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Modified single-loop reconstruction for pancreaticoduodenectomy

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TITLE:

Modified Single-Loop Reconstruction for Pancreaticoduodenectomy

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KEYWORDS:
Modified single loop reconstruction, pancreaticoduodenectomy, Whipple's procedure, pancreatic fistula

SUMMARY:
The technique of modified single-loop reconstruction following pancreaticoduodenectomy separates pancreatic secretion from bile, thus reducing the severity of POPF without prolonging the duration of surgery.

ABSTRACT:
Modified single-loop reconstruction in pancreaticoduodenectomy separates pancreatic secretion from bile. It is performed in cases of high-risk pancreatic remnants to reduce the severity of postoperative pancreatic fistulas and moreover the overall postoperative morbidity. This reconstruction technique is characterized by an extra-long jejunal loop for the construction of the pancreaticojejunostomy and hepaticojejunostomy. The longer distance between these anastomoses and an additional jejuno-jejunostomy between the afferent and efferent limb of the hepaticojejunostomy separate the fluids and prevent backflow of bile towards the pancreaticojejunostomy. Thus, the secretions cannot activate each other and aggravate an existing anastomotic leakage. We observed a reduced rate of severe postoperative pancreatic fistulas after modified single-loop reconstruction compared to conventional single loop reconstruction. The technique is easy to perform, safe, and less time-consuming than a traditional double-loop reconstruction.

INTRODUCTION:

Pancreaticoduodenectomy (PD) is considered a sophisticated surgical procedure. While mortality has decreased over the last decades, morbidity still remains high[1]. The most frequent

and feared complication is the postoperative pancreatic fistula (POPF), which occurs in over 20% of operations[2-5]. POPF can lead to subsequent complications such as postpancreatectomy hemorrhage, delayed gastric emptying, intraabdominal abscess and sepsis. Increased hospital costs, prolonged hospital stay, and delayed initiation of chemotherapy in cancer patients have a dramatic socioeconomic impact[2-4].

Different surgical approaches have been introduced in the last decades to decrease the frequency and severity of POPF. One of those is the double-loop reconstruction (DLR) with isolated Roux-en-Y loops for the biliary and pancreatic anastomoses. Separating pancreatic juice from bile is thought to decrease the detrimental effects of mutually activated secretions on the pancreaticojejunostomy (PJ). Results in the literature have been encouraging[6-8]. However, operative time is significantly prolonged with DLR[4,9].

We here introduce the technique of modified single-loop reconstruction (mSLR) during PD to separate pancreatic secretion from bile compared to the conventional single-loop reconstruction (SLR, **Figure 1**). In this method, a single long small-bowel loop is used for the construction of the hepaticojejunostomy (HJ) and PJ. A side-to-side anastomosis between the afferent and efferent limb of the HJ facilitates isolated flow of bile and pancreatic secretions. The first promising results confirming decreased mortality and morbidity in patients with high-risk pancreata were reported by our group in 2018[10].

This method reduces the severity of POPF by separating pancreatic fluid and bile without prolonging the duration of surgery significantly compared to the double-loop reconstruction.

PROTOCOL:

This protocol focuses on the reconstruction phase of PD using mSLR and follows the guidelines of the ethics committee of the Ruhr-University Bochum, Germany.

NOTE: Patients with a resectable tumor of the pancreatic head, the papillary region or severe refractory chronic calcifying pancreatitis underwent PD. Resectability was present if the tumor had less than 50 % contact to the peripancreatic arteries and did not infiltrate the portal vein or the superior mesenteric vein. Distant metastases in cases of adenocarcinomas were also contraindications for PD. The resection technique in PD is standardized and described in detail elsewhere[11,12]. It does not affect the type of reconstruction itself.

1. Patient preparation

1.1. After the patient has been brought to the operation theatre by the nurses, have the anesthesiologist start the anesthesia. Monitor the depth of anesthesia throughout the operation by the anesthesiologist including continuous check of the vital signs.

2. Establishing the indication for mSLR

2.1. Confirm the indication for a mSLR after the resection phase in PD. Construct a mSLR in cases of a high-risk pancreatic remnant characterized by soft and fragile pancreatic tissue and/or a tiny main pancreatic duct with a diameter of 1-2 mm.

2.2. Palpate the pancreas to determine subjectively whether the pancreatic texture is soft or hard. Use a Shore durometer to measure the pancreatic texture. Shore units < 40 are characteristic for soft pancreata.

3. Reconstruction phase: mobilization of the jejunal loop

3.1. Resect the first 10 inches of the jejunum to provide enough length of the mesentery. The jejunum follows the duodenum and begins after the ligament of Treitz.

