



REVIEW

Intestinal autotransplantation

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Abstract

Most abdominal neoplasms involving the root of the superior mesenteric artery and/or celiac artery are difficult to manage with conventional operative techniques because of limited intestinal ischemia times and poor accessibility to the tumor region. *Ex vivo* surgery followed by intestinal autotransplantation (IATx) is a relatively novel surgical strategy to offer chances for complete resection in such hopeless circumstances. This review aims to assess potential surgical indications, operative techniques and clinical outcomes after IATx. Currently the main indications reported for IATx broadly include pancreatic, mesenteric and retroperitoneal neoplasms closely involving the superior mesenteric vessels. The preliminary results show that radical resection can be effectively achieved in carefully selective patients. Although perioperative morbidity and mortality are relatively high, there are several long-term survivors, particularly after complete resection of benign and low-grade tumor. Early tumor recurrence, however, remains a major problem in patients with high-grade tumor, particularly pancreatic ductal carcinoma. In conclusion, IATx allows patients with selected abdominal neoplasms involving the major mesenteric vessels to be completely resected. However, this aggressive approach is associated with a considerable operative risk, and should only be performed at experienced centers. Additional and adjunctive treatment therapies are required to improve the efficacy of this treatment.

Key words: Intestinal autotransplantation; *ex vivo* surgery; pancreatic cancer; mesenteric tumors

Introduction

Abdominal neoplasms involving the root of the superior mesenteric artery (SMA) and/or celiac artery are rare and consist of a heterogeneous group of benign and malignant lesions. These neoplasms may originate from any of mesenteric components, retroperitoneal tissues or the head of pancreas [1–3]. To date, complete surgical resection to obtain tumor clearance (R0 resection) is the primary goal and is essential to achieve better clinical outcomes [4]. However, an extensive surgical resection, particularly in the management of major mesenteric arterial and venous involvement, is a technically challenging procedure and is associated with high perioperative morbidity and mortality rates [5–7].

With advances in organ preservation and surgical strategies, *ex vivo* surgery and autotransplantation have been

successful in the kidney, liver and heart [8–12]. Such techniques have broadened treatable diseases, ranging from complex vascular reconstructions to complicated surgical oncological cases. As an extension of the above ideas, an *en bloc* removal of a tumor together with the intestine, *ex vivo* resection and intestinal autotransplantation (IATx) was briefly described in 1996 by Li *et al.* [13] and was further described in detail in 2000 by Tzakis *et al.* [14]. The key feature for consideration of IATx involves techniques of organ preservation as used in intestinal allotransplantation. Potential benefits of *ex vivo* surgery included providing adequate surgical exposure, a bloodless operative field and hypothermic protection of the bowel against ischemic damage. To further refine this complex procedure, our team developed a modified method in which a

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segmental bowel autograft is selected and is harvested first during the initial stage of the procedure and radical resection of the neoplasm is performed thereafter [15]. Our modification theoretically better protects a healthy bowel autograft from potential damage due to prolonged warm ischemia and allows the subsequent lengthy process of dissection to be performed in an unrushed manner.

The use of IATx has currently emerged as a potential surgical option for patients with selected abdominal neoplasms involving the root of the SMA. Because IATx is a highly specialized and technically complex procedure, only a few cases have been reported in the literature to date. In this review, we summarize surgical indications, technical considerations, potential complications and clinical outcomes after this procedure.

Surgical indications

A MEDLINE-assisted search was conducted in English publishing from January 1996 to October 2016 to identify patients in whom IATx was undertaken. **Table 1** presents an overview of various indications for a total of 44 patients who underwent IATx. The pancreatic head neoplasms form the largest group ($n = 28$), followed by mesenteric-originated lesions ($n = 12$), retroperitoneal neoplasms ($n = 2$) and other diagnoses ($n = 2$).

