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A NOVEL PANCREATICOJEJUNOSTOMY TECHNIQUE AFTER PANCREATODUODENECTOMY IN CASE OF THE SOFT PANCREATIC PARENCHYMA

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Abstract

Introduction. In this paper we present a novel sleeve-shaped pancreaticojejunostomy (NSSP) technique developed for pancreaticoduodenectomies in case of soft pancreatic parenchyma. **Material and Methods.** The efficacy of NSSP was compared to “duct-to-mucosa” (DTMA), invaginational (IA), and catheter-guided (CGA) types of pancreatic anastomoses. A total of 173 pancreaticoduodenectomies were analyzed. **Results.** The rate of clinically relevant postoperative pancreatic fistulas (CR-POPF) was 6.6 % in the group of “duct-to-mucosa” anastomoses, 16.0 % in the group of invaginational anastomoses, and 22.2 % in the group of catheter-guided ones. CR-POPF have not been registered in the group of NSSP. The risk of CR-POPF after application of NSSP was significantly lower compared to the group of IA (OR 3.44 [2.63–11.11]), the group of CGA (OR 5.54 [3.41–8.22]) and did not differ from the group of DTMA (OR 1.19 [0.65–2.38]). **Conclusion.** The novel sleeve-shaped pancreaticojejunostomy has proved to be effective and in a short series of surgeries demonstrated the lowest rate of CR-POPF compared to other known types of anastomoses.

Key words: pancreaticoduodenectomy, pancreatic fistula, pancreatic anastomotic leakage, pancreaticojejunostomy.

СПОСОБ ФОРМИРОВАНИЯ ПАНКРЕАТОЕЮНОАНАСТОМОЗА ПОСЛЕ ПАНКРЕАТОДУОДЕНАЛЬНОЙ РЕЗЕКЦИИ ПРИ МЯГКОЙ ПАРЕНХИМЕ ПОДЖЕЛУДОЧНОЙ ЖЕЛЕЗЫ

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Аннотация

Введение. В работе предложен оригинальный муфтообразный панкреатоеюноанастомоз (ОМА), разработанный для панкреатодуоденальных резекций при мягкой поджелудочной железе. **Материал и методы.** В статье представлена техника выполнения ОМА и проведен анализ его эффективности по сравнению с «duct-to-mucosa» (ДТМА), инвагинационным (ИА) и катетер-направленным (КНА) панкреатическими анастомозами. Всего проанализированы 173 панкреатодуоденальные резекции. **Результаты.** Частота клинически значимых послеоперационных панкреатических фистул (КЗ-ПОПФ)

в группах «duct-to-mucosa» анастомозов составила 6,6 %, инвагинационных анастомозов – 16,0 %, катетер-направленных анастомозов – 22,2 %, в группе ОМА панкреатических фистул не было. Риск КЗ-ПОПФ после применения ОМА был значимо меньше по сравнению с группой ИА (ОШ 3,44 [2,63–11,11]), группой КНА (ОШ 5,54 [3,41–8,22]) и не отличался от группы ДТМА (ОШ 1,19 [0,65–2,38]). **Заключение.** Оригинальный муфтообразный панкреатоеюноанастомоз оказался эффективным и в короткой серии операций продемонстрировал наименьшую частоту КЗ-ПОПФ по сравнению с другими известными типами анастомозов.

Ключевые слова: панкреатодуоденальная резекция, панкреатическая фистула, несостоятельность панкреатического анастомоза, панкреатоеюноанастомоз.

Introduction

Creating the pancreatic anastomosis (PA) is one of the key points of a pancreaticoduodenectomy (PDE) reconstruction. It is obvious that the risk of the clinically relevant postoperative pancreatic fistula (CR-POPF) of types B and C, as defined by International Study Group on Pancreatic Surgery [1], directly depends on reliability of PA.

In turn, it is common knowledge that mortality in the group of patients with CR-POPF varies from 5.0 to 40.0 % [2–5]. Postoperative hemorrhage, another life-threatening specific complication of PDE, usually develops due to CR-POPF and results in the higher mortality rate from 20.0 to 50.0 % [3].

