

Endovascular management of bleeding events following robotic pancreaticobiliary surgery

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PURPOSE

To describe the utility, safety, and efficacy of endovascular intervention for treating bleeding events after robotic pancreaticobiliary surgery.

MATERIALS AND METHODS

In this retrospective study, six patients (male/female, 3/3; mean age, 64 years) with histories of robotic pancreaticobiliary resection were referred for endovascular management of delayed postoperative intra-abdominal hemorrhage. Visceral angiography was performed, and the sites of suspected arterial hemorrhage were interrogated with selective microcatheter arteriography. The visualized bleeding sources were treated using catheter-directed embolotherapy with metallic coils, bare metal or covered stent insertion, or a combination of the two. The measured outcomes included the technical success of the angiographic occlusion, procedure safety, and procedure efficacy.

RESULTS

Pseudoaneurysms resulted in bleeding in six cases (100%). The endovascular interventions included coil embolization in three cases (50%), covered stent exclusion in two cases (33%), and bare metal stent-assisted coil embolization in one case (17%). The technical success was 100%, with complete cessation of bleeding in all cases. No immediate or delayed procedure-related complications were encountered in any of the patients. The efficacy of the endovascular therapy was 100% in this series, with no recurrent hemorrhage during the mean clinical follow-up period of 262 days (range, 67–446 days).

CONCLUSION

Endovascular therapy provides a minimally invasive, safe, and effective method for managing hemorrhagic events after complicated pancreaticobiliary surgery.

Key words: • endovascular procedures • telerobotics • pancreas • biliary tract • hemorrhage

Initially described in the early twentieth century, operative resection has become a well-established therapy for benign and malignant pancreaticobiliary disease (1). Although promising modifications to the original techniques described by Whipple and Kausch have occurred over time, including minimally invasive approaches using laparoscopic and robotic surgery, morbidity after complex pancreaticobiliary resections remains problematic (2–4). Postoperative hemorrhage is an uncommon complication of pancreaticobiliary surgery, but it may result in significant morbidity and mortality (3). With the rise of image-guided and catheter-based therapies, endovascular techniques have become an accepted treatment option for postoperative bleeding complications (5, 6). While endovascular methods for addressing bleeding after pancreatic surgery have been described (7), there are limited data on the application of such approaches after minimally invasive robotic pancreaticobiliary surgery. In this retrospective study, we report our initial experience with the endovascular treatment of bleeding events following robotic pancreaticobiliary surgery, discuss our management approach and interventional techniques, and highlight the utility of minimally invasive catheter-directed therapies in these challenging surgical patients.

Materials and methods

This study complied with the U.S. Health Insurance Portability and Accountability Act, and the institutional review board approved a waiver of consent for participation in the study. All of the patients provided written informed consent for the surgical and endovascular procedures.

Patients and surgeries

From February 2009 to November 2010, six patients with histories of robotic pancreaticobiliary surgery were referred to our interventional radiology (IR) department for assistance with managing postoperative intra-abdominal hemorrhage. The patient demographic information, surgical indications, and operative interventions are listed in Table 1. The cohort consisted of three men and three women. The mean patient age was 64 years (range, 50–83 years). Two patients had undergone surgery for pancreatic head adenocarcinoma, one for a pancreatic neuroendocrine tumor, and three for complications related to chronic pancreatitis. The surgical procedures included robotic-assisted Whipple pancreaticoduodenectomy (n=2), pylorus preserving robotic-assisted pancreaticoduodenectomy (n=2), robotic-assisted pancreaticogastrostomy with cholecystectomy (n=1), and robotic-assisted cholecystectomy with Roux-en-Y hepaticojejunostomy (n=1).

The patients presented with the clinical symptoms and laboratory signs of blood loss during the postoperative period (Table 2). Three patients (50%) had upper gastrointestinal (GI) bleeding, one patient (17%)

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had lower GI bleeding, and two patients (33%) had both upper and lower GI bleeding. The mean onset of post-surgical hemorrhage was on postoperative day 29 (range, 15–55 days). All of the patients had laboratory evidence of active blood loss, with a mean hemoglobin reduction of 2.6 g/dL (range, 0.9–4.6 g/dL). Of the six patients, four (67%) were acutely hypotensive (a systolic blood pressure less than 90 mmHg) at the time of presentation. All of the patients were stabilized with a transfusion of packed red blood cells (mean, 2.8 units; range, 2–5 units) and intravenous fluid resuscitation in the intensive care unit within 24 hours of their referral for angiographic therapy. In addition, all of the patients underwent pre-procedure computed tomography (CT) scans, and intra-abdominal hemorrhage was confirmed in five cases (83%). Given the potential complexity and morbidity of additional surgery and the immediate availability

of endovascular therapy, arteriography and endovascular management were requested by the referring general surgeon in each case, and patient care was expedited.

