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Review of Techniques for Pancreatic Surgery

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Abstract

Pancreatic surgery, especially pancreaticoduodenectomy, requires the resection and reconstruction of multiple organs which is a technical challenge. Fine surgical techniques are warranted to reach the R0 resection and reduce morbidity and mortality. However, due to the complicated anatomy and surgical procedure, the postoperative complication of pancreatic resection remains high. Thus, current techniques for pancreatic surgery still need to be optimized to increase the resectability and decrease the postoperative complication. This article intends to provide an overview of techniques for pancreatic surgery.

Keywords: Pancreatic surgery; Surgical techniques; Resection; Reconstruction

After the establishment of Whipple Procedure in 1935, the surgical techniques for pancreatic surgery evolved rapidly with the improvement of surgical skills, radiology, anesthesiology and intensive care. For now, the mortality rates for Whipple procedure can be achieved by less than 5% [1]. Though this procedure has been optimized over time, however, due to the complex anatomy of the pancreas, the overall complication rate for pancreaticoduodenectomy (PD) remains about 40% [2]. Thus, improvements of surgical techniques for pancreas remains urgently needed to increase the resectability and reduce the postoperative complications. This review intends to summarize the surgical techniques of pancreatic surgery and provide some experience for pancreatic surgeons.

Resection

Artery first and uncinate approach

R0 resection of pancreatic cancer exhibits its powerful prognostic prediction for recurrence and survival [3]. Up to date, the involvement of the superior mesenteric artery (SMA) determines the resectability of pancreatic cancer. Standard approach for Whipple procedure is to transect thepancreatic neck first and separate the tumor-harboring head from the body of the pancreas [4]. If the tumor invades the posteromedial tissue around SMA, the standard Whipple procedure will force the surgeons to the do the resection, with high chance of tumor residual and hemorrhage. Artery first approach may be a solution for this dilemma. Artery first approach could evaluate the involvement of SMA and offer the early determination of resectability. Currently, there are several protocols available, including: posterior approach, medial uncinate approach, inferior infracolic or mesenteric approach, left posterior approach, inferior supracolic approach and superior approach [5]. The artery first approach emphasizes the posterior root exposure of SMA and early resection of posteromedial tissue. Moreover, in case of pancreatic body cancer with the lesion adjacent to celiac artery and its branches, artery first approach can also be practiced in distal pancreatectomy to increase the lymphadenectomy around the celiac artery. The techniques for this situation include: 1. Transect of pancreas neck first. 2. Dissect the root of the SMA and perform the lymphadenectomy around SMA. 3. Transection of the spleen vein and artery. 4. Perform the lymphadenectomy around the celiac artery. This procedure will facilitate the R0 resection of distal pancreatectomy. Uncinate process approach was another novel approach advocated by Hackert et al. [6]. It is a retrograde resection of the pancreatic head in a manner of caudo-cranial direction and offers equivalent effect to artery first approach on operation time, blood loss, lymph nodes harvest, margin positivity and operative morbidity [7]. These innovative approaches offer optional weapons for surgeons, however, its long term effect on survival and recurrence requires further validation by large scaled clinical trials.

Venous Resection

Involvement of Superior Mesenteric Vein (SMV) or Portal Vein (PV) by pancreatic cancer is no longer a contradiction for radical resection. Vascular involvement was reported to be an indicator of unfavorable tumor topography, but not a sign of adverse tumor biology [8]. Combined venous resection in PD did neither increase perioperative morbidity or mortality, nor reduce the long term survival [9]. Skillful vascular suture technique is warranted to reduce bleeding, thrombosis and stenosis. It is indicated that anticoagulation policy could not reduce the incidence of early thrombosis [10]. Venous resection includes tangential and segmental resection. It is recommended that tangential resection with primary suture closure is preferred for less than 25% involvement of the circumference, and patch venorrhaphy is generally performed with 25–50% involvement, while segmental resection is needed with the circumferential involvement of greater than 50% [11]. When tumor lesion is close to the converge of SMV and spleen vein, the narrow space will not allow the placement of Satinsky's clamp and perform the tangential resection. In this situation, two paralleling clamps can be used for the occlusion of spleen vein, followed by sharp resection of the vein between two paralleling clamps with the scalpel and simple continuous suture of the defect vein with 5-0 Prolene embedding the clamp (continuous loop suturing). When the first round suturing is done, gently remove the clamp and tighten up the Prolene simultaneously, followed by second round continuous suturing back to origin. This method allows the easy closure of defect of venous wall. For patch venorrhaphy, it was reported that autologous or allogeneic umbilical vein, femoral and saphenous vein, and iliac vein as well as artificial patch can be used for patching or reconstruction [12-14]. For segmental venous resection, direct and tension free end-to-end venous anastomosis could be performed easily by liver mobilization

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and Cattell-Braasch maneuver [15]. In case of longer venous defect or tension anastomosis, patch reconstruction is needed. For venous suture, simple continuous suture of venous wall is generally practiced.