Pancreatic neoplasms

Due to anatomic proximity, the head of pancreatic neoplasms frequently invades into the major mesenteric vasculature and

Table 1. Details of patient characteristics and clinical outcomes ($n = 44$)

Case	First author	Year	Sex/age (years)	Primary locations	Diagnosis	Survival (months)/status	Recurrence
1	Lai [36]	1996	Male/56	Pancreas	Islet cell carcinoma	18/alive	None
2	Li [13]	1996	Male/34	Pancreas	Adenocarcinoma	2/NA	NA
3	Quintini [24]	2007	Male/43	Pancreas	Adenocarcinoma	15/dead	Yes
4			Male/51	Pancreas	Adenocarcinoma	19/dead	Yes
5	Zeng [25]	2008	Male/21	Mesentery	Hemangioma	9/alive	None
6	Amano [23]	2009	Female/57	Pancreas	Adenocarcinoma	11/dead	Yes
7			Male/64	Pancreas	Adenocarcinoma	12/dead	Yes
8	Kitchens [26]	2011	Male/60	Mesentery	Carcinoid tumor	30/alive	None
9	Kato [27]	2012	Female/63	Mesentery	Leiomyosarcoma	38/alive	None
10			Female/7	Pancreas	Inflammatory myofibroblastic tumor	27/alive	None
11			Female/8	Pancreas	Kaposiform hemagioendothelioma	17/alive	None
12	Tzakis [21]	2012	Male/4	Mesentery	Fibroma	138/alive	None
13			Male/5	Mesentery	Vascular dysplasia	117/alive	None
14			Female/41	Mesentery	Desmoid tumor	67/dead	None
15			Female/63	Mesentery	Leiomyosarcoma	26/alive	None
16			Male/52	Pancreas	Adenocarcinoma	6/dead	Yes
17			Male/0.5	Pancreas	Poorly differentiated tumor	23/alive	None
18			Female/17	Pancreas	Solid cystic pseudopapillary tumor	78/alive	None
19			Female/35	Pancreas	Solid pseudopapillary tumor	13/alive	None
20			Female/38	Pancreas	Desmoid tumor	94/alive	None
21			Male/38	Jejunum	Adenocarcinoma	8/dead	Yes
22	Tzvetanov [28]	2012	Male/60	Mesentery	Desmoid tumor	36/alive	Yes
23			Male/56	Mesentery	Desmoid tumor	30/alive	None
24	Nikeghbalian [22]	2014	Female/52	Pancreas	Adenocarcinoma	NA/dead	None
25			Female/32	Pancreas	Adenocarcinoma	NA/dead	None
26			Male/45	Pancreas	Adenocarcinoma	NA/alive	None
27			Female/56	Pancreas	Adenocarcinoma	NA/dead	None
28			Male/46	Pancreas	Adenocarcinoma	NA/alive	None
29			Male/50	Pancreas	Adenocarcinoma	20/alive	Yes
30			Male/73	Pancreas	Adenocarcinoma	6/dead	Yes
31			Male/33	Pancreas	Adenocarcinoma	NA/alive	Yes
32			Female/58	Pancreas	Pseudotumor	NA/alive	None
33			Male/47	Pancreas	Pseudotumor	NA/dead	None
34			Female/16	Retroperitoneum	Rhabdomyosarcoma	NA/dead	None
35			Female/55	Intestine	Gastrointestinal stromal tumor	NA/alive	None
36	Wu [15, 51]	2016	Male/63	Mesentery	Desmoid tumor	62/alive	None
37			Male/53	Mesentery	Desmoid tumor	28.3/alive	None
38			Male/24	Retroperitoneum	Ganglioneuroma	21/dead	None
39			Female/56	Pancreas	Solid pseudopapillary tumor	43.9/alive	None
40			Female/67	Pancreas	Serous cystadenocarcinoma	28.4/alive	None
41			Male/58	Pancreas	Neuroendocrine tumor	13.9/alive	None
42			Female/20	Pancreas	Adenocarcinoma	12.4/alive	Yes
43			Male/32	Pancreas	Adenocarcinoma	10.9/alive	None
44			Male/52	Pancreas	Adenocarcinoma	5.9/alive	None

NA, not available.