Endovascular procedures

The angiographic procedures were performed in the IR suite using moderate intravenous sedation. In general, the patients were prepared and draped in the standard sterile fashion while supine on the angiographic procedure table, and routine arterial access was gained via the right common femoral artery. An initial diagnostic visceral angiography was then performed using a 4 or 5 F visceral (Sos or cobra) catheter. The sites of the suspected arterial hemorrhage that had been identified on non-selective mesenteric arteriography were further interrogated with a selective arteriography performed via a coaxially placed 1.9–3.0 F microcatheter. The visualized bleeding

sources were treated using catheter-directed embolotherapy with metallic coils, bare metal or covered stent insertion, or a combination of the two. Selective therapy was pursued to spare occlusion of the arterial branches not contributing to the hemorrhage. Following the treatment, a completion arteriography was performed to confirm cessation of the bleeding. Finally, all of the catheters and vascular access devices were removed, and hemostasis was achieved at the arterial access site with manual compression or using a vascular closure device. Primarily due to the recent hemorrhage and the presence of excellent antegrade arterial blood flow following the stent deployment, the patients treated with stent-graft insertion were not prescribed anti-platelet agents following the procedure.

Measured outcomes

The primary outcome measure was the immediate technical success of the endovascular therapy, which was defined as angiographic occlusion or exclusion of the bleeding source with cessation of hemorrhage. The secondary outcome measures included procedure safety, as assessed by the thirty-day complication rate, and procedure efficacy, as evaluated by the presence or absence of recurrent hemorrhage on clinical follow-up.

Results

The bleeding source was identified as a pseudoaneurysm in six cases (100%). A pre-procedure CT demonstrated the bleeding pseudoaneurysm in two cases (33%). Active contrast extravasation was seen at the time of the angiography in one patient (17%). Bleeding lesions were identified in other cases by the location of vascular abnormalities near intra-abdominal hematomas seen on the pre-procedure CT scan. The endovascular interventions are presented in Table 3. Coil embolization, both distal and proximal to the bleeding source, was performed in three cases (50%) (Fig. 1), covered stent exclusion of the bleeding source was performed in two patients (33%) (Fig. 2), and bare metal stent-assisted coil embolization of the bleeding source was performed in one patient (17%) (Fig. 3). Technical success was achieved in six patients (100%), with no further angiographic evidence of hemorrhage

Table 1. The patient demographics, disease states, and surgical histories

Patient	Age (years)	Gender	Disease	Surgical history
1	56	M	Chronic pancreatitis	Robotic-assisted pancreaticogastrostomy
2	65	M	Pancreatic ca	Robotic-assisted pancreaticoduodenectomy
3	83	F	Chronic pancreatitis	Robotic-assisted pancreaticoduodenectomy
4	66	F	Pancreatic NET	Robotic-assisted pancreaticoduodenectomy
5	50	F	Chronic pancreatitis	Robotic-assisted hepaticojejunostomy
6	66	M	Pancreatic ca	Robotic-assisted pancreaticoduodenectomy

F, female; M, male; ca, adenocarcinoma; NET, neuroendocrine tumor.

Table 2. Bleeding events

Patient	Clinical presentation	Onset (days)	CT findings
1	Hematemesis	POD 35	SMA pseudoaneurysm
2	Gastrostomy tube bleeding	POD 20	Intra-enteric hemorrhage
3	Hematochezia	POD 22	Surgical bed hematoma
4	Hematemesis	POD 15	Surgical bed fluid
5	Hematemesis and hematochezia	POD 55	Hemobilia
6	Nasogastric tube bleeding and melena	POD 28	RHA pseudoaneurysm

POD, postoperative day; CT, computed tomography; SMA, superior mesenteric artery; RHA, right hepatic artery.