Celiac Axis Resection

Neoplastic lesion located in pancreatic neck or body often extends its extrapancreatic invasion to celiac artery (CA) or/and common hepatic artery (CHA). *en bloc* celiac axis resection was first proposed for extended resection of gastric cancer by Appleby in 1953 [16]. Recent data indicates distal pancreatectomy with *en bloc* celiac axis resection (DP-CAR) could also harvest R0 resection for locally advanced pancreatic cancers located in neck, body, or tail [17-21]. Collateral pathways via the SMA, pancreatoduodenal arcades, and GDA to hepatic artery could maintain the arterial blood supply for liver and avoid liver failure [17]. It is important to confirm sufficient collateral blood flow to the liver by arteriography before resection. Intraoperative temporary occlusion of CHA will reinforce the confirmation of the establishment of retrograde blood supply to liver. For patients with pancreatic cancer, DP-CAR harvested 14 months of median survival time, which was much better than conventional distal pancreatectomy [22].

Mesopancreas Resection

Retroperitoneal invasion, which can be detected in 77% of the cases of the pancreatic head cancer, is one of the major risk factors determining survival [23]. The mesopancreas is a newly described anatomical retroperitoneal conception which aims to achieve similar therapeutic effect as mesorectum and decrease the loco-regional recurrence of pancreatic cancer. It is a firm and well-vascularized structure extending from the posterior surface of the pancreatic head to behind the mesenteric vessels SMV and SMA [24]. Specimen analysis indicated that mesopancreas infiltration was detected in 66.6% cases and represented the most frequent site of noncurative resection [25]. It was reported that total mesopancreas excision increased the harvest of regional lymph nodes around the SMA and decreased the loco-regional recurrence of the pancreatic head cancer [26]. However, the existence of the mesopancreas remains controversial. Agrawal et al. concluded that the fibrous sheath or fascia around the retropancreatic structure, namely mesopancreas, was not founded anatomically [27]. Furthermore, it was indicated that extended mesopancreatic resection could not be accomplished *en bloc* with the PD specimen due to the inexistence of fibrous sheath or fascia and the continuity of the mesopancreatic and para-aortic areas [28].

Reconstruction

PD requires anastomosis of remaining pancreas, common bile duct and stomach to jejunum. Ideal anastomosis requires simple and safe techniques, appropriate caliber, good blood supply, appropriate tightness of the knots tied to avoid cutting, reliable hemostasis and so on.

Pancreatic anastomosis

Pancreatic anastomosis remains the most challenging anastomosis in visceral surgery. Generally, pancreas remnant can be reconstructed with stomach or jejunum, namely pancreaticojejunostomy (PJ) and Pancreaticogastrostomy (PG). It is still controversial to identify either PJ or PG is superior in reducing the postoperative complications after PD. Recent meta-analysis of randomized controlled trials concluded that PG and PJ exerted similar effects on pancreatic fistula, biliary fistula, overall complications and mortality [29,30]. Pancreatic anastomosis is commonly used technique in PD by either invaginating the remaining pancreas or anastomosing the pancreatic duct directly to the jejunum or stomach [31]. Duct-to-mucosa and end-to-side anastomosis are commonly practiced, but show no significant difference in reducing postoperative complications including pancreatic fistula [32]. The incidence of pancreatic fistula does not differ regarding to conventional loop reconstruction or Roux-en-Y reconstruction, and delayed gastric emptying remains similar in terms of antecolic or retrocolic reconstruction [33,34]. Usage of external pancreatic stents in PJ may decrease the postoperative pancreatic fistula and overall morbidity, but increase the loss of the pancreatic juice [35]. Though more than 80 different methods of pancreatic anastomosis were proposed, none of them could exhibit its superiority by reducing the incidence of post-operative pancreatic fistula while the surgical volume of PD was reversely correlated with the incidence of the pancreatic fistula [36,37]. The factors that contributed to the failure of the pancreatic anastomosis were pancreatic tissue texture, surgical technique and the extent of dilatation of the pancreatic duct, while only surgical technique can be optimized [38,39]. The anastomotic quality is much more important than the methods itself. Selection of the familiar anastomotic method and improvement of anastomotic technique are the key points to reduce the incidence of pancreatic fistula after PD. It was indicated that deformation and cutting through the fragile pancreatic parenchyma by compressive and shear forces may contribute to the failure of the anastomosis [40]. Continuous single-layer sutures can also achieve the simple and reliable pancreatic anastomosis. Furthermore, it is recommended to use end-to-side anastomosis to adapt the incision of the jejunum or stomach to fit the pancreatic remnant.