Currently, more than 100 variants of pancreatic anastomoses have been proposed, among which pancreaticogastro- and pancreaticojejunostomy are distinguished. The latter, in turn, may be classified into 1) invaginational (IA), 2) “duct-to-mucosa” (DTMA), and 3) catheter-guided (CGA), external or internal tube drainage of the pancreatic duct being implied [6]. However, as modern meta-analyses show, no type has advantages and the rate of CR-POPF remains high, from 2.0 to 37.0 %, with an average of 13.0 % [11.0–15.0] [7, 8]. Overall, it can be stated that CR-POPF remains the “Achilles heel” of surgical pancreatology.

The main problem is the formation of PA with the soft, frail parenchyma of the pancreatic gland (PG), when the rate of the CR-POPF becomes the highest [9, 10]. In this article, we propose a novel pancreatic anastomosis developed specifically for the soft pancreas.

Material and Methods

Technique of the novel sleeve-shaped pancreaticojejunostomy

The novel pancreatic anastomosis (Russian Federation patent for invention No. 2857988) involves dense enveloping a pancreatic stump (PS) by a small intestine in a sleeve-shaped manner and the precise sewing of the pancreatic duct (PD) into the intestinal lumen. Upon completion of the resection stage, the first loop of the jejunum is brought to the pancreatic stump in a retrocolic position. Having been denuded 2–2.5 cm from the transection plane, the PS is passed through the aperture in the mesentery of the jejunal loop to be anastomosed (Fig. 1). The aperture mentioned is located directly at the mesenteric edge of the intestine. The size of the aperture in the mesentery must match

the PS as tight as possible. At the next stage, the PS is fixed to the ascending and descending loops of the intestine by two U-shaped sutures (Fig. 2).

The U-shaped sutures hold only the serous-muscular layer of the intestine, run along the axis of the main PD through the parenchyma of the PS, in such a way that the wall of the ascending and the descending loops of the intestine play the role of supporting pads, preventing the parenchyma of the gland from being cut through. The small intestine sleeve is then closed from below by one or two inter-intestinal sutures, involving a mesentery layer (Fig. 3).

After this, a precision anastomosis of the main PD to the descending intestinal loop is formed (Fig. 4). Pancreatic duct is sewn to the serous-muscular layer of the opening of the small intestine by interrupted sutures, the number of which depends on the diameter of the PD. When the aperture is formed in the intestine, the excess mucosa is excised as much as possible. Microsurgical instruments, optical magnification, monofilament non-absorbable suture material 6-0 or 7-0 are used. After the completion of the PD anastomosis, the ascending and descending loops of the intestine are sewn together with serous-muscular sutures, closing the intestinal sleeve at the front (Fig. 5).

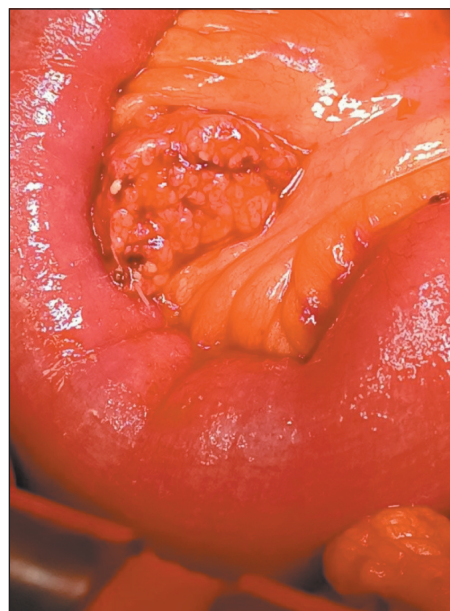


Fig. 1. The stump of the pancreas passed through the aperture in the mesentery. Note: created by the authors

Рис. 1. Культия ПЖ проведена через отверстие в брыжейке тонкой кишки. Примечание: рисунок выполнен авторами