Figure 1. a–d. A 50-year-old woman presenting with hematemesis 55 days after robotic-assisted hepaticojejunostomy. A non-contrast CT scan showed hemobilia (a), as evidenced by the presence of high-attenuation blood in right biliary system (arrowhead). A subsequent celiac arteriogram (b) revealed an irregularity of the right hepatic artery (arrow), with a small pseudoaneurysm (arrowhead). A selective right hepatic arteriogram (c) demonstrated active bleeding (arrow) from a pseudoaneurysm into the duodenum (arrowheads). After confirmation of portal venous patency, a successful embolization across the bleeding site was performed using metallic coils (arrowheads, d).

following endovascular therapy occurring in any of the cases. Because no immediate or delayed procedure-related complications were encountered, the endovascular therapy demonstrated an excellent safety profile. Specifically, no end-organ (visceral or abdominal solid organ) ischemia occurred, and there were no infectious complications in the treatment cohort. The clinical efficacy of endovascular therapy was 100% in this series, with no evidence of recurrent hemorrhage in six of the cases during the mean clinical follow-up period of 262 days (range, 67–446 days).

Discussion

Complex pancreatic resections are challenging procedures that are associated with a high peri-operative morbidity of 40% and a mortality rate of 5% (8, 9). Robotic technologies are relatively new additions to the surgical

Table 3. Endovascular management

Patient	Bleed location	Management	Devices used
1	SMA branch	Coil embolization	One 5 mm Interlock ^a and one 4 Nester ^b microcoils
2	Replaced RHA	Stent exclusion and coil embolization	6 mm Smart ^c stent and four 4 mm Trufill DCS ^c microcoils
3	GDA stump	Covered stent exclusion	Two overlapping 5 mm Jostent ^d stents
4	RHA	Coil embolization	One 6 mm and one 4 mm Tornado ^b microcoils
5	CHA stump	Coil embolization	One 6 mm and one 4 mm Nester ^b microcoils
6	RHA	Covered stent exclusion	One 5 mm iCast ^e stent

SMA, superior mesenteric artery; RHA, right hepatic artery; LOC, loss of consciousness;

GDA, gastroduodenal artery; CHA, common hepatic artery.

^aBoston Scientific, Natick, Massachusetts, USA.

^bCook Medical, Bloomington, Indiana, USA.

^cCordis, Bridgewater, New Jersey, USA.

^dAbbot Vascular, Abbott Park, Illinois, USA.

^eAtrium Medical Corporation, Hudson, New Hampshire, USA.