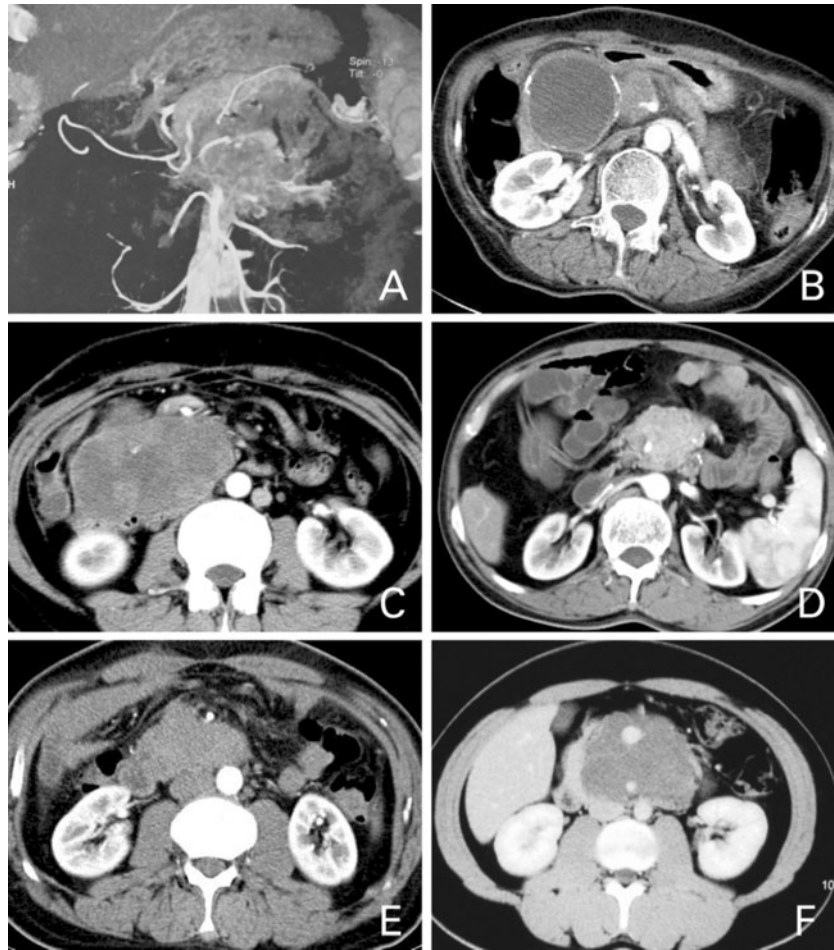


Figure 1. Contrast-enhanced CT image demonstrating tumor invasion to SMA in varying diseases. (A) A 52-year-old male with pancreatic head adenocarcinoma. Coronal CT image shows infiltrative growth of mass totally surrounding SMA. (B) A 68-year-old female with pancreatic head cystic mass that was proven to be serous cystadenocarcinoma. The mass was closely associated with SMA. (C) A 56-year-old female with pancreatic head low-attenuation solid mass, which was confirmed to be pancreatic pseudopapillary neoplasm at surgery. (D) A 58-year-old male with pancreatic head high-attenuation mass that was proven to be pancreatic neuroendocrine tumor. The mass completely encases SMA. (E) A 55-year-old male with Gardner syndrome and large mesenteric desmoid tumor. CT image shows low-attenuation desmoid at the mesenteric root with ill-defined tumor surrounding mesenteric vessels. (F) A 24-year-old male with retroperitoneal ganglioneuroma with a history of chronic abdominal pain and vomiting. CT shows hypo-attenuation homogeneous mass with involvement of mesenteric vessels.

retroperitoneal tissue (Figure 1A, B, C and D). A complete resection is essential to obtain long-term survival and has become an acceptable option for neoplasms involving the root of the SMA and/or celiac artery [16,17]. However, an extensive pancreaticoduodenectomy, particularly in the management of major arterial and venous involvement, has remained an issue of controversial debate due to high perioperative morbidity and mortality rates and inconsistent oncological outcomes [5,18,19]. An attempted resection by conventional surgery may result in uncontrolled bleeding, irreversible intestinal ischemic damage or a non-curative resection (R1 or R2) [20]. An extensive pancreaticoduodenectomy together with IATx has been used by various authors to improve curative-intent resection rates [21–24]. In the 28 pancreatic head neoplasms undergoing IATx, most are pancreatic ductal carcinoma ($n = 18$), while solid cystic pseudopapillary tumor ($n = 3$) and other rare diagnoses ($n = 7$) are also present (Table 1).

