lowering with our growth in experience. Probably our future cases may reach levels of 10–20%, similar to open surgery series. Fortunately we had no mortality in this initial experience.

Case selection in this initial series was defined as pancreatic lesions without relation to the inferior mesenteric vein with no obvious need of vein reconstruction and with the same indications as for laparoscopic resection. We believe this is a good choice while we are probably still in our learning curve for duodenopancreatectomies.

Important steps of pancreatic surgery could be improved with robotic surgery, including better visualization than laparoscopy, dissection of the pancreatic gland, stable optics, lymph node retrieval with less bleeding, precise dissection of the uncinate process, and, most importantly, the Aquile's tendon, reconstruction of the pancreas when compared to laparoscopy alone. The robot also allows the surgeon to perform challenging tasks and procedures that are technically difficult in laparoscopic surgery, combining the advantages of both minimally invasive and open surgery.

According to Giulianotti et al. [18–20], robotics has the potential to offer a solution to the high conversion rate reported for laparoscopy, which averages 46% (range, 12–100%) [20]. The robotic system can overcome many of the limitations of classical laparoscopy that often lead to conversion. The studies found an overall conversion rate of only 4.9%, with no conversions in one of the groups, and also found a shorter length of stay associated with robotics (overall mean, 12.3 days) compared with that reported in the laparoscopic literature (18 days), concluding that full robot-assisted pancreaticoduodenectomy can be performed safely with acceptable mortality and morbidity rates. There were no perioperative deaths in our series, and postoperative morbidity was acceptable, with just one case of intraoperative conversion due to difficulty in exposing the hepatic hilum.

Blood transfusion was necessary in only one case. These rates are similar to published laparoscopic and robotic series from other authors [19, 20].

In the present analysis, although our series is still in its infancy, it shows similar results to those reported in the medical literature regarding oncologic margins. PNT and cysts could be safely removed with acceptable levels of morbidity and no mortality. Hospital stay, need for blood transfusion and tumor margins were similar to larger reported series on the use of robotics in pancreatic surgery.

Large series of robotic pancreatic surgery should be described and the decision for its routine use will come from cumulative experience. This surgical system allows difficult procedures to be performed more easily, effectively and precisely.

In conclusion, we believe that robotic pancreatic surgery can be used as a tool for the treatment of PNT, periampullary tumors and cysts in advanced minimally invasive surgery centers.

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