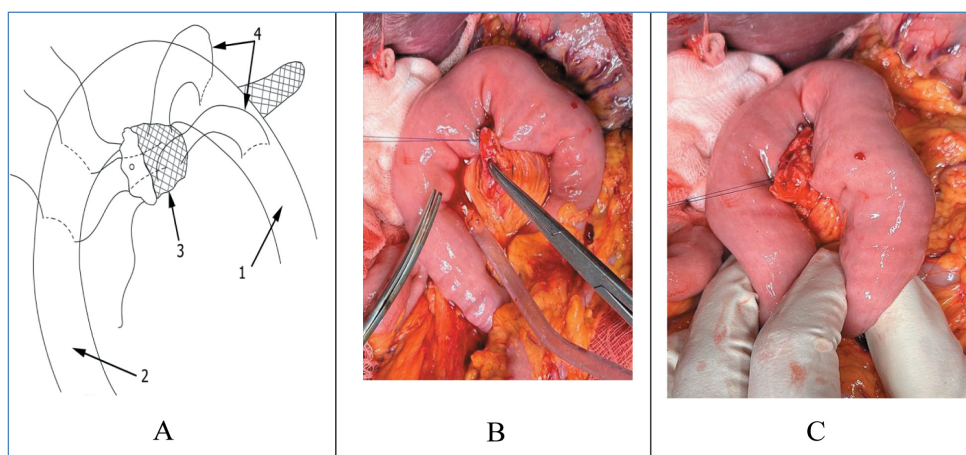


Fig. 2. Fixing of the pancreatic stump to the ascending and descending loops of the small intestine. A – fixation scheme: 1 – ascending loop, 2 – descending loop, 3 – pancreatic stump, 4 – lower and upper U-shaped sutures. B – the upper U-shaped suture is tied. C – the lower U-shaped suture is tied. Note: created by the authors

Рис. 2. Фиксация культи ПЖ к приводящей и отводящей петлям тонкой кишки. А – схема фиксации: 1 – приводящая петля, 2 – отводящая петля, 3 – культя ПЖ, 4 – верхний и нижний П-образные швы. В – завязан верхний П-образный шов. С – завязан нижний П-образный шов. Примечание: рисунок выполнен авторами

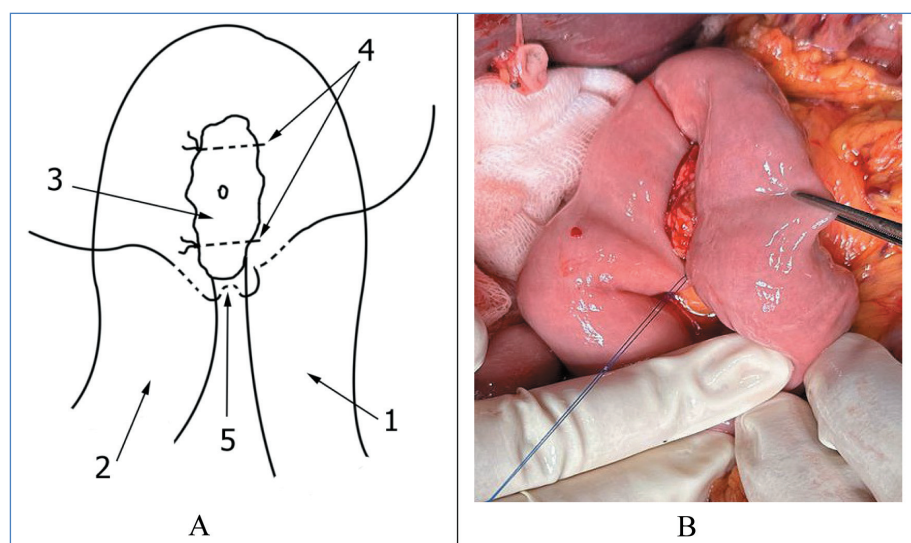


Fig. 3. Closure of the intestinal sleeve around the pancreatic stump from below. A – scheme: 1 – ascending loop, 2 – descending loop, 3 – pancreatic stump, 4 – lower and upper U-shaped sutures are tied, 5 – lower closing suture. B – view of intestinal sleeve closed around. Note: created by the authors

Рис. 3. Замыкание тонкокишечной муфты вокруг культи ПЖ снизу. А – схема замыкания: 1 – приводящая петля, 2 – отводящая петля, 3 – культя ПЖ, 4 – верхний и нижний П-образные швы завязаны, 5 – нижний замыкающий шов. В – вид замкнутой снизу тонкокишечной муфты. Примечание: рисунок выполнен авторами