Mesenteric neoplasms

Primary mesenteric tumors are rare but can often be complex and difficult to manage. In the literature, potential indications

for IATx have included desmoid tumor ($n = 5$), leiomyosarcoma ($n = 2$), complex vascular abnormalities ($n = 2$) and other diagnoses ($n = 2$) [14,15,21,25–28]. Mesenteric desmoid tumors involving the major mesenteric vasculature are most indicated for IATx. These tumors are progressive fibroblastic and fibrotic proliferations arising from the mesentery. They may occur sporadically, or in the context of familial adenomatous polyposis (FAP) or Gardner's syndrome [29,30]. The frequency of desmoid tumors in patients with familial polyposis ranges from 4% to 32% in various reports, but only 8% of desmoid tumors are localized to the mesentery [31,32]. They have a tendency to aggressively invade major vascular structures, often obstruct the bowel and recur repeatedly. Despite their benign histologic appearance and negligible metastatic potential, their infiltrative features of growth can ultimately lead to life-threatening patterns of visceral involvement (Figure 1E). These characteristics make the treatment of these relatively rare fibrous tumors challenging. Surgical treatment is the only therapy of demonstrated benefit for desmoid tumors. Local recurrent rates after conservative resection range from 39% to 70%. Aggressive, wide local resection remains the treatment of choice for most of patients with desmoid tumors and complete surgical excision of desmoid tumors

with a negative surgical margin is the most effective method of cure. However, complete resection is not always feasible because of difficulty in differentiating the desmoid tumor from adjacent tissue, and involvement of major mesenteric vessels.

Retroperitoneal neoplasms

Primary retroperitoneal neoplasms are relatively rare lesions with a diverse group of benign and malignant tumors originating from the retroperitoneal space [33,34]. Retroperitoneal neoplasms usually grow slowly with no symptoms at the early stage and tend to be extremely large at presentation. At the time of diagnosis, tumors may have surrounded and invaded vital organs and major vascular structures, making complete surgical resection difficult to achieve (Figure 1F). Local recurrence after incomplete surgical resection is frequently related to the large tumor size, the inability to achieve wide surgical margins, and the limitations of adjuvant radiation and chemotherapy [35]. Therefore, an optimal surgical approach that allows a complete resection of retroperitoneal neoplasms, whilst protecting important blood vessels, tissues and organs, is required to improve poor outcomes. The surgical indications for IATx included rhabdomyosarcoma ($n = 1$) and ganglioneuroma ($n = 1$).

IATx has also been used to treat malignant neoplasms originating from the proximal jejunum encasing the root of the SMA ($n = 2$). In addition, we recently used the IATx approach to treat a case with a huge isolated pseudoaneurysm of the SMA that was not manageable by endovascular stenting or conventional open surgery, but was successfully managed by IATx.

Pre-operative work-up

Thorough pre-operative evaluation is essential before proceeding to IATx. Prior to the procedure, our multidisciplinary team assesses thoroughly each case, particularly for the extent of the disease, the metastatic potential of the neoplasm and the estimated chance of survival without resection. Particular attention is paid to imaging studies, oncologic review of prior therapy, evaluation of cardiopulmonary risk, and nutritional and psychosocial assessments.

Imaging studies must specifically address several pertinent points when evaluating potential patients for IATx, including involvement of the major vasculature (the superior mesenteric vessels, the celiac axis and the hepatic artery), regional lymphadenopathy and local invasion of other structures. Non-invasive CT angiography with 3D reconstruction or conventional selective angiography was used to evaluate the superior mesenteric vessels prior to surgery.