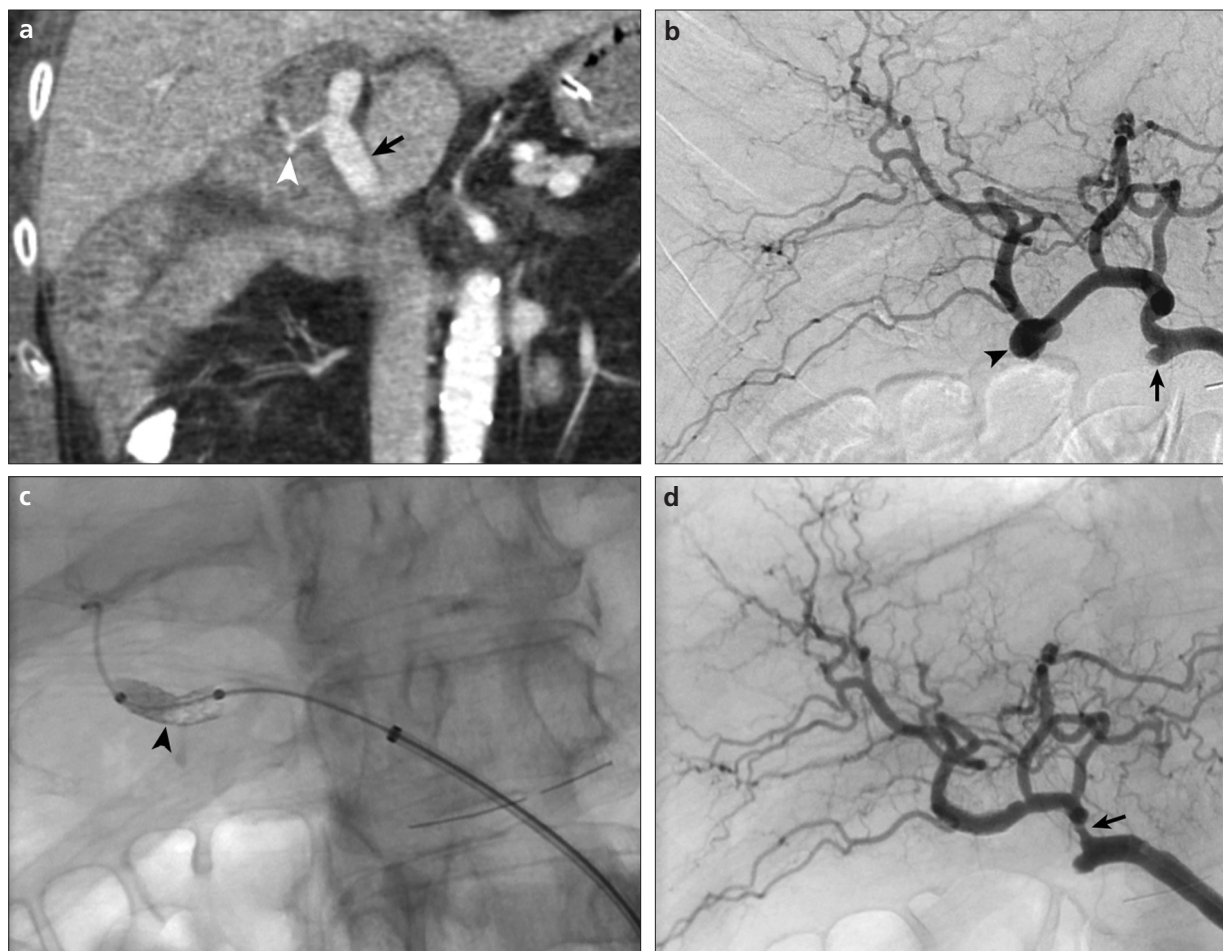


Figure 2. a–d. A 66-year-old man presenting with a drop in hemoglobin levels 28 days after robotic-assisted pancreaticoduodenectomy. A coronal reformatted CT scan image (**a**) revealed a pseudoaneurysm (*arrowhead*) arising from the right hepatic artery (the arrow indicates the main portal vein). A subsequent arteriogram (**b**) confirmed the presence of a lobulated pseudoaneurysm (*arrowhead*). Note the stump of a ligated gastroduodenal artery (*arrow*). After placing a 5×22 mm iCast (Atrium Medical Corporation, Hudson, New Hampshire, USA) covered stent (*arrowhead*, **c**), no further pseudoaneurysm filling was observed on the post-deployment arteriogram (**d**). A residual arterial spasm was noted in the proper hepatic artery (*arrow*, **d**).

