



## 腹腔镜胰腺切除术中静脉重建方法的选择及预后\*

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**【摘要】** 胰腺癌是一种高度恶性、预后极差的消化系统肿瘤,其早期隐匿,发展迅速,确诊时经常侵犯周围重要血管,因此胰腺切除术中常需要联合门静脉和(或)肠系膜上静脉的切除重建。目前有多种静脉切除重建的方法,各有其优缺点和适用性,但总体相较开放手术,腹腔镜下胰腺手术对技术的要求更高,决策需求更加精准。为了促进腹腔镜胰腺切除术中静脉重建技术的进步,本文结合团队实践经验和文献报道对重建取材、操作难度、风险、近远期通畅性等方面进行了总结和评价,着重讨论了不同方式和材料的适用性。此外,针对术后重建静脉通畅性,介绍了本团队模仿冠状动脉通畅程度的评价模式所提出但尚未得到外部验证的“横截面积法”,用以精确定量术后静脉通畅情况。通过总结腹腔镜胰腺手术中静脉重建方法的选择和预后现状,未来有望提出腹腔镜胰腺手术静脉切除重建的技术规范,并个体化地评估患者术后静脉通畅情况,推动胰腺微创手术技术进步和提高患者的长期预后。

**【关键词】** 胰腺切除术 腹腔镜检查 移植物闭塞,血管 综述

## Selection and Prognosis of Different Venous Reconstruction Methods in Laparoscopic Pancreatectomy

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**[Abstract]** Pancreatic cancer is a highly malignant tumor of the digestive system and has an extremely poor prognosis. Due to its insidious onset and rapid progression, major surrounding vessels are frequently invaded at the time of diagnosis. Consequently, resection and reconstruction of the portal vein and/or superior mesenteric vein are often required during pancreatectomy. Various methods of venous resection and reconstruction have been developed, each with its own advantages, limitations, and specific applicability. Compared with open surgery, laparoscopic pancreatectomy requires higher technical proficiency and more precise intraoperative decision-making. To promote the advancement of venous reconstruction techniques in laparoscopic pancreatectomy, in this article, we summarize and evaluate our team's practical experience and relevant literature, focusing on graft selection, technical difficulty, operative risk, and short- and long-term patency. Special emphasis was placed on the applicability of different approaches and materials. In addition, regarding postoperative reconstruction of venous patency, we introduced the "Cross-sectional Area Algorithm", a method simulating the evaluation mode of coronary artery patency, to accurately quantify postoperative venous patency. The evaluation method was first proposed by the team but has not yet been externally validated. By reviewing the current status of venous reconstruction strategies and the prognosis of laparoscopic pancreatic surgery, we aim to inform the development of standardized technical guidelines, enable individualized assessment of venous patency after surgery, and ultimately improve minimally invasive pancreatic surgery and the long-term prognosis of patients.

**[Key words]** Pancreatectomy Laparoscopy Graft occlusion, vascular Review

胰腺癌是一种高度恶性、预后极差的消化系统肿瘤,其早期隐匿,发展迅速,发病率约为1/100 000~10/100 000,在全世界范围内和中国的死亡率位于所有癌症中第6位<sup>[1-3]</sup>。胰腺位于左上腹部的后腹膜腔内,居于胃后,横行于腹后壁,其解剖特点为多支血管自然穿行其中,相对于腹部其他实质性脏器,胰腺较小而薄,因此胰

腺肿瘤侵犯周围血管为常见事件<sup>[4]</sup>。相对于多发的动脉侵犯,胰腺中部穿行的门静脉(portal vein, PV)、肠系膜上静脉(superior mesenteric vein, SMV)、脾静脉(splenic vein, SV)侵犯并不属于切除禁忌,可以在胰腺切除术中联合切除和重建<sup>[5-6]</sup>。

根据国际胰腺外科研究组(International Study Group of Pancreatic Surgery, ISGPS)的共识,胰腺切除术中静脉切除重建方法分为4种类型,对于血管侧壁切除,分为1型侧壁缝合(tangential suture)和2型补片(patch)成形;针

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对血管节段切除,可分为3型端端吻合(end-to-end anastomosis)和4型间置血管修补材料架桥(interposition grafting, IG)<sup>[7]</sup>。当术中发现静脉切口缺损大和(或)静脉切口张力过高,无法侧壁缝合/端端吻合时,则需要血管修补材料,其选择包括人造血管、自体静脉、自体腹膜组织等。

腹腔镜胰腺手术是外科史上重要的技术进步,代表着胰腺外科也进入了微创时代<sup>[8]</sup>。相较开放手术,腹腔镜胰腺切除术中PV/SMV静脉切除技术的发展历史稍短。较早于2011年由美国KENDRICK教授报告,其中包括10例侧壁切除和1例节段切除,1个月后通畅性为100%<sup>[9]</sup>;2014年,其又报道了一项关于胰十二指肠切除术(pancreaticoduodenectomy, PD)联合PV/SMV切除的对照研究,其中31例患者采用腹腔镜手术,58例患者行开放手术,术中平均静脉阻断时间分别为46.8 min和25.1 min,但术后并发症率、死亡率相似,重建血管通畅性、生存时间并无明显差异<sup>[10]</sup>。此后,腹腔镜胰腺切除联合静脉切除重建逐步在高水平、大容量胰腺中心得到推广应用,安全性也逐渐得到确认<sup>[5, 11-12]</sup>。

总体而言,相比于开放手术,腹腔镜下胰腺切除术重建静脉对技术的要求更高,决策需求更加精准,各中心往往以主刀医生的经验判断为准<sup>[13]</sup>,尚未有研究系统地论述其技术难点和总结各重建方式的选择。因此,本文结合团队实践经验和文献报道对重建取材及操作难度、风险、近远期通畅性等方面进行比较和评价。此外,针对术后重建静脉通畅性,介绍了本团队模仿冠状动脉通畅程度的评价模式提出的“横截面积法”,用以精确定量术后静脉通畅情况。通过总结腹腔镜胰腺手术中静脉重建技术的选择和预后现状,旨在为腹腔镜胰腺手术技术规范完善提供一定参考依据。