3.2. Advance the loop into the right upper abdominal quadrant through a wide slit in the transverse mesocolon distal to the right colic artery.

3.3. Close the slit with an interrupted polypropylene 4 – 0 suture.

3.4. Oversew the stapled line with a continuous PDS 5-0 suture.

4. Reconstruction phase: pancreaticojejunostomy

4.1. Position the jejunal loop as demonstrated in **Figure 1** ("modified single-loop reconstruction") to construct an end-to-side pancreaticojejunostomy.

4.2. Create a double-layer, end-to-side, duct-to-mucosa PJ using an interrupted polydioxanone (PDS) 5-0 suture for the outer layer and interrupted polypropylene 5-0 suture for the inner layer.

4.3. Use interrupted sutures between the pancreatic duct and the jejunal mucosa for the inner layer. Construct the outer layer with single sutures between the pancreatic parenchyma/capsule and the seromuscular layer of the jejunal loop.

5. Preparation of the long jejunal limb and jejunojejunostomy

5.1. Choose a jejunal segment between the PJ and HJ (which will be constructed afterwards), which measures 25–35 cm instead of 10 cm as in conventional single-loop reconstruction. Create the jejuno-jejunostomy before or after construction of the HJ.

5.2. Now construct an additional side-to-side jejunojejunal anastomosis at the lowest point between the afferent and efferent limbs of the HJ. Begin by placing marking sutures at the sites of the jejuno-jejunostomy with single PDS 5-0 stitches.

5.3. Perform the intestinal anastomosis in a continuous double-layer PDS 5-0 suture

technique. Construct the outer layer of the backwall with a continuous seromuscular suture. Perform the inner layer of the backwall with a continuous suture with stitching of all jejunal layers on both sides. Construct the inner layer and the outer layer of the front wall in the same way.

5.4. Ensure that the anastomosis is sufficiently wide – about 1 inch. This allows good flow of bile and pancreatic secretions even in the early postoperative period when themucosa is edematous and may obstruct a narrow anastomosis. Close the slit around the jejunal loop using interrupted polypropylene 5-0 sutures.

6. Reconstruction phase: hepaticojejunostomy

6.1. Use a single-layer interrupted or continuous PDS 5-0 suture for construction of the HJ. Use interrupted sutures especially for tiny ducts. Ensure that the stitches enclose all jejunal layers and all layers of the common bile duct.

6.2. Splint thin-walled and tiny common bile ducts with an externally diverted T-tube.

7. Reconstruction phase: duodenojejunostomy

7.1. Reconstruct the intestinal passage with an end-to-side, double-layer duodeno(pyloro-)jejunostomy using continuous PDS 4-0 sutures.

7.2. Construct continuous seromusculary sutures for the outer layer of the back- and front wall as described in step 5.3. Use continuous sutures with stitching of all duodenojejunal layers for the inner layers of the anastomosis.

8. Management of drainages, postoperative medical treatment and POPF - monitoring

8.1. At the end of the surgery, place 2 intraabdominal soft silicone drains in the vicinity of the HJ and PJ. Channel them separately through the skin of the right and left middle abdomen.

8.2. Apply subcutaneous octreotide 100 µg three times a day for 7 days after surgery. Use pasireotide as an alternative.

8.3. Determine pancreatic amylase and lipase activity in the drain fluid every 48 h beginning on postoperative day 3.

8.4. Discharge the patient once they have recovered from surgery – usually around postoperative day 21. Ensure that the drainages have been removed, the patient is fully mobile and able to eat regularly.

8.5. Perform follow-up investigations including computed-tomography of the abdomen, magnet-resonance-cholangiopancreatography and esophagogastroscopy at least 6, 12 and 24

months after surgery to rule out tumor recurrence, metastases and anastomotic ulcers. The tumor marker carbohydrate antigen 19 – 9 must be determined as well.

REPRESENTATIVE RESULTS:

Every patient undergoing PD underwent an investigation of the pancreatic tissue to evaluate the indication for mSLR. High-risk pancreatic remnants (i.e., soft pancreatic tissue and a tiny main pancreatic duct) were reconstructed using a modified single loop whenever possible.

We identified 50 patients with high risk pancreatic tissue and a small main pancreatic duct. All of them underwent mSLR. The mean age was 63 ± 13 years old. The male/female ratio was 17:33. Indications for surgery were malignant diseases in 33 patients (66%) and benign diseases in 17 patients (34%). The mean operative time was 365 ± 77 min. This cohort was compared to two matched historical cohorts, one with SLR (n = 50; 368 ± 93 min) and one with DLR (n = 25; 424 ± 76 min). The operative time was significantly longer with DLR compared to the mSLR (p = 0.019).