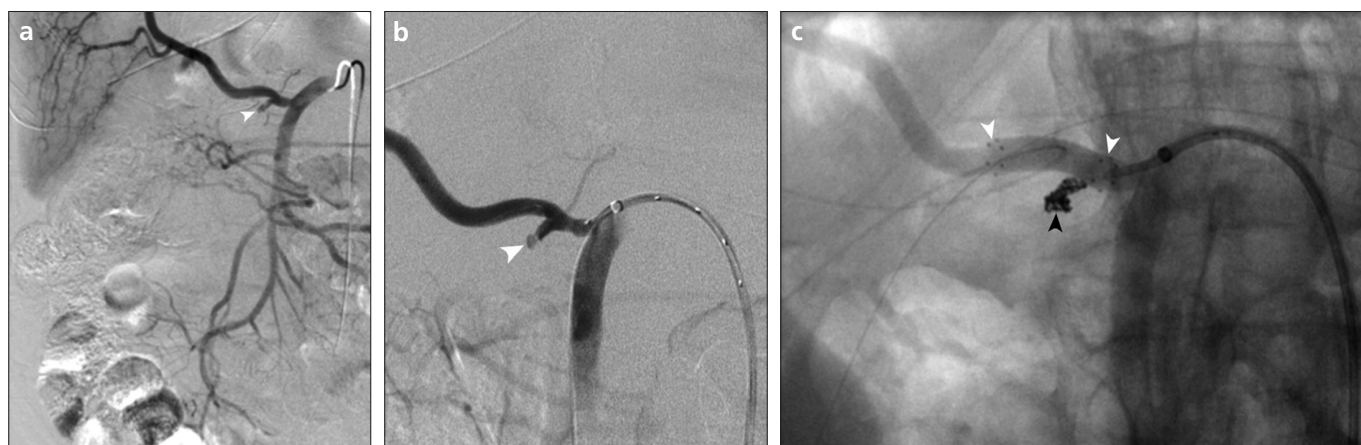


Figure 3. a–c. A 65-year-old man presenting with hypotension 20 days after robotic-assisted pancreaticoduodenectomy. A superior mesenteric arteriogram (**a**) revealed a small pseudoaneurysm (*arrowhead*) arising from the replaced right hepatic artery; the pseudoaneurysm is better seen on the magnified image (**b**). Due to the wide pseudoaneurysm neck and the risk of coil migration, stent-assisted coil embolization was performed using a 6×2 cm Smart stent (Cordis, Bridgewater, New Jersey, USA) (*white arrowheads*, **c**) to constrain 4 mm metallic coils (*black arrowhead*, **c**) within the pseudoaneurysm. A completion arteriogram (**c**) showed no further filling of the pseudoaneurysm.

armamentarium and provide exciting new minimally invasive approaches for treating benign and malignant pancreaticobiliary disease (2). Robotic systems, which allow the surgeon to remotely control multi-articulated instruments under three-dimensional visual guidance, may reduce morbidity and mortality after complex pancreaticobiliary resections by minimizing trauma during the surgical exposure and handling of tissue (2). These devices have advantages in motion scaling, fine motor control, magnified imaging, and filtering of small physiological movements (10). Robotic technologies have been shown to be safe for multiple disease processes in a variety of abdominal and retroperitoneal surgical settings (11). Our institution, at which approximately thirty robotic pancreatic surgeries are performed annually, has had substantial and growing experience with robotic-assisted pancreatic surgery (2).

Postoperative hemorrhage is an uncommon complication of pancreaticobiliary surgery, occurring with an incidence of between 3% and 13% (3). Acute hemorrhage, occurring within the first 24 hours of surgery, is typically the result of inadequate hemostasis, slipped ligatures, or anastomotic bleeding (1). Depending on the etiology, immediate reoperation or conservative management is generally used for acute postoperative bleeding. Delayed hemorrhage, or bleeding that occurs after the sixth postoperative day (12), has a pathogenesis characteristically related to inflammatory vessel erosion (with or without pseudoaneurysm formation) as a result of pancreatic secretions, bile leaks, and other postoperative complications, including anastomotic leaks and localized abscesses (13). Delayed hemorrhage commonly arises from the hepatic artery or gastroduodenal artery stump due to the close proximity of these vessels to the surgical site (13). Other vessels, including the superior mesenteric artery and pancreaticoduodenal arteries, have been described as bleeding sources (6).

In a series of 134 patients who underwent robotic-assisted pancreatic surgery, only six (4.5%) patients developed postoperative bleeding events (2), highlighting the rarity of this outcome. While prospective studies comparing bleeding complications between open, laparoscopic, and robotic

surgeries are scarce in the literature, meta-analyses examining the post-surgical outcomes show similar rates of intra-operative complications, post-operative complications, and mortality between robotic and laparoscopic surgery (14). Furthermore, large series examining the incidence and nature of bleeding complications following major pancreatic surgery indicate that the typical bleeding site (hepatic and visceral arteries), type (caused by pseudoaneurysm), and timing (predominantly delayed) are similar between conventional surgical approaches to pancreatic resection and robotic pancreatic surgical interventions (15, 16).

While surgery should always be an initial consideration for acute or delayed postoperative hemorrhage, depending upon the source of the bleeding (12), several factors limit its utility. First, the location of the hemorrhage (usually from the hepatic artery or gastroduodenal stump) behind the surgical anastomoses precludes easy access to the bleeding site. Second, the adhesions and significant inflammation present during the postoperative period may create a hostile environment for the surgeon. Finally, an open surgical approach to a bleeding complication after robotic surgery undermines the minimally invasive philosophy of this operative technique, which is associated with more rapid recovery (17). For these reasons, endovascular interventions performed by interventional radiologists may offer technically easier, safer, and less invasive access to bleeding sites. As such, prompt angiography and possible endovascular therapy should be an early consideration.