Special technical considerations

Surgical procedures primarily consist of three distinct operations: selection and preparation of appropriate bowel autograft, extensive pancreaticoduodenectomy and IATx. Detailed descriptions of these operative procedures are well described in the literature and are beyond the scope of this review. The technical considerations of each procedure are outlined.

Exploration and decision for IATx

Surgical exposure for a pancreaticoduodenectomy is first obtained either through an upper midline incision or a bilateral subcostal incision. The abdominal cavity is carefully assessed for evidence of distant metastatic diseases beyond a primary

tumor, particularly the liver, peritoneal surfaces, duodenojejunal flexure and pelvic cavity. The lesser sac is opened with the assessment of the hepatic and celiac arteries for tumor involvement. The pancreatic head and duodenum are mobilized to assess involvement of the superior mesenteric vein (SMV) and SMA with tumor. Lesions that are suspicious for cancer are biopsied and sent for frozen section analysis. Upon confirming the extent of the tumor involvement and excluding distal metastasis, a final decision is usually made to proceed with IATx.

In situ or ex vivo surgery

Basically, there are two different approaches to accomplish IATx. *In situ* IATx was the early method described by Lai et al. [36]. He presented a case with a locally advanced nonfunctioning islet cell carcinoma that underwent radical total pancreatectomy, gastrectomy, colectomy, hepatic revascularization and *in situ* IATx without hypothermic perfusion. Amano et al. also used this approach for two patients with pancreatic ductal carcinoma [23]. In the literature, most authors used an *ex vivo* approach to accomplish tumor resection followed by IATx, similarly to the method developed by intestinal allotransplantation. In this technique, a tumor together with the root of the mesentery, the partial or whole pancreas, duodenum, intestine and right colon were removed *en bloc* and were *in vitro* flushed through the SMA with chilled preservation solution [14,24,37,38]. Upon the tumor being completely resected at the back-table, the intestinal autograft was implanted with vascular and gastrointestinal reconstruction. These maneuvers allow tumor resection and vascular reconstruction in a bloodless surgical field with minimal injury to the explanted organs. We further developed a modified method as we used in living donor intestinal allotransplantation [15]. In this modification, a segmental bowel autograft is initially selected and harvested during an earlier stage of the operation, and complete resection of the neoplasm is carried out next. We believe this change would better protect a healthy bowel autograft from potential damage due to prolonged warm ischemia and allow the subsequent lengthy process of dissection to be performed in an unrushed manner. Furthermore, the alteration would better adhere to the general principles of minimal tumor manipulation during operation and potentially decrease the risks of tumor implantation during *in vitro* organ perfusion. Our initial experience indicates that this technique is safe and effective to assist R0 resection.

A suitable segment of the intestine with a reasonably sized SMA for vascular anastomosis is initially selected below the tumor and is measured for future grafting. The location of a distal branch of the SMA supplying the future segmental graft can be identified with palpation and transillumination; the SMV can usually be found on the right anteriolateral aspect of the SMA. The mesentery is then divided in a 'V'-shaped fashion with the tip of the 'V' at the takeoff of the vessel. The bowel graft is marked with a simple stitch to recognize proximal and distal ends, and divided using a gastrointestinal anastomosis stapler. Once the vessels are transected at the designed line, the graft is removed and flushed immediately through the artery with cold histidine-tryptophan-ketoglutarate (HTK) solution until clear return from the vein is obtained. Then, the bowel graft is kept chilled in preservation solution until use (Figure 2).

Back-table preparation and use of vascular graft

Either the University of Wisconsin Solution (UW) or HTK has successfully been used as a preservation solution. In our