## 1 腹腔镜胰腺切除术中联合静脉切除的技术特点和难点

### 1.1 张力控制困难

张力控制是技术层面最大的难点。开放手术中术者可通过手法下降肝脏、上推肠系膜减少重建静脉的张力,但腹腔镜手术中较难实现此步骤;当需要PV/SMV切除时,小肠系膜需要经充分游离而肠系膜上动脉(superior mesenteric artery, SMA)需要被骨骼化,小肠重力施加于PV/SMV,加之头高足低位,静脉离断后,断端距离会因重力原因大大增加;另一方面,静脉切除后血管两端需要助手牵拉靠拢,在腹腔镜手术中也很难完美配合;此外,在张力高时,血管连续缝合时缝线的牵拉也会导致薄

弱的血管撕裂。

同时,腹腔镜手术需要维持气腹状态和头高足低位,气腹直接升高腹内压(intra-abdominal pressure, IAP)影响血管状态。猪的磁共振成像(magnetic resonance imaging, MRI)图像上显示,气腹引起IAP>14 mmHg(1 mmHg=0.133 kPa)将直接引起下腔静脉和PV的纵向管腔狭窄(longitudinal diameter),但PV横径(transverse diameter)无显著性减小<sup>[14]</sup>。同时,头高足低位而无气腹时,观察到PV截面积增加,但将IAP升高至14 mmHg后, PV管腔却相对于水平体位显著缩小,表明IAP对PV的影响强于体位改变<sup>[15]</sup>。临床中也发现, IAP>7 mmHg起, PV直径、平均血流量和速度已经出现显著下降<sup>[16]</sup>。

因此,笔者团队认为腹腔镜气腹状态下,相对薄弱的静脉血管壁受到力学和生理上的影响,其环向应力和纵向回缩力可能上升;既往理论研究也表明,静脉内外部机械性压力的增大将导致其产生一定程度的塌陷和扭曲<sup>[17]</sup>,种种变化或可引起断端/吻合口的“失真”,遗憾的是气腹与张力的直接关系目前尚未得到研究。但是可以确认的是,胰腺手术涉及脏器较多,降低气腹会显著影响腹腔镜手术视野的暴露,增加操作难度,尤其当静脉阻塞导致系膜和肠壁水肿后,此举将直接增加血管损伤风险。

### 1.2 准确测量难题

当需要修补成形时,首先需要测量血管缺损,修补的材料也需对应进行适当剪裁。开放手术可以直接将材料与缺损对应和固定修剪,腔镜手术中缺乏较好的测量尺度和工具以及固定方法。笔者团队目前术中常采用丝线对比修剪的简便方法,利用丝线作为标尺测量对比血管缺损,以实现补片的合适剪裁(图1)。

### 1.3 暴露和操作

腹腔镜胰腺手术患者体位为头高足低位,但此体位当PV/SMV离断后小肠重力原因会增加血管两端张力;此外,腔镜静脉重建操作时间显著长于开放手术,长时间静脉阻断将导致肠系膜淤血水肿,进一步增加暴露难度;因此,术中可适当放平患者体位,或采用侧方腹腔镜套针(trocar)进入镜头以增加缝合器械操作角度,或适当阻断SMA减少淤血水肿等技巧控制张力。

## 2 胰腺切除术中PV/SMV切除重建方法的评估要素

### 2.1 重建质量评估重点

手术重建的质量评估主要包括技术层面和预后层面,技术层面包括经济性、取材难度、操作难度、操作时间(血管阻断时间);预后层面包括术后早期安全性和重

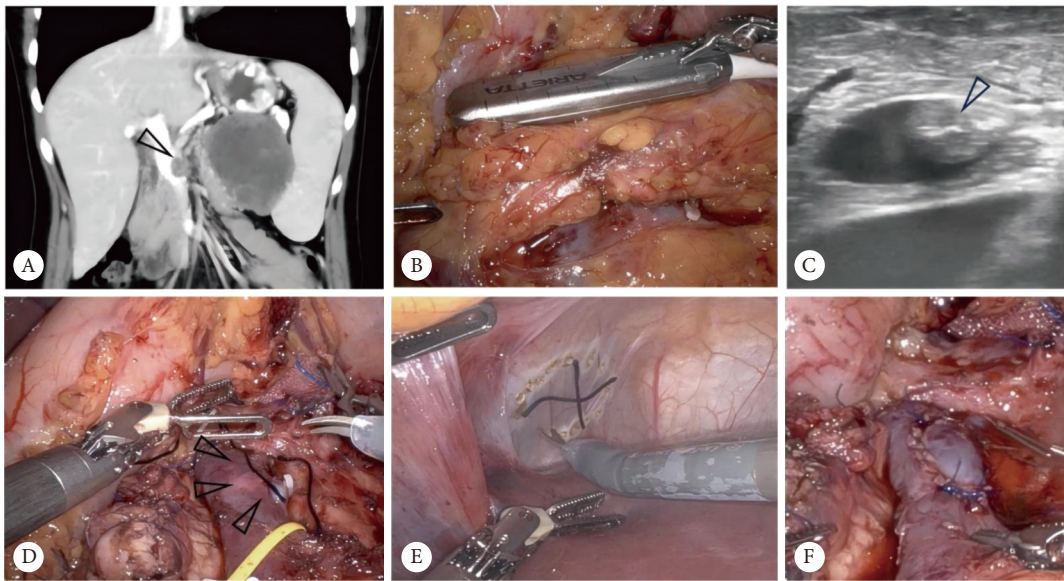


图1 腹腔镜下测量血管缺损和获取准确尺寸补片的简便方法

Fig 1 A simple method for measuring vascular defects and obtaining accurate size patches under laparoscopy

A, CT shows a tumor thrombus (hollow arrow) at the portal vein opening where the splenic vein meets. B and C, Intraoperative ultrasound localization of tumor thrombus. D and E, Sutures were used to measure the possible incision size. F, Reconstruction completed.