The duration of surgery was 56 min longer with DLR averagely, whereas mSLR increased the operative time only by 8.1 ± 2.5 min. The occurrence of clinically relevant POPF was the same in all three cohorts. However, we observed a significantly higher rate of POPF grade C requiring surgical revision and postoperative pancreatic hemorrhages in patients with SLR compared to those with mSLR (n = 8/50 [16%] vs. n = 1/50 [2%]; p = 0.01). Patients with mSLR had a significant lower overall rate of major morbidity (6/50 patients [12%] vs. 16/50 patients [32%]; p < 0.028) and a shorter hospital stay (21 ± 9 vs. 35 ± 14 days; p < 0.001.).

Regarding the mSLR, mobilization of the long jejunal limb was unproblematic in most cases. In rare cases, mobilization was limited due to extreme visceral obesity or severe adhesions in patients with a past surgical history. Furthermore, patients of very short statures have less space in the upper abdomen, impeding the preparation as well.

The continuous double-layer reconstruction of the jejuno-jejunostomy was performed without any difficulties in all patients. No anastomotic insufficiency occurred postoperatively.

Intra- or postoperative proof of true separation of the pancreatic fluid and bile could not be provided by us at this point. Avoidance of kinking of the jejunal limb and positioning of the jejuno-jejunostomy at the lowest point between the afferent and efferent limb of the HJ theoretically increased the probability of separation of bile and pancreatic fluid by preventing backflow of the secretions.

This method is technically simple to perform and improves the postoperative outcome by reducing the incidence of severe POPF in patients with high-risk pancreatic remnants[9]. Subsequently, the total number of postpancreatectomy hemorrhages and re-operations is significantly lower with mSLR. Furthermore, the time in intensive care and total hospital stay are shorter. Compared to DLR, this procedure is significantly less technically demanding and less time consuming[9].

FIGURE AND TABLE LEGENDS:

Figure 1: Demonstration of three reconstruction techniques in PD.

Table 1: Advantages and disadvantages of mSLR

Table 2: Representative results

DISCUSSION:

To date, POPF contributes significantly to the postoperative morbidity following PD[1].

A mixture of bile and pancreatic juice can lead to mutual activation of both secretions, increasing their adverse effects on the PJ or the HJ[9,13-16]. Cytotoxic activity of activated phospholipase A2, which converts biliary lecithin to detrimental lysolecithin, puts the pancreatic anastomosis at risk. Furthermore, biliary lipopolysaccharides can increase the activity of pancreatic enzymes[14,15,17-19].

The mSLR is an attempt to functionally mimic a DLR diverting bile from pancreatic juice to reduce the detrimental effects of mixed secretions[10]. A single long small-bowel loop for the reconstruction of the HJ and PJ allows the construction of a side-to-side anastomosis between the afferent and efferent limb of the HJ and further creates a greater distance between both anastomoses.

This method allows a simple separation of both secretions without construction of a sometimes technically challenging and time consuming DLR[10]. Its beneficial effects are thought to occur in patients with high-risk pancreatic remnants (i.e., soft pancreatic tissue and a pancreatic duct diameter of <3 mm). Patients with hard pancreatic remnants and wide ducts benefit from conventional single-loop reconstruction as shown before[2-4].

Although the side-to-side jejuno-jejunostomy is the key feature of the mSLR, careful construction of the PJ and HJ remain the most critical steps in the protocol because of their high level of difficulty. The additional enteroenteric anastomosis theoretically represents an additional risk. However, insufficiency of this anastomosis has not been observed in our cohort.

Preparation of the long limb of the jejunum can be impeded by a short mesentery due to extreme visceral obesity causing a small space in the right upper quadrant. Severe adhesions in patients with a past surgical history may impede the preparation of a sufficiently long jejunal loop for the mSLR. It is important to avoid kinking of the jejunal loop and construct the side-to-side anastomosis at the lowest point to prevent backflow of secretions. Short stature can also hamper preparation due to a limited space between the common bile duct and the pancreatic remnant. Since this method has just been introduced by our group, there is no direct proof that a relevant diversion of the flow of bile and pancreatic juice exists. However, first results suggest that severe POPF seems to occur less frequently. The significance of inflammation around the PJ or the pancreatic juice activity remains unclear[10].