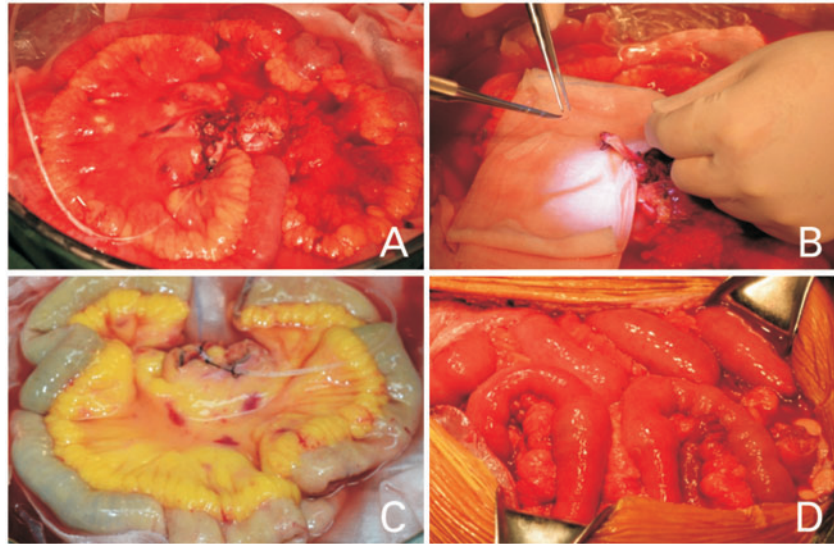


Figure 2. An intra-operative photograph demonstrating how intestinal autotransplantation is undertaken. (A) Bowel autograft is flushed through graft artery with cold preservation solution. (B) Internal iliac artery autograft is procured and used for extension. (C) Bowel autograft is kept chilled in preservation solution until use. (D) Bowel autograft returned to a pink color immediately after reperfusion.

experience, we prefer to use HTK in terms of the low potassium content that reduces the risk of cardio-circulatory complications after reperfusion, and the low viscosity that allows fast and homogenous intestine perfusion.

In most cases, the intestinal autograft SMA and SMV can be directly used with no vascular autograft for reconstruction. In the case of shorter vascular vessels of an intestinal graft, interpositional graft is used to facilitate vascular reconstruction (Figure 2B). In addition to meticulous surgical skills, selection of appropriate vascular grafts is very important to accomplish the procedure and avoid post-operative complications. In the literature, three different vascular grafts including an autograft, allograft and artificial graft have been used. Nikeghbalian *et al.* reported two cases with decreased donor vascular grafts under immunosuppressive and both patients died due to severe surgical complications, including uncontrolled sepsis and thrombosis-caused small bowel necrosis [22]. Other authors did not report vascular allograft-related complications. Kato *et al.* reported three cases of multivisceral *ex vivo* surgery followed by vascular reconstruction by synthetic vascular grafts without complications [27]. A vascular autograft from the internal jugular vein, saphenous vein or internal iliac artery was also used with good outcomes. In our practice, we prefer to use a vascular autograft in case of needs instead of a synthetic graft or decreased donor vascular allograft. Special attention should be paid to avoid the endothelial damage or detachment from the muscular layer.

Portal versus systemic drainage

Either the portal venous or systemic drainage can be applied to accomplish vascular reconstruction. Theoretically, portal venous drainage is more physiological than systemic drainage due to the hepatotropic effects of the portal blood. In our center, the portacaval anastomosis is frequently used as an anastomotic location because of its shorter graft vein. Similarly to intestinal allotransplantation, the systemic venous drainage usually carries a low risk of dramatic metabolic consequences in the presence of normal liver function [39].

Gastrointestinal reconstruction

In most cases, pancreaticojejunostomy is commonly performed with a duct-to-mucosa technique. We prefer to place a pancreatic duct stent to reduce a pancreatic leak. Anastomosis of the pancreatic duct remnant to the posterior wall of the stomach is also used to decrease the risk of pancreatic fistula. The hepaticojejunostomy is performed downstream from the pancreatic anastomosis in an end-to-side manner. Continuity of the gastrointestinal tract is reconstructed using a 45- to 50-cm Roux-en-Y limb to complete pancreaticoenterostomy, choledochenterostomy, gastroenterostomy and ileocolostomy.

Surgical complications and management

Table 2 summarizes the surgical procedures and perioperative outcomes for the 44 patients who underwent IATx.

Perioperative mortality

With increase in experience and specialization, pancreaticoduodenectomy in some high-volume centers can be performed with a perioperative mortality of 1-3% [40,41]. Theoretically, the extensive pancreaticoduodenectomy together with IATx may be associated with a high level of mortality. With a total of 44 patients undergoing IATx over a 20-year period, 4 (9.1%) died during the initial hospital stay and the causes of death were multi-organ failure, infection, pancreatic leak and cerebrovascular accident, respectively [15,22].