建血管的通畅性两方面,其中安全性和技术层面因素直接相关,而血管通畅性不仅与技术层面密切相关,还与术后抗凝及护理、引流管放置、肿瘤复发情况等多因素有关。一般而言,术后重建PV/SMV发生急性完全闭塞,且伴有如SV、SMV的离断,会导致急性SMV栓塞的临床表现,包括回流障碍导致的肠壁淤血水肿、腹压增高、大量腹水,以及入肝血流减少所导致的肝功能障碍,甚至会导致低血压、酸中毒以及急性肾功能不全,严重时危及生命;但亚急性、慢性、不完全性的血管闭塞,多不会引起非常显著的临床症状,表现为患者一般状态较差、腹部不适、胃肠功能恢复慢,CT显示侧支循环形成、腹水、脾大等表现<sup>[18]</sup>。术后抗凝是重要的血管重建后预防措施,但目前研究少有报道术后抗凝策略,且各中心抗凝措施异质性较大,以至于较难比较抗凝对血管重建结果具体的影响<sup>[19]</sup>。

## 2.2 重建静脉通畅性的科学、定量评估

在临床实践工作中,常常用术中超声或加超声多普勒加以初步判断,术后使用CT或超声对血管重建结果进行评估。超声对于判断流速、流量有独特价值,但对于评估血管走行路径的全貌,受到显著限制,同时也受检测者操作和检测位置选择的影响;MRI亦与CT评估效果类似,但经济和时间成本高于CT,因此使用CT是相对更可靠的客观方法<sup>[20]</sup>。

对于胰腺切除术后重建静脉的通畅性评估,总体认为直接吻合优于自体血管,后者又优于人造血管。但目

前文献普遍缺乏科学、定量的通畅效果评估方法<sup>[21]</sup>。目前的研究大多在结局中笼统声明重建血管的通畅与否,即术后重建血管未完全堵塞的患者记录为“通畅”,将被记录为“通畅”患者数与整组患者数的比率用于不同静脉切除术式效果的比较,而不是基于每个个体的术后血管通畅状态,即“通畅比率”(overall patency)。与此同时,部分研究术后利用CT或超声评估重建血管的直径变化,将重建节段直径减小的现象定义为狭窄(stenosis)。

重建静脉的通畅性定义应当是重建血管和正常血管之间的面积比,如此有利于科学评估静脉重建效果。模仿国际公认的冠状动脉通畅效果的评估算法,笔者团队采用横截面积法(cross-sectional area algorithm, CSAA)评估PV/SMV通畅率,在术后CT和(或)MRI影像中,采用Syngo软件(SIEMENS, Munich, Germany)自动选取和计算目标静脉的最狭窄处截面积和远端正常静脉的截面积,两者相比即可得到量化通畅率(quantitative patency),使得每个患者重建静脉的通畅性得以定量评估<sup>[22]</sup>,但此方法尚未得到外部验证,且计算的复杂性较前增加。

## 3 胰腺切除术中PV/SMV静脉不同重建方法的比较

由于上述困难,目前临床上仍缺少公认的重建技术指南,因此笔者团队将针对腹腔镜手术中重建术式的选择,以及不同血管替代物的适用领域两项临床问题,结合团队多年临床实践经验(图2)和既往文献报道,分别就其

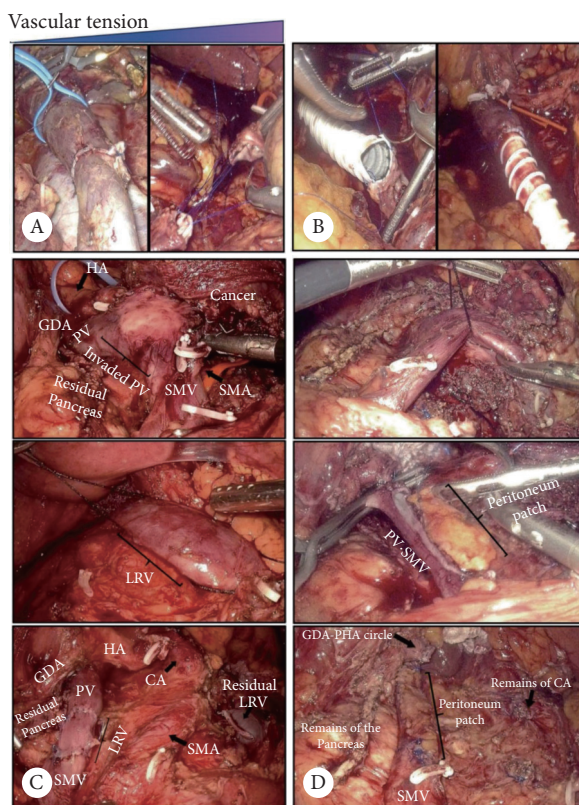


图 2 腹腔镜下不同重建方法的术中展示

Fig 2 Intraoperative demonstration of different reconstruction strategies in laparoscopic pancreatotomy

HA: hepatic artery; GDA: gastroduodenal artery; SMA: superior mesenteric artery; LRV: left renal vein; CA: celiac axis; PHA: proper hepatic artery. A, Surgical records of direct end-to-end anastomosis from two patients, with moderate vascular tension on the left and high tension on the right. B, Interposition grafting using artificial vascular grafts to bridge portal vein (PV)-superior mesenteric vein (SMV) during surgery. C, Laparoscopic distal pancreatotomy combined with portal vein resection in which left renal vein graft was used to accomplish tension-free reconstruction. D, A case with tumor invasion into the abdominal trunk and PV-SMV long sidewall in which peritoneum patch was used for PV-SMV reconstruction during operation.

经济性、取材难度、操作难度、操作时间(尤其血管阻断时间)进行比较,并对相关危险度、重建血管的通畅性进行简要述评。

### 3.1 端端吻合(3型)

端端吻合术式选择将离断的静脉直接相接,理论上其通畅性高于采用修补材料,且无需额外取材和花费,只需单一吻合口,操作时间减半,但实际操作难度非常极端,从低到很高(+~+++ )均有可能,对应的手术风险也相应不同(+~+++),极端情况下甚至可能为最危险的重建方法。

如前所述,切除后的张力及张力控制难题是手术难度大和风险高的主要原因。由于腹腔镜手术较难像开放手术可以利用一些操作手段减少两端张力,当切除血管短、张力低时,吻合难度低、耗时短、安全性高;但当切除

血管长、张力高时,吻合难度随之增加,耗时显著延长,而且强力牵拉会导致血管撕裂,有时需要被迫重新吻合或更换修补材料,或者强行牵拉勉强完成吻合导致PV/SMV急性狭窄,造成肠道淤血水肿、酸中毒、低血压休克,甚至有术后急性肝肾功能衰竭死亡的风险。笔者团队1例患者术中行SMV切除端端吻合,因张力高,血管进针处撕裂,失败后临时更换人造血管,术中PV/SMV阻断时间70 min,导致严重小肠淤血、酸中毒和低血压。