Endovascular interventions are associated with low overall complication rates and, in the appropriate clinical setting, offer outcomes similar to those of surgery (12). In this study, we were able to achieve safe, effective, and clinically durable cessation of post-operative bleeding using a variety of endovascular techniques. None of the patients in this series experienced clinical recurrence of their hemorrhage, suggesting the efficacy of endovascular approaches that utilize both occlusion (embolization) and exclusion (stent insertion) of bleeding abnormalities. While coil embolization, covered stent placement, and combinations of the two have been described for treating post-surgical bleeding (7, 12), the

results described here highlight the utility of these endovascular interventions in cases where hostile abdominal environments contain pancreatic and biliary secretions that may erode the vasculature. As a point of precaution, we recommend that endovascular specialists always review and discuss the prospective treatment options with their surgical colleagues prior to pursuing an intervention. Surgical alterations in the abdominal organs and visceral blood flow may compromise normal vascular collateral pathways in postoperative patients, increasing the risk for end-organ ischemia after vascular stent exclusion or embolotherapy. Support from the surgical staff is necessary should such an adverse outcome arise, which may require further direct surgical intervention.

The use of covered stents is ordinarily contraindicated in an infected area due to the potential bacterial colonization of the graft material (18, 19), and covered stent insertion is generally not thought to provide a long-term treatment for infected pseudoaneurysms (20). If a post-surgical intra-abdominal infection is suspected, the decision to proceed with an endovascular intervention needs be made on a case-by-case basis, with the best interests of the patient taken into account and after a thorough discussion of the procedure benefits, risks, and alternatives. None of the patients in this series had suspected infections, suggesting that the integrity of the enteric anastomoses was maintained. In the absence of infection, we speculate that the vascular abnormalities we encountered were related to vessel erosion caused by intra-abdominal inflammation (perhaps from pancreatic secretions) without superimposed infection. Pre-procedure prophylactic antibiotics were not routinely administered prior to the angiography, and none of the patients in this series suffered from an IR procedure-related infection.

Given the potential complications of biliary and hepatic necrosis with hepatic arterial occlusion, bleeding from the hepatic artery or gastroduodenal stump requires hemostatic maneuvers that spare hepatic arterial flow (21). To this end, we were able to preserve hepatic arterial flow using bare metal or covered stent insertion in three cases in this series without untoward effects on liver function. Finally, it is noteworthy

that a complete hepatic arterial embolization (22) was performed in one case in this series. When coil embolization of the hepatic artery is pursued, however, it is vital to demonstrate the patency of the portal venous system using delayed-phase superior mesenteric arteriography to confirm that adequate liver perfusion will remain intact following arterial occlusion. In our case, there was no clinical or imaging evidence of liver ischemia or infarction following the hepatic arterial embolization in the setting of portal venous patency.

The value of pre-procedure cross-sectional imaging with CT is considerable in complex post-surgical patients. Identifying critical imaging findings, such as vascular abnormalities (pseudoaneurysms), intraperitoneal hematomas, and intraluminal (biliary or enteric) bleeds, may support the need for angiography and may help guide the subsequent arteriography to a particular vascular territory for therapeutic intervention. Cross-sectional imaging was useful in our series of patients because CT identified the culprit pseudoaneurysm in two patients prior to arteriography and directed arteriography to the correct vascular territory in one cases (Fig. 1). As such, we advocate the liberal use of CT imaging for diagnostic evaluation and pre-procedure planning in postoperative bleeding patients.

The major limitations of this study are its retrospective nature and small sample size. The lack of conventional or CT angiographic follow-up to assess the patency of the deployed stent-grafts represents an additional drawback, although extensive clinical follow-up was performed. Despite these limitations, however, the initial results obtained in this series suggest that endovascular therapy with coil embolization and/or stent insertion provides a minimally invasive, safe, and effective method for managing