Early graft loss

The intestine autograft loss caused by SMA thrombosis is a serious early complication after IATx. Early SMA thrombosis occurred in 3 of the 44 cases and portal vein thrombosis occurred in 1 case after surgery [15,21,22,26]. All four cases were complicated with bowel necrosis, and entire autograft loss in three and partial loss in one. Early detection of this complication is critical to avoid irreversible bowel damage, although a strategy to make a definitive diagnosis is currently lacking [42,43]. Serum lactic acid may be a useful marker for detecting intestinal ischemic

Table 2. Summary of surgical procedures and perioperative outcomes (n = 44)

First author	No. of cases	In situ/ ex vivo	Total operative time (hours)	Cold ischemia time (minutes)	Blood transfusion (units)	Surgical complication	Hospital stay (days)	Perioperative mortality
Lai [36]	1	In situ	6	None	20	Lung atelectasis	21	–
Li [13]	1	Ex vivo	14.5	241	10	None	NA	–
Quintini [24]	2	Ex vivo	9.3, 11.4	55, 114	Nil	Intra-abdominal hematoma	16, 29	–
Zeng [25]	1	In situ	15	None	8	None	NA	–
Amano [23]	2	In situ	NA	None	NA	Enterocolostomy leak	NA	–
Kitchens [26]	1	Ex vivo	NA	NA	NA	SMA thrombosis/ pancreatic leak	72	–
Kato [27]	3	Ex vivo	NA	195,218	NA	Hepatic artery stenosis	21, 44	–
Tzakis [21]	10	Ex vivo	8–14	NA	NA	Portal vein thrombosis/ SMA thrombosis/sepsis	NA	–
Tzvetanov [28]	2	Ex vivo	5	NA	NA	Arteriovenous fistula	14, 8	–
Nikeghbalian [22]	12	Ex vivo	11.9 (9–16)	160 (60–210)	NA	Graft thrombosis/ multi-organ failure/ cerebrovascular accident	9.7 (1–24)	3/12
Wu [15,51]	9	Ex vivo	12.1 (9.5–16.5)	219 (184–250)	9.2 (4–20)	SMA thrombosis/ pancreatic leak	19.7 (14–26)	1/9

NA, not available; SMA, superior mesenteric artery.

damage. Doppler ultrasonography is very useful in the evaluation of mesenteric blood flow, although marked abdominal gas earlier after operation may preclude adequate visualization of the SMA. Because of the serious consequences, we suggest that prompt re-exploration may be warranted to correct any bowel ischemia from progressing to irreversible bowel infarction in case of high suspicion.

Pancreatic anastomotic leak

Post-operative pancreatic leakage is one of the most serious complications after pancreaticoduodenectomy [44]. The rate of the pancreaticoenteric anastomotic leakage ranges from 8% to 18% of patients undergoing routine pancreaticoduodenectomy at major centers, which contributes significantly to the morbidity and mortality [40,45]. Patients who undergo an extensive pancreaticoduodenectomy together with IATx may be at particular risk of developing leakage from the pancreatic anastomosis. In the literature, confirmed leakage from the pancreaticoenterostomy occurred in 2 of the 44 patients with IATx (4.8%). One case with a small leak was successfully managed without surgery. We reported a case with an anastomotic leak at the pancreaticojejunostomy and the patient died 3 weeks after the procedure [15]. This case presented with high fever, abdominal distention, ileus and leukocytosis with mildly increased amylase and lipase in the peritoneal drainage. CT showed a localized fluid collection in the region of the pancreaticojejunostomy without an air-fluid level. Exploratory laparotomy confirmed a fistula from the pancreaticojejunal anastomosis, possibly related to ischemic necrosis of the remaining pancreatic tail. After a thorough wash and debridement of nonviable pancreatic tissue, the patient developed a massive intraperitoneal hemorrhage from the disrupted SMA anastomosis and died of severe hypovolemic shock. Therefore, great concern should always be given to appropriate management of the pancreatic remnant during IATx. The adequacy of blood supply at the cut surface of the pancreas should be evaluated routinely and, if deemed inadequate, more of the pancreas should be removed or even a total pancreatectomy may be considered to avoid this deadly complication.