因此,术中血管张力的预测和评估对于端端吻合术式尤为重要,其往往与肿瘤侵犯的长度、部位、患者体位相关,其中肿瘤侵犯引起的移行张力从PV至SMV呈增加趋势。术中通常可以尝试适当放平体位,切断SV、助手辅助牵引等手段控制张力。但当术中发现血管断端难以靠拢时,需果断放弃直接端端吻合。此外,由于直接吻合必然存在张力,术后需适当增加卧床时间减少小肠重力牵拉静脉吻合口。

### 3.2 人造血管架桥(4型)

人造血管需要提前准备额外的材料和费用,但术中无需额外取材,该方式便利性较高。成人的人造血管替代PV/SMV通常为8 mm直径的尼龙或聚四氟乙烯(polytetrafluoroethylene, PTFE)材质,其中带环的人造血管支撑力更好,但螺旋环导致血管顺应性差,缝合难度稍高;无环的血管顺应性好,易缝合,但支撑力较差。同时,血管架桥需上下两个吻合口,引起阻断时间增加。人造血管术后存在急性血栓和植入物感染的风险(因胰腺手术存在高胰瘘和腹腔感染风险)。其通畅性理论上不如直接吻合和自体血管,但临床中应用并不少见,经过术后抗凝治疗,一些研究认为其通畅性也有一定保障<sup>[18,23]</sup>。

胰腺切除术采用人造血管替代PV/SMV已有不少文献报道<sup>[24-31]</sup>(表1),笔者团队也于2016年报道7例,其中2例于术后30 d内出现血栓<sup>[27]</sup>。此外总体而言,术后移植感染并不是显著的问题。

### 3.3 自体静脉架桥(4型)

自体静脉架桥理论上通畅率优于人造血管,常用于临床选择的自体血管包括:颈内静脉(internal jugular vein, IJV)、SV、左肾静脉(left renal vein, LRV)。

IJV取材需额外手术区域;SV术中需要额外和胰腺体尾部做长段分离,且当患者伴随胰腺慢性炎症时,难度大幅增加,并可能造成左侧PV高压。LRV具有合适直径,理论上可取6~10 cm长度,并能保留左侧肾上腺静脉和生殖静脉代偿,不影响左肾静脉回流,在文献中<sup>[32-36]</sup>推荐较多(表2)。其他静脉如股静脉等使用则相对较少<sup>[37-38]</sup>。

但在笔者团队的实践中,1例患者术中行胰体尾切除

表 1 胰腺切除术中人造血管用于PV/SMV重建的文献报道

Table 1 Published reports on artificial vascular grafts in PV/SMV reconstruction during pancreatotomy

Study	Material (type)	Mortality	Thrombosis*	Patency
LIAO (2014) <sup>[24]</sup>	PTFE (IG): n = 34	1 in hospital	1 ≤ POD30, 5 > POD30	Estimated overall patency: 30 (87.9%) at POM6
GLEBOVA (2015) <sup>[25]</sup>	PTFE/Dacron (IG): n = 6	0 in hospital	3 ≤ POD100	Overall patency: 3 (50%) at POD100
FLIS (2016) <sup>[26]</sup>	Dacron (IG): n = 8	/	0 in hospital	/
GAO (2016) <sup>[27]</sup>	PTFE (IG): n = 7	0 in hospital	2 ≤ POD30, 5 > POD30	Stenosis > 50%: 3 (42.9%) at POD30
DUMITRASCU (2018) <sup>[28]</sup>	PTFE (IG): n = 19	/	3 in hospital	/
TSIOTOS (2019) <sup>[29]</sup>	PTFE (IG): n = 13	/	0 in hospital	Overall patency: 13 (100%) at POM2
GARNIER (2021) <sup>[30]</sup>	PTFE (IG): n = 19	1 ≤ POD30	2 ≤ POD30	Overall patency: 13 (68.4%) at POM6
VUORELA (2024) <sup>[31]</sup>	BP (Patch): n < 52	0 in hospital	0 at POD90	/

IG: interposition grafting; PTFE: polytetrafluoroethylene; POD: postoperative day; POM: postoperative month; BP: bovine pericardium. \* Venous reconstruction related thrombosis (excluding distant thromboembolism).

表 2 胰腺切除术中自体血管用于PV/SMV重建的文献报道

Table 2 Published reports on autologous vessel grafts in PV/SMV reconstruction during pancreatotomy

Study	Material (type)	Mortality	Thrombosis*	Patency	Donor-site morbidity
LOVEDAY (2019) <sup>[32]</sup>	LRV (End-to-end): n = 6; LRV (IG): n = 11	/	4 in hospital	/	AKI: 5 (29.4%) at POD1, 3 (17.6%) at POD3
PANTOJA (2019) <sup>[33]</sup>	SV (IG): n = 13; IJV (IG): n = 5	0	2 in hospital; 2 in hospital	Follow-up primary patency: 63% in SV; 65% in IJV	Seroma: 1 (7.7%) in hospital in SV
TERASAKI (2019) <sup>[34]</sup>	EIV (IG): n = 25	0	1 ≤ POM12	Stenosis > 70%: 4 (16%) at POM12	/
FOGLIATI A (2023) <sup>[35]</sup>	LRV (IG): n = 59; LRV (Patch): n = 1	3 ≤ POD90	2 in hospital	Overall patency: 47 (78.3%) at POM6	AKI: 31 (50.8%) in hospital
IRFAN (2025) <sup>[36]</sup>	LRV (IG): n = 41	2 ≤ POD90	4 in hospital	/	Median SCr increased 15.7% at POD1, 39 (95.1%) recovery at discharge

LRV: left renal vein; IG: interposition grafting; AKI: acute kidney injury; POD: postoperative day; SV: saphenous vein; IJV: internal jugular vein; EIV: external iliac vein; POM: postoperative month; SCr: serum creatinine. \* Venous reconstruction related thrombosis (excluding distant thromboembolism).