Cholangiojejunostomy

Bile leakage and bile duct stenosis are common short and long term complications of cholangiojejunostomy. In order to facilitate the anastomosis, the transection of the Common Bile Duct (CBD) should be close to the hepatic hilar to avoid possible positive margin, sacrifice of blood supply and distortion of CBD remnant. In case of fine CBD with thin wall, the connective tissue around CBD could be sutured together to the jejunum to reinforce the strength of the anastomosis and reduce the bile leakage. T-tube placement or biliary stent is not necessary while absorbable sutures are recommended. Single layer continuous suture with 3-0 PDS offers reliable and fast anastomosis in our center.

Gastrojejunostomy

Currently, disposable stapler is widely used for gastrointestinal anastomosis. With the respect of complications, stapler was found to be comparable to hand suture, but offered quicker anastomosis time [41]. It is of noting that the hand suture exerts much cheaper medical expense than stapler. Thus, handing suture should still be remained as a routine option for PD as stapler. During the anastomosis, the duodenum stump often exhibits mucosal eversion which influences the smooth suture. The clamped duodenum stump can be cauterized for achieving the hemostasis and the sealing of the duodenum margin to one layer to avoid the mucosal eversion. Furthermore, latest meta-analysis showed that the single layer suture of gastrointestinal anastomosis offered comparable results to double layer in terms of anastomotic leakage, perioperative complications, mortality and hospital stay, but can be achieved quicker [42].

Efferent Loop Decompression

Efferent loop decompression can be achieved by external and internal drainage of pancreatic juice. Recent trials indicated that external drainage of pancreatic duct with a stent could decrease the postoperative pancreatic fistula and closed suction of the drainage will reinforce the preventive effect [43,44]. Recent meta-analysis indicated that routine nasogastric intubation (NGI) offers no benefits for the patients after abdominal surgery, and NGI neither accelerates the recovery of gastrointestinal function, nor reduces the postoperative complications, but results in some undesired effects, such as discomfort (in 60% of the NGI patients) and a later return to a liquid diet [45]. Retrospective cohort analysis indicated that routine postoperative NGI was not mandatory procedure for the majority of the PD patients [46-48]. However, no randomized controlled trials provide solid evidence to exclude the use the NGI, though for some selective patients, NGI could be a therapeutic strategy [47]. Decompression and drainage are the main two reasons for the application of NGI. Intra-gastrointestinal distension may lead to the edema or ischemia of the anastomosis, affect its healing and cause perforation or leakage. Thus, the placement of the NGI must exert its direct decompressive effect on the efferent loop. It may be appropriate to extend the remote end of nasogastric tube to the pancreatic stump (Child). As a result, the NGI could decrease the tension of the whole efferent loop. When the leakage happens, the NGI could exhibit its internal decompression effect. Compared to external drainage, internal NGI may exhibits similar decompressive effect, but more convenient and simple surgical procedure.

Minimally Invasive Pancreatectomy

It was previously indicated that laparoscopic pancreatic anastomosis represented the independent factor for postoperative complications, thus, laparoscopic approach was recommended for benign pancreatic tumors not requiring pancreaticoenteric reconstruction [49]. With the advances in technology, laparoscopy can duplicate all open pancreatic resections [50].