Several types of PJ construction have been proposed. The standard reconstruction method at our institution is the duct-to-mucosa PJ. However, mSLR has not yet been compared to other techniques like the pancreaticogastrostomy or invagination PJ. Modified techniques aimed at separating secretions for the same physiological effect as mSLR are the DLR or the P-loop reconstruction[14]. Randomized controlled studies comparing mSLR with other reconstruction techniques in patients with high-risk pancreata are required to identify the superiority of any modification. The decision as to which reconstruction technique to perform is dependent on the patient's anatomy and center's surgical experience.

A tailored surgical approach is necessary for the construction of a PJ in PD. Anatomical, structural, and functional characteristics of the pancreas must be taken into account as well as the surgeon's experience. Hence, the modern-day pancreatic surgeon should be well versed in a wide spectrum of reconstructive techniques.

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Not applicable

DISCLOSURES:
The authors have nothing to disclose.

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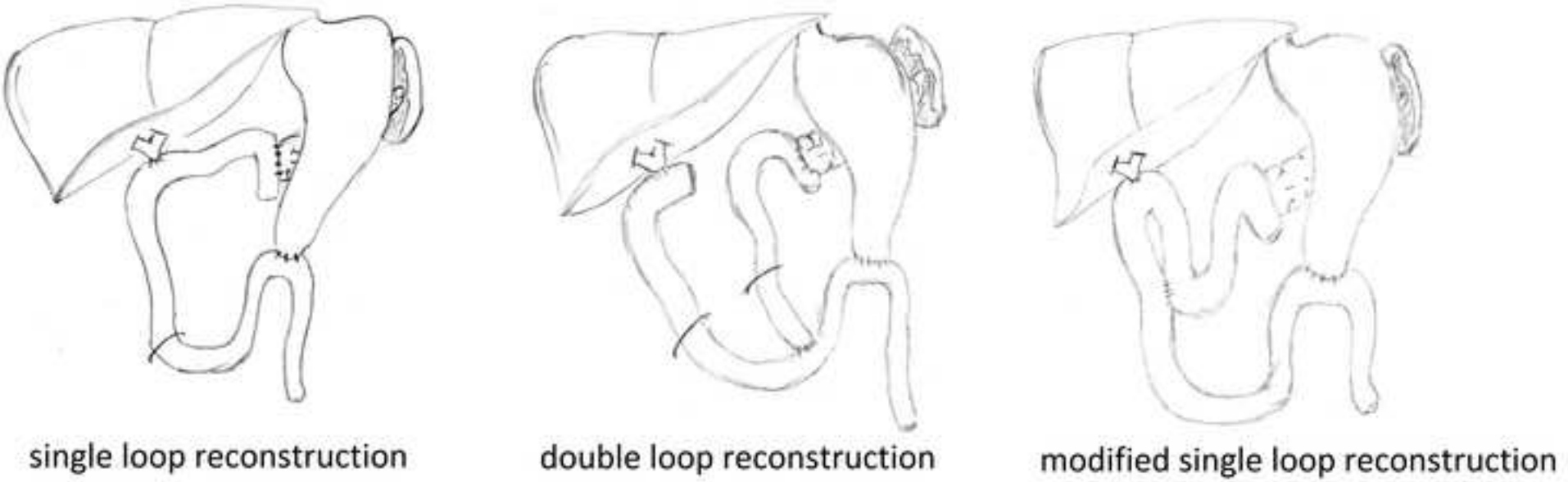
Figure



advantages

· mobilization of the long jejunal limb usually no problem

· no difficulties in construction and no complications with continuous double-layered jejunojejunostomy

· technically simple to perform

· reduces the incidence of severe POPF in patients with high-risk pancreatic remnants. Number of postpancreatectomy hemorrhages and re-operations lower

· ICU- and hospital stay shorter

· in comparison to DLR less technically demanding and time consuming

disadvantages

possible limiting factors:

· extreme visceral obesity

· severe adhesions due to past surgeries

· small stature

no verification possible if bile and pancreatic fluid were really separated

Table

	mSLR (n = 50)	SLR (n = 50)	DLR (n = 25)	p-value
Age (years)	63 ± 13	65 ± 11	64 ± 11	1,000
Sex (female/male)	33:17	33:17	15:10	1,000
Surgical indication				
malignant disease	33 (66%)	33 (66%)	15 (60%)	1,000
benign disease	17 (34%)	17 (34%)	10 (40%)	1,000
Duration of surgery (min.)	365 ± 77	368 ± 93	**424 ± 76**	**0.019**
major morbidity	6 (12%)	16 (32%)	2 (8%)	**< 0.028**
clinically relevant POPF	13 (26%)	13 (26%)	6 (24%)	1,000
POPF grade B	12 (92%)	5 (38%)	5 (83%)	**0.011**
POPF grade C	1 (8%)	8 (62%)	1 (17%)	**0.011**
Hospital stay (days)	21 ± 9	35 ± 14	19 ± 10	**<0.001**