联合腹腔干切除、联合SMV节段切除, 取LRV架桥, 尽管保留了左侧肾上腺静脉和生殖静脉, 但术后增强CT发现左肾灌注下降, 术后复查血清肌酐水平虽无异常, 但左肾肾小球滤过率与右肾相比显著持续下降, 在术后第7天分别为23.7 mL/min和30.8 mL/min, 第40天分别为42.7 mL/min和55.5 mL/min。静脉通畅率方面, 量化评估术后第2天、第8天、第40天分别为80%、10%和0%, 后期完全闭塞和显著侧支循环形成, 来自静脉吻合处的胰腺残端包裹性积液可能是压迫导致血管闭塞因素之一。

### 3.4 自体组织 (2型或4型)

自体组织理论上组织相容性好、易获取, 常用的包括自体腹膜、镰状韧带和肝圆韧带<sup>[22, 39-41]</sup>(表3)。自体腹膜

易于获取, 有足够的面积充分剪裁, 一篇文献报道其用于2型通畅比率好于4型(100% vs. 33%), 但大多文献无论2型或4型通畅比率均良好<sup>[42]</sup>。同时, 部分术者也使用过镰状韧带和肝圆韧带作为材料。笔者团队也曾尝试不同移植材料, 1例采用髂窝腹膜、1例采用镰状韧带进行2型PV/SMV重建的患者, 其术后CT静脉造影(computed tomography venography, CTV)显示, 重建血管出现了一定狭窄, 侧支循环快速形成; 但超声检测发现向肝血流充盈良好, 其肝功能不受影响, 推测门静脉血流或许会因侧支循环的形成而得到明显改善。

在笔者团队的一项对照研究中, 对比了腹腔镜下使用自体腹膜重建PV/SMV(2型或4型, 6例)与PV/SMV直

表 3 胰腺切除术中自体组织用于PV/SMV重建的文献报道

Table 3 Published reports on autologous substitute in PV/SMV reconstruction during pancreatotomy

Study	Material (type)	Mortality	Thrombosis*	Patency
SHAO (2021) <sup>[39]</sup>	FL (Patch): n = 13	0 at POD90	0 at POM6	Overall patency: 13 (100%) at POM6
De PAUW (2023) <sup>[40]</sup>	PP (Patch): n = 14; PP (IG): n = 1	0 in hospital	1 at POD30	Overall patency: 93.3% at POD7, 53.3% at POW12
ZHU (2023) <sup>[41]</sup>	LTH (Tangential/Patch/IG): n = 26	2 ≤ POD30	/	Overall patency: 26 (100%) at POM12; stenosis < 50%: 5 (19.2%) at POM12
YAN (2024) <sup>[22]</sup>	PP (Patch): n = 5; PP (IG): n = 1	0 at POM3	/	Median quantitative patency: 18.51% at POM3

FL: falciform ligament; PP: peritoneal patch; IG: interposition grafting; POD: postoperative day; POM: postoperative month; POW: postoperative week; LTH: ligamentum teres hepatis. \* Venous reconstruction related thrombosis (excluding distant thromboembolism).

接端吻合(3型, 8例)的血管近远期通畅性,发现两组量化通畅率均显著下降,且自体腹膜组通畅比率(18.5%)显著低于直接端吻合组(46.5%)<sup>[22]</sup>。

除此之外,笔者团队曾尝试术中切除的胆管是否可以作为静脉重建的材料。在猪的动物实验中,笔者团队发现当用其进行颈内静脉和PV修补时,尽管出现了小的血栓形成,但重建血管总体通畅。但利用胆管进行PV/SMV架桥时,缺少血液供应,重建节段会出现瘢痕纤维化,最终导致管腔狭窄和坏死,尝试失败<sup>[43]</sup>。

#### 4 血管替代物的基本要求及自体重建材料通畅率不良原因分析

一种理想的静脉替代材料,理应具备类静脉的生物学特征。生理学上,替代血管应具有组织相容性、可存活性和潜在的内皮化能力,内皮化的微观转变将使之与血管残端组织充分吻合,保证了残端血管内皮细胞的存活并提供一定血栓抑制能力;同时,物理学上其也应具备足够弹性和顺应性,提供足够的支撑力以对抗张力。

因此,理论上自体血管和组织(腹膜)组织相容性好,通畅率会优于人造血管,但在笔者团队较多的实践中,发现通畅率显著低于文献报道,其原因可能在于:①目前的文献中普遍缺乏科学的量化评估方法,而“横截面积法”会放大通畅率差异,例如笔者团队1例腹腔镜下胰十二指肠

切除联合PV/SMV进行直接吻合(3型)患者,CTV重建虽目测良好,可定义为完全通畅,但如采用面积比量化评估,重建段直径约7.3/8.6 mm(短径/长径),远端自然血管段直径约8.8/11.0 mm,虽直径接近,但截面积分别为49.4 mm<sup>2</sup>和77.3 mm<sup>2</sup>,量化评估通畅率仅为63.9%<sup>[22]</sup>;②自体血管或组织脱离其自然血供后,会引起缺血、纤维化问题;③自体血管及组织质地柔软,缺乏足够的支撑力和抗张力,作为静脉修补物,管腔内压也不足,在胰腺术后,特别容易受到局部积液、胰瘘后组织瘢痕、引流管压迫等外力压迫导致狭窄闭锁。

#### 5 腹腔镜胰腺切除术联合PV/SMV切除重建方法的选择和个人推荐

综上所述,各种重建方法各有其优缺点,结合腹腔镜胰腺切除术的特点,直接吻合理论上最好,但可能是实践中难度最大和最危险的方法;人造血管虽理论上存在一定的血栓和感染风险,且通畅性中等,但来源方便无需额外修剪时间,在4型修补中优选;自体血管需额外损伤供血管器,要求额外取材时间,通畅率存疑,临床中应谨慎采用;自体腹膜虽通畅率存疑,但优点突出,取材方便可任意剪裁,在2型修补中可以采用(表4)。此外,无论选择何种重建方式,如能保证短期回流,即使延期出现狭窄闭塞,由于侧支循环形成,多不会造成严重后果。

表 4 腹腔镜下胰腺切除术中PV/SMV切除重建方法的比较和推荐

Table 4 Comparisons of and recommendations for PV/SMV resection and reconstruction methods in laparoscopic pancreatotomy

Index	Direct reconstruction (type 1/3)	Vascular substitutes (type 2/4)		
		Artificial vessel	Autologous vessel	Autologous tissue
Common material	Vascular stump	PTFE	LRV	PP
Harvesting difficulty	+	++	+++	++
Time	+...+++	++	++	++
Risk	Depends on the tension	Poor compliance	Requires vessel harvesting	Requires vessel crafting
	+...+++	++	++	+
Other limitations	Tension = Difficulty	Foreign material, infection, and long-term anticoagulation required	Extra injury and latent functional compromise at donor site	Extra injury
Patency	+++	++	+	+
Priority level	First choice for low tension	First choice for type 4	/	First choice for type 2
Recommendation	+...+++	++	+	++

PTFE: polytetrafluoroethylene; LRV: left renal vein; PP: peritoneal patch. The number of plus (+) signs corresponds to the intensity, graded from low/mild (+) to high/strong (+++).