Laparoscopic distal pancreatectomy in selected patients showed its rational superiority in reducing intraoperative bleeding and early recovery after operation [51,52]. Laparoscopic PD (LPD) is still not universally accepted because of its technical difficulty and lengthy learning curve [53]. Intraoperative bleeding and difficult dissection contributed to the main reasons for the conversion of open surgery [54]. It was reported that LPD showed no significant difference in terms of overall complications and oncological margins, but longer operative time [55]. The interesting concern about its survival benefits is yet to be answered by prospective randomized controlled trials. Robotic PD was also practiced recently in a manner of robotic, robotic-assisted, robot-assisted laparoscopic and robotic hybrid. Though robotic PD showed its safety and feasibility in highly selected patients, lack of technical standardization and small volume of case series with robotic PD make it difficult to draw an objective conclusion on this novel approach [56]. Further investigations are required to evaluate its survival benefit, perioperative complications and cost-effectiveness [57].

Management of Postoperative Complications

Postoperative bleeding

Incidence of postoperative bleeding varies about 1% to 8%, but the mortality rate is as high as 18% to 47% [58,59]. Generally, postoperative bleeding occurs within 3 days (early bleeding) or 8 days later (delayed bleeding) [60]. Early bleeding is usually related to the defects of the surgical technique, while delayed bleeding is often caused by pancreatic fistula, pseudoaneurysm formation, or abdominal infection [61]. Common bleeding site after pancreaticoduodenectomy includes: pancreaticojejunostomy, gastrointestinal anastomosis, GDA stump, and pancreatic stump. Common causes of bleeding include: Tight ligation of artery causes the cutting of the vascular wall and induces the formation of pseudoaneurysm; Coagulated eschar detaches from the pancreas stump and triggers delayed bleeding; Over-squeezing of mechanical stapler leads to the damage of gastrointestinal anastomosis; Pancreatic leakage causes the erosion of skeletonized vessels; vascular thermal injury. Solutions include: avoidance of direct clamping artery; appropriate ligation of artery; reliable suture to stop bleeding of pancreas stump; proper usage of the stapler; coverage of pancreatic anastomosis by omentum to prevent the direct erosion of vessels by pancreatic juice. Once bleeding happens, 80% patients can be treated conservatively including endoscopy or embolization, and ensuing emergency laparotomy should be performed for patients with severe or recurrent bleeding [61].

Pancreatic fistula

According to the International Study Group on Pancreatic Fistula (ISGPF), Postoperative Pancreatic Fistula (POPF) is defined as drainage output of any measurable volume of fluid on or after postoperative day 3 with an amylase content greater than 3 times the serum amylase activity [62]. According to ISGPF criteria, about 20% of the PD will develop POPF with 20% grade A fistula, 70% grade B and 10% grade C [63]. The main risks for POPF are the induction of subsequent intra-abdominal abscess and the erosion of neighboring tissues including vessels, with a mortality rate of 40% or more [64]. Prevention of POPF will not only reduce postoperative mortality but also decrease the medical expense. It is suggested that the failure of healing/sealing of the pancreatic anastomosis or wound contributes to the POPF [62]. Surgical attention must be paid to avoid the ischemia of anastomosis and obstruction of distal jejunum. Moreover, reinforcement of the sealing could offer extra sealing of the pancreatic anastomosis or wound. Choi et al. reported that omental roll-up technique around pancreaticojejunostomy offered low incidence of POPF and early removal of drainage [65]. In case of distal pancreatectomy, the omentum can directly be sutured in the pancreatic stump, and the stump closure could be done by the stapler without increasing the POPF, with an exception of pancreas thicker than 12 mm [66,67]. Hackert et al. suggested the flap plasty of the tereshepatis ligament could be used for the coverage of the localized pancreatic wound [68]. Zhou et al. indicated that ligamentum teres hepatis patch did not reduce the incidence of POPF, but promoted the recovery of POPF after distal pancreatectomy [69]. Moreover, it was reported that the coverage of the pancreatic remnant after distal pancreatectomy by falciform ligament could decrease the rate of POPF [70]. Peripancreatic external drainage is important for the treatment of the POPF. We recommend the placement of two drainage tubes at the anterior and posterior pancreatic anastomosis. This will allow the maximal drainage of pancreatic juice when fistula happens. If the conservative therapy fails, we recommend the biliopancreatic diversion procedure. This procedure emphasizes the re-establishment of pancreatic anastomosis by Roux-en-Y reconstruction.

Conclusion

Pancreatic surgery is a sophisticated procedure that involves visceral and vascular surgical techniques which must be handled by experienced surgeons. Though the general protocol of pancreatic surgery has been fixed, its detailed management still requires improvement to increase the resectability and decrease the postoperative complications.

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