Table of Materials

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Name of Material/ Equipment	Company	Catalog Number
Alexis O XXL	Applied medical	C8405
Bauchtuch Grün 10x90	Nobatrast	603219
Bauchtuch Grün 45x45	Nobatrast	607544
GIA 60mm-3.8mm	Covidien/Medtronic	GIA6038S
GIA Loading Unit	Covidien/Medtronic	GIA6038L
OP-Flex Yankauer	Unomedical	34094182
Präpariertupfer-Set	Fuhrmann	32019
Schlinggazetupfer 30x40	Fuhrmann	32016
Telescopic Smoke Pencil	LiNA Medical	SHK-TSP-CL
Thermocover ECO	PEMAX	TC43-75EC2
Whipple-Set	Mölnlycke	97016042-00
Drainages:		
Drainagebeutel	Coloplast	?
Silikon-Kapillardrainage	AsidBonz	551012
Trichteransatz für T-Rohr	Rüsch	333169-000025
T-Rohr nach Kehr	Rüsch	423600-000025
Sutures:		
Ethiloop 2mm 2x45cm	Ethicon	EH387
Mersilene 0 FSL	Ethicon	EH7637
PDS 1 CT	Ethicon	PDP9234
Vicryl 2-0 , 6x45cm	Ethicon	VCP1226
Vicryl 2-0 SHplus, 8x70	Ethicon	VCP7850
Vicryl 3-0 MH-1plus	Ethicon	VCP245
Pancreatic anastomoses:		
Prolene 5-0 c1	Ethicon	8890
PDS 5.0 RB-1plus	Ethicon	X1153
Prolene 4-0 RB-1	Ethicon	8871
Hepaticojejunostomy:		
Prolene 5-0 c1	Ethicon	8890
PDS 5-0 c1	Ethicon	PDP1013
PDS 6-0 c1	Ethicon	PDP1012
Gastrojejunostomy:		
PDS 4-0 SH-1 plus	Ethicon	X1154
Jejuno-Jejunostomy		
Ligasure	Covidien	LS1520
PDS 5-0 RB-1 plus	Ethicon	X1153
Prolene 2-0 SH	Ethicon	8833
Prolene 3-0 SH	Ethicon	8832
Prolene 4-0 RB-1	Ethicon	8871

Comments/Description
abdominal compress
abdominal compress
suction device
sterile swab
sterile swab
electro cautery
bowel cover
drainagebag
capillary drainage
2,5 mm
t-tube 2,5 mm
loop
fixation of the drainage
suturing of the fascia
for ligature
for ligature
subcutaneous suture
6 x
2 x Multipack
2 x holding sutures
2 x holding sutures
7 x
1 x mucosa fixation sutures
1 x Multipack
1 x Multipack
Vessel-suture, etc.
Cystic duct, cystic artery
meso

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Dear Mr. Nam,

enclosed I send you the revised video-file. I have changed all the required aspects in the video exactly as desired and would be very happy to publish the video/manuscript in JOVE finally.

Please feel free to contact me anytime if there are any questions.

Best regards,

Andreas Luu

Editorial comments:

1. Please normalize the volumes throughout the video. The audio volume levels in the voiceover narration fluctuate throughout the course of the video. It sounds like audio from a few different recording sessions was used. Overall, the narration levels are too low, and, by comparison, the music volume is too hight. I recommend lowering the music by about 3-6 dB. The voiceover narration should be peaking between -6 and -12 dB. For example, the narration around 7:55 is currently at an appropriate volume.

- the volume has been normalized throughout the whole video. The background music volume is lowered as required and the narration volume has been increased significantly and be understood clearly now.

2. The audio and video are not in sync in the initial author interview. Also, please identify the first on screen speaker. There is some static in the audio as well.

Audio and video are in sync throughout the whole video now. Static in the audio is not present anymore.

• 0:12-0:58 - The audio and video do not appear to be completely synchronized. I can't tell the exact cause, as the synch discrepancy does not appear to be consistent. Whatever the cause, this needs to be corrected. If if cannot be corrected, the interview statements will need to be rerecorded.

Audio and video are completely synchronized now. Discrepancy does not occur anymore.

Furthermore, please submit a high resolution version of your video (up to 2 GB) here: https://www.dropbox.com/request/WzrWBokH4elxYx1aJIGU?oref=e

The video resolution has been increased to a high resolution now (1920 x 1088 pixels).