#### 6 总结与展望

腹腔镜胰腺切除术中的PV/SMV切除重建,关系微创手术患者的短期安全和远期预后,并直接影响患者的手

术获益。目前的研究表明,联合静脉切除重建并不会显著增加患者手术方面的死亡风险<sup>[5, 7, 44-45]</sup>,但部分研究会增加术后并发症的发生风险<sup>[46]</sup>。与此同时,新辅助治疗日新月异的发展使更多的患者获得了手术机会,新辅

助治疗后患者的腹腔内情况往往更加复杂,尤其是当静脉合并动脉侵犯时,对外科医生的技术要求会更高<sup>[47-48]</sup>。专业胰腺外科医生需掌握各种重建方式,合理决策,一方面需要考虑血管重建通畅的病理生理学基础,另一方面需要根据距离和张力选择是否采用血管修补材料,并根据便捷性、支撑力和顺应性选择血管修补物种类。急性狭窄影响患者近期安全,远期通畅性则影响患者术后并发症的发生和生活质量。

同时,笔者团队的临床实践中亦有一定局限性,如采用异种血管如牛心包较少<sup>[49]</sup>,且未尝试过同种异体冻存血管<sup>[50-51]</sup>。笔者团队推荐的血管通畅性的“横截面积法”定量测定,尚未在其他胰腺相关文献中规范采用。胰腺切除术中重建静脉的通畅性评估,仍亟需建立公认且科学的定量评估方法。

综上所述,本文总结了目前研究中对于腹腔镜下静脉重建技术的选择和预后现状,并分享了本团队临床实践经验,希望能够为推动微创胰腺手术技术进步和促进患者手术获益做出些许贡献。

\* \* \*

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## 参 考 文 献

- [1] STOOP T F, JAVED A A, OBA A, *et al.* Pancreatic cancer. *Lancet*, 2025, 405(10485): 1182-1202. doi: 10.1016/s0140-6736(25)00261-2.
- [2] BRAY F, LAVERSANNE M, SUNG H, *et al.* Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin*, 2024, 74(3): 229-263. doi: 10.3322/caac.21834.
- [3] HAN B, ZHENG R, ZENG H, *et al.* Cancer incidence and mortality in China, 2022. *J Natl Cancer Cent*, 2024, 4(1): 47-53. doi: 10.1016/j.jncc.2024.01.006.
- [4] CHRISTIANS K K, EVANS D B. Pancreaticoduodenectomy and vascular reconstruction: indications and techniques. *Surg Oncol Clin N Am*, 2021, 30(4): 731-746. doi: 10.1016/j.soc.2021.06.011.
- [5] NAGAKAWA Y, JANG J Y, KAWAI M, *et al.* Surgical outcomes of pancreatectomy with resection of the portal vein and/or superior mesenteric vein and jejunal vein for pancreatic head cancer: a multicenter study. *Ann Surg*, 2023, 277(5): e1081-e1088. doi: 10.1097/sla.0000000000005330.
- [6] KIM H S, CHAE H, LIM S Y, *et al.* Implications of portal vein/superior mesenteric vein involvement in pancreatic cancer: a comprehensive correlation from preoperative radiological assessment to resection, pathology, and long-term outcomes. A retrospective cohort study. *Int J Surg*, 2025, 111(4): 2962-2972. doi: 10.1097/js9.0000000000002307.
- [7] HACKERT T, KLAIBER U, HINZ U, *et al.* Portal vein resection in pancreatic cancer surgery: risk of thrombosis and radicality determine survival. *Ann Surg*, 2023, 277(6): e1291-e1298. doi: 10.1097/sla.0000000000005444.
- [8] 蔡合, 彭兵. 胰腺微创手术的现状和发展趋势. *四川大学学报(医学版)*, 2020, 51(4): 441-445. doi: 10.12182/20200760601.
- CAI H, PENG B. State-of-the-art and development trends of minimally invasive pancreatic surgery. *J Sichuan Univ (Med Sci)*, 2020, 51(4): 441-445. doi: 10.12182/20200760601.
- [9] KENDRICK M L, SCLABAS G M. Major venous resection during total laparoscopic pancreaticoduodenectomy. *HPB (Oxford)*, 2011, 13(7): 454-458. doi: 10.1111/j.1477-2574.2011.00323.x.
- [10] KAMATH A S, SARR M G, NAGORNEY D M, *et al.* Portal venous thrombosis after distal pancreatectomy: clinical outcomes. *J Gastrointest Surg*, 2014, 18(4): 656-661. doi: 10.1007/s11605-014-2465-9.
- [11] 李永彬, 蔡云强, 王昕, 等. 流程优化的全腹腔镜胰十二指肠切除术的临床总结(附手术视频). *四川大学学报(医学版)*, 2020, 51(4): 446-452. doi: 10.12182/20200760108.
- LI Y B, CAI Y Q, WANG X, *et al.* Optimization of operative procedure in total laparoscopic pancreaticoduodenectomy (with Video). *J Sichuan Univ (Med Sci)*, 2020, 51(4): 446-452. doi: 10.12182/20200760108.
- [12] 杨景瑞, 陈梦阔, 邓侠兴, 等. 机器人手术系统联合血管切除重建行胰十二指肠切除术的17例疗效评价(附手术视频). *四川大学学报(医学版)*, 2020, 51(4): 462-466. doi: 10.12182/20200760202.
- YANG J R, CHEN M M, DENG X X, *et al.* Efficacy of 17 cases of pancreaticoduodenectomy combined with vascular resection and reconstruction by using robotic operation system (with video). *J Sichuan Univ (Med Sci)*, 2020, 51(4): 462-466. doi: 10.12182/20200760202.
- [13] HAN A, AHN S, MIN S K. Techniques of oncovascular reconstruction of portal and mesenteric veins during pancreatic and hepatobiliary surgery. *Vasc Specialist Int*, 2024, 40: 45. doi: 10.5758/vsi.240073.
- [14] SÁNCHEZ-MARGALLO F M, MOYANO-CUEVAS J L, LATORRE R, *et al.* Anatomical changes due to pneumoperitoneum analyzed by MRI: an experimental study in pigs. *Surg Radiol Anat*, 2011, 33(5): 389-396. doi: 10.1007/s00276-010-0763-9.
- [15] MOYANO-CUEVAS J L, SÁNCHEZ-MARGALLO F M, MAESTRE-ANTEQUERA J, *et al.* Effects of pneumoperitoneum and body position on the morphology of abdominal vascular structures analyzed in MRI. *J Magn Reson Imaging*, 2012, 36(1): 177-182. doi: 10.1002/jmri.23615.
- [16] TAKAGI S. Hepatic and portal vein blood flow during carbon dioxide pneumoperitoneum for laparoscopic hepatectomy. *Surg Endosc*, 1998, 12(5): 427-431. doi: 10.1007/s004649900696.
- [17] MARTINEZ R, FIERRO C A, SHIREMAN P K, *et al.* Mechanical buckling of veins under internal pressure. *Ann Biomed Eng*, 2010, 38(4): 1345-1353. doi: 10.1007/s10439-010-9929-1.
- [18] HECKLER M, POLYCHRONIDIS G, KINNY-KÖSTER B, *et al.* Thrombosis and anticoagulation after portal vein reconstruction during pancreatic surgery: a systematic review. *J Gastrointest Surg*, 2025, 29(1): 101852. doi: 10.1016/j.gassur.2024.10.007.
- [19] MARCHETTI A, GARNIER J, HABIB J R, *et al.* The APROVE (Anti-coagulation/Platelet Treatment in Pancreatic Resections Involving Vascular Reconstruction) study: results from a worldwide survey. *Ann Surg Oncol*, 2025. doi:10.1245/s10434-025-17686-y.
- [20] THOMPSON S M, FLEMING C J, YOHANATHAN L, *et al.* Portomesenteric venous complications after pancreatic surgery with venous reconstruction: imaging and intervention. *Radiographics*, 2020, 40(2): 531-544. doi: 10.1148/rg.2020190100.
- [21] LABORI K J, KLEIVE D, KHAN A, *et al.* Graft type for superior mesenteric and portal vein reconstruction in pancreatic surgery--a