A combination of optimization of blood supply to the pancreatic remnant, a meticulous operative technique and appropriate selection of pancreaticoenterostomy or pancreaticogastrostomy should be considered to reduce this deadly complication.

Delayed gastric emptying

Delayed gastric emptying in the absence of any mechanical obstruction is one of the most common post-operative complications after pancreatic surgery [46,47]. This complication may be related to denervation of the upper gastrointestinal tract during dissection of the pancreatic head and the superior mesenteric vessels [48]. Delayed gastric emptying usually resolves in 4–12 weeks in most patients after pancreatic surgery. It is unclear regarding the rate and severity of this complication after extensive pancreaticoduodenectomy and IATx. In our series, 2 of 10 patients had delayed gastric emptying that was successfully managed with conservative treatment. We usually place a gastrostomy tube at the time of surgery to relieve symptoms and insert a feeding jejunostomy tube to deliver enteral feeding.

Post-operative hemorrhage

Early intra-abdominal bleeding within 24 hours of surgery may require reoperation for hemostasis. In the literature, one case had an intra-abdominal hematoma within 48 hours post-operatively which required reoperations [24]. Delayed bleeding more than 1 week after surgery may be related to pancreatic fistula with erosion into retroperitoneal vessels [15]. In our opinion, this potentially lethal complication is best managed with early exploratory laparotomy to exclude pancreatic fistula.

Clinical outcomes

Tumor recurrence appears to be a major problem in patients with high-grade advanced cancer after IATx. In 18 patients with pancreatic ductal adenocarcinoma, 7 out of 11 patients with a documented follow-up time had tumor recurrence at short-term median follow-up of 11.5 months (range, 5.9–20 months). Among them, five patients died at the time of follow-up and

two were under chemotherapy. Clearly, adjunctive therapies including chemotherapy and/or radiation may be required to improve tumor clearance after IATx.

The best outcomes can be achieved in patients with a diagnosis of benign or low-grade malignant lesions. In six patients with desmoid tumor, only one had tumor occurrence at a median follow-up of 36 months and the other five patients remained recurrence-free at a median follow-up of 52.9 months (range, 28.3–94 months). It appears that curative surgery is the best treatment option for this group of patients.

Long-term nutritional outcomes have not been well described in the literature. Based on our experience and others with living-related intestinal allotransplantation, a 160- to 180-cm length of an ileal graft is sufficient to support an adult [49,50]. Considering a 45- to 50-cm Roux-en-Y limb, we suggest that a minimum length of 200 cm for a bowel autograft is required for completing the gastrointestinal reconstruction and achieving nutritional autonomy [15]. In 33 patients with a documented length of bowel graft, the length of the transplanted intestinal autografts more than 130 cm, only one patient who received 40 cm of bowel required total parenteral nutrition (TPN) and later died of urosepsis. Most successful bowel autografts did not require TPN or any supplemental parenteral nutrition or intravenous fluids after hospital discharge. Early mild, controllable diarrhea was suggestive of rapid intestinal transit time with the lack of a right colon but did not affect the adequacy of nutritional absorption.

Summary

IATx has been used to treat the pancreatic, mesenteric and retroperitoneal neoplasms encasing the root of the SMA and/or celiac artery. This complex approach may prove to be an effective option for highly selected patients with reasonable clinical outcomes. The procedure allows patients with locally advanced abdominal neoplasms involving the major mesenteric vessels to be resected completely and result in early intestinal autonomy from parenteral nutrition. Careful pre-operative assessment and planning will maximize the chance for a safe and uncomplicated pancreaticoduodenectomy and potentially minimize local tumor recurrence. This operative strategy is technically demanding and probably should be performed only at centers experienced with intestinal transplantation.

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Conflict of interest statement: none declared.

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