hemorrhagic events after robotic pancreaticobiliary surgery. The use of endovascular approaches in this setting provides a minimally invasive complement to surgical intervention (which may be challenging in the postoperative period) and allows the patient to benefit from the growing arsenal of minimally invasive procedures offered by surgeons and interventional radiologists alike.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Farney A, Sutherland D. A quick look back at the history of pancreatic surgery. *Ann Surg* 2008; 248:498–499.
2. Giulianotti PC, Sbrana F, Bianco FM, et al. Robot-assisted laparoscopic pancreatic surgery: single-surgeon experience. *Surg Endosc* 2010; 24:1646–1657.
3. Ho CK, Kleeff J, Friess H, Buchler MW. Complications of pancreatic surgery. *HPB (Oxford)* 2005; 7:99–108.
4. Kooby DA, Chu CK. Laparoscopic management of pancreatic malignancies. *Surg Clin North Am* 2010; 90:427–446.
5. Saad WE. Management of nonocclusive hepatic artery complications after liver transplantation. *Tech Vasc Interv Radiol* 2007; 10:221–232.
6. Miura F, Asano T, Amano H, et al. Management of postoperative arterial hemorrhage after pancreato-biliary surgery according to the site of bleeding: re-laparotomy or interventional radiology. *J Hepatobiliary Pancreat Surg* 2009; 16:56–63.
7. Heiss P, Bachthaler M, Hamer OW, et al. Delayed visceral arterial hemorrhage following Whipple's procedure: minimally invasive treatment with covered stents. *Ann Surg Onc* 2008; 15:824–832.
8. Winter JM, Cameron JL, Campbell KA, et al. 1423 pancreaticoduodenectomies for pancreatic cancer: a single-institution experience. *J Gastrointest Surg* 2006; 10:1199–1211.
9. Yeo CJ, Cameron JL, Lillmoen KD, et al. Pancreaticoduodenectomy with or without distal gastrectomy and extended retroperitoneal lymphadenectomy for peripapillary adenocarcinoma, part 2: randomized controlled trial evaluating survival, morbidity, and mortality. *Ann Surg* 2002; 236:355–368.
10. Melvin WS. Minimally invasive pancreatic surgery. *Am J Surg* 2003; 186:274–278.
11. Talamini MA, Chapman WH, Horgan S, Melvin WS; Academic Robotics Group. A prospective analysis of 211 robotic-assisted surgical procedures. *Surg Endosc* 2003; 10:1521–1524.
12. Yekebas E, Wolfram L, Cataldegirmen G, et al. Postpancreatectomy hemorrhage: diagnosis and treatment: an analysis in 1669 consecutive pancreatic resections. *Ann Surg* 2007; 246:269–280.
13. Yamashita Y, Taketomi A, Fukuzawa K, et al. Risk factors for and management of delayed intraperitoneal hemorrhage after pancreatic and biliary surgery. *Am J Surg* 2007; 193:454–459.
14. Gutt CN, Oniu T, Mehrabi A, Kashfi A, Schemmer P, Buchler MW. Robot-assisted abdominal surgery. *Br J Surg* 2004; 91:1390–1397.
15. Miura F, Asano T, Amano H, et al. Management of postoperative arterial hemorrhage after pancreato-biliary surgery according to the site of bleeding: re-laparotomy or interventional radiology. *J Hepatobiliary Pancreat Surg* 2009; 16:56–63.
16. Schafer M, Heinrich S, Pfammatter T, Clavien PA. Management of delayed major visceral arterial bleeding after pancreatic surgery. *HPB (Oxford)* 2011; 13:132–138.
17. Godfrey A. Minimally invasive surgery. Robotic technology speeds recovery and improves outcomes. *JAAPA* 2010; 23:53–54.
18. Kan CD, Lee HL, Yang YJ. Outcome after endovascular stent graft treatment for mycotic aortic aneurysm: a systematic review. *J Vasc Surg* 2007; 46:906–912.
19. Lee WK, Mossop PJ, Little AF, et al. Infected (mycotic) aneurysms: spectrum of imaging appearances and management. *Radiographics* 2008; 28:1853–1868.
20. Lupattelli T, Garaci FG, Basile A, et al. Emergency stent grafting after unsuccessful surgical repair of a mycotic common femoral artery pseudoaneurysm in a drug abuser. *Cardiovasc Intervent Radiol* 2009; 32:347–351.
21. Kadir S, Athanasoulis CA, Ring EJ, Greenfield A. Transcatheter embolization of intrahepatic arterial aneurysms. *Radiology* 1980; 134:335–339.
22. Camerlo A, Turrini O, Marciano S, et al. Delayed arterial hemorrhage after pancreaticoduodenectomy: is conservation of hepatic arterial flow vital? *Pancreas* 2010; 39:260–262.