- systematic review. *HPB (Oxford)*, 2021, 23(4): 483-494. doi: 10.1016/j.hpb.2020.11.008.
- [22] YAN H, SHI H, ULLAH I, *et al.* Patency evaluation after venous resection and reconstruction with autologous peritoneum in laparoscopic pancreatic resection. *Curr Probl Surg*, 2024, 61(10): 101561. doi: 10.1016/j.cpsurg.2024.101561.
- [23] KINNY-KÖSTER B, LAMBRECHT A, FLOSSMANN V, *et al.* Alloplastic vascular grafts for venous interposition in pancreatic surgery: readily available and reliable. *Ann Surg*, 2024. doi:10.1097/sla.0000000000006581.
- [24] LIAO K, WANG H, CHEN Q, *et al.* Prosthetic graft for superior mesenteric-portal vein reconstruction in pancreaticoduodenectomy: a retrospective, multicenter study. *J Gastrointest Surg*, 2014, 18(8): 1452-1461. doi: 10.1007/s11605-014-2549-6.
- [25] GLEBOVA N O, HICKS C W, PIAZZA K M, *et al.* Technical risk factors for portal vein reconstruction thrombosis in pancreatic resection. *J Vasc Surg*, 2015, 62(2): 424-433. doi: 10.1016/j.jvs.2015.01.061.
- [26] FLIS V, POTRC S, KOBILICA N, *et al.* Pancreaticoduodenectomy for ductal adenocarcinoma of the pancreatic head with venous resection. *Radiol Oncol*, 2016, 50(3): 321-328. doi: 10.1515/raon-2015-0017.
- [27] GAO W, DAI X, DAI C, *et al.* Comparison of patency rates and clinical impact of different reconstruction methods following portal/superior mesenteric vein resection during pancreatic resection. *Pancreatol*, 2016, 16(6): 1113-1123. doi: 10.1016/j.pan.2016.09.010.
- [28] DUMITRASCU T, MARTINIUC A, BRASOVEANU V, *et al.* One hundred pancreatic resections with venous resection for pancreatic adenocarcinoma. *Chirurgia (Bucur)*, 2018, 113(3): 363-373. doi: 10.21614/chirurgia.113.3.363.
- [29] TSIOTOS G G, BALLIAN N, MICHELAKOS T, *et al.* Portal-mesenteric vein resection in borderline pancreatic cancer; 33 month-survival in patients with good performance status. *J Pancreat Cancer*, 2019, 5(1): 43-50. doi: 10.1089/pancan.2019.0013.
- [30] GARNIER J, TRAVERSARI E, EWALD J, *et al.* Venous reconstruction during pancreatic resection using polytetrafluoroethylene grafts: a single-center experience with standardized perioperative management. *Ann Surg Oncol*, 2021, 28(9): 5426-5433. doi: 10.1245/s10434-021-09716-2.
- [31] VUORELA T, VIKATMAA P, KOKKOLA A, *et al.* Long term results of pancreatic resection with and without venous resection: a comparison of safety and complications of spiral graft, end-to-end and tangential/patch reconstruction techniques. *Eur J Vasc Endovasc Surg*, 2022, 64(2/3): 244-253. doi: 10.1016/j.ejvs.2022.04.006.
- [32] LOVEDAY B P T, DIB M J, SEQUEIRA S, *et al.* Renal outcomes following left renal vein harvest for venous reconstruction during pancreas and liver surgery. *HPB (Oxford)*, 2019, 21(1): 114-120. doi: 10.1016/j.hpb.2018.07.015.
- [33] PANTOJA J L, CHANG K, PELLIONISZ P A, *et al.* Paneled saphenous vein grafts compared to internal jugular vein grafts in venous reconstruction after pancreaticoduodenectomy. *Ann Vasc Surg*, 2020, 65: 17-24. doi: 10.1016/j.avsg.2019.11.008.
- [34] TERASAKI F, FUKAMI Y, MAEDA A, *et al.* Comparison of end-to-end anastomosis and interposition graft during pancreaticoduodenectomy with portal vein reconstruction for pancreatic ductal adenocarcinoma. *Langenbecks Arch Surg*, 2019, 404(2): 191-201. doi: 10.1007/s00423-019-01749-2.
- [35] FOGLIATI A, FIORENTINI G, ALVA-RUIZ R, *et al.* Technical outcomes of porto-mesenteric venous reconstruction in pancreatic resection using autologous left renal vein graft as conduit. *J Am Coll Surg*, 2023, 237(1): 58-67. doi: 10.1097/xcs.0000000000000744.
- [36] IRFAN A, KIM P, LADAK F, *et al.* The left renal vein: the optimal interposition graft for pancreatic surgery? *HPB (Oxford)*, 2025, 27(5): 614-618. doi: 10.1016/j.hpb.2025.01.004.
- [37] SHIBUYA K, KIMURA N, WATANABE T, *et al.* Usefulness of the femoral vein as a graft for portal vein/superior mesenteric vein reconstruction during pancreatic resection. *J Hepatobiliary Pancreat Sci*, 2023, 30(10): 1196-1197. doi: 10.1002/jhbp.1320.
- [38] TAKAHASHI Y, MATSUO K, OYAMA H, *et al.* Superior mesenteric vein reconstruction during pancreaticoduodenectomy using a dilated right ovarian vein in a patient at future risk for pelvic congestion syndrome: a case report. *Surg Case Rep*, 2022, 8(1): 67. doi: 10.1186/s40792-022-01421-w.
- [39] SHAO Y, FENG J, JIANG Y, *et al.* Feasibility of mesentericoportal vein reconstruction by autologous falciform ligament during pancreaticoduodenectomy-cohort study. *BMC Surg*, 2021, 21(1): 4. doi: 10.1186/s12893-020-01019-9.
- [40] De PAUV V, PEZZULLO M, BALI M A, *et al.* Peritoneal patch in vascular reconstruction during pancreaticoduodenectomy for pancreatic cancer: a single Centre experience. *Acta Chir Belg*, 2023, 123(3): 257-265. doi: 10.1080/00015458.2021.1979173.
- [41] ZHU W T, WANG H T, GUAN Q H, *et al.* Ligamentum teres hepatis as a graft for portal and/or superior mesenteric vein reconstruction: from bench to bedside. *World J Gastrointest Surg*, 2023, 15(4): 674-686. doi: 10.4240/wjgs.v15.i4.674.
- [42] DOKMAK S. Pancreaticoduodenectomy with reconstruction of the mesentericoportal vein by the parietal peritoneum: 'Safi Dokmak Vascular Graft'. *Ann Surg Oncol*, 2015, 22(Suppl 3): S343-S344. doi: 10.1245/s10434-015-4635-8.
- [43] FAN J L, LU C, DAI X L, *et al.* Feasibility of bile duct as venous graft for venous reconstruction in pancreatic surgery: an animal experimental study. *Vascular*, 2020, 28(4): 450-456. doi: 10.1177/1708538120902653.
- [44] RANGELOVA E B, GHORBANI P, VALENTE R, *et al.* Overcoming the technical challenge of venous resection with pancreatic resection: Which factors determine survival? *Eur J Surg Oncol*, 2025, 51(8): 109629. doi:10.1016/j.ejso.2025.109629.
- [45] XU D, WU P, ZHANG K, *et al.* The short-term outcomes of distal pancreatic resection with portal vein/superior mesenteric vein resection. *Langenbecks Arch Surg*, 2022, 407(5): 2161-2168. doi: 10.1007/s00423-021-02382-8.
- [46] STOOP T F, AUGUSTINUS S, BJÖRNSSON B, *et al.* Surgical outcome after distal pancreatic resection with and without portomesenteric venous resection in patients with pancreatic adenocarcinoma: a transatlantic evaluation of patients in North America, Germany, Sweden, and The Netherlands (GAPASURG). *Ann Surg Oncol*, 2024, 31(12): 8327-8339. doi: 10.1245/s10434-024-15932-3.
- [47] MACHAIRAS N, RAPTIS D A, VELÁZQUEZ P S, *et al.* The impact of neoadjuvant treatment on survival in patients undergoing pancreaticoduodenectomy with concomitant portomesenteric venous resection: an international multicenter analysis. *Ann Surg*, 2021, 274(5): 721-728. doi: 10.1097/sla.0000000000005132.
- [48] STOOP T F, THEIJSE R T, SEELEN L W F, *et al.* Preoperative chemotherapy, radiotherapy and surgical decision-making in patients with borderline resectable and locally advanced pancreatic cancer. *Nat Rev Gastroenterol Hepatol*, 2024, 21(2): 101-124. doi: 10.1038/s41575-023-00856-2.
- [49] BURLA L, SCHWEGLER I, WEIBEL P, *et al.* Intraoperatively self-made bovine pericardial graft for portomesenteric reconstruction in pancreatic surgery. *Langenbecks Arch Surg*, 2020, 405(5): 705-712. doi: 10.1007/s00423-020-01920-0.
- [50] KIM M K, SHIN S H, HAN I W, *et al.* Cryopreserved allografts versus end-to-end anastomosis for the reconstruction of a segment-resected portomesenteric vein during advanced pancreatic cancer surgery. *Asian J Surg*, 2023, 46(9): 3741-3747. doi: 10.1016/j.asjsur.2023.02.050.
- [51] BACALBASA N, BALESCU I, VILCU M, *et al.* Superior mesenteric and portal vein reconstruction with cadaveric allograft during pancreaticoduodenectomy--a case report and literature review. *In Vivo*, 2020, 34(2): 787-791. doi: 10.21873/invivo.11839.

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