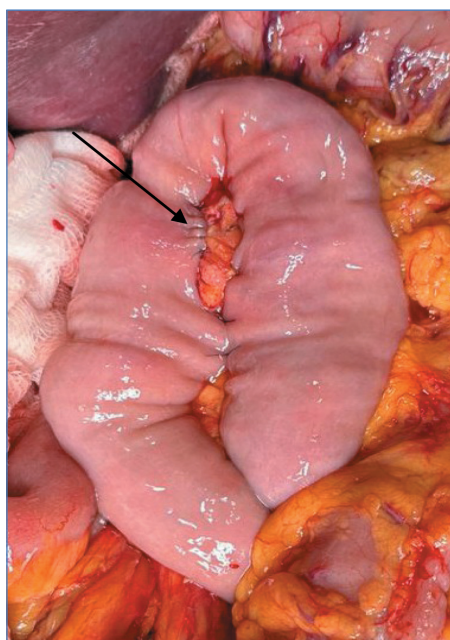


Fig. 4. Completed anastomosis of the pancreatic duct (the arrow). Note: created by the authors

Рис. 4. Сформированный панкреатикоюноанастомоз (стрелка). Примечание: рисунок выполнен авторами

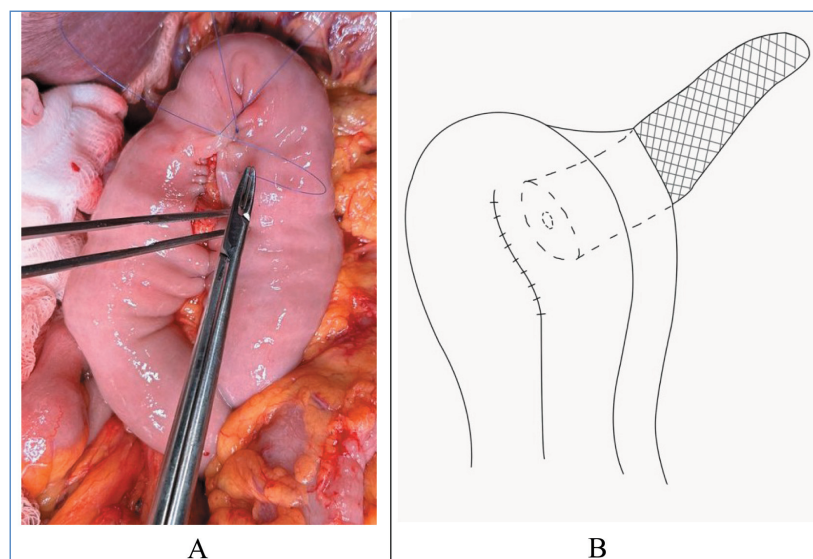


Fig. 5. Forming of the anterior wall of the anastomosis. A – serous-muscular interintestinal running suture. B – scheme of the pancreaticojejunostomy, final view. Note: created by the authors

Рис. 5. Формирование передней стенки анастомоза. А – серозно-мышечный межкишечный непрерывный шов. В – схема панкреатоеюноанастомоза, окончательный вид. Примечание: рисунок выполнен авторами

Patients characteristics

A total of 173 patients undergoing PDE between 2013 and 2025 were analyzed. The inclusion criteria for the study were: 1) PDE, 2) a periampullary tumor, 3) a chronic pancreatitis complicated by pain, obstructive jaundice, pancreatic hypertension. Exclusion criteria were: PDE performed as a multivisceral resection for a non-periampullary tumor invading the head of the PG or duodenum. Patient characteristics are presented in Table 1.

Pancreatic and duodenal carcinomas prevailed among all pathologies. Other malignant tumors were represented by a duodenal lymphoma and a metastasis of a colorectal carcinoma in the apical lymph nodes with invasion into the pancreas or duodenum. Pancreatitis and benign tumors did not exceed 10 % of all the diseases. Details of surgeries are given in Table 2.

Seven operations were multivisceral (4.0 %), 4 anatomical liver resections, 2 resections of the colon and 1 of the small intestine were performed. In 35 (20.2 %) patients PDE was associated with resection and angioplasty of main vessels: the resections of the hepatic artery and the superior mesenteric artery in 3 cases and venous porto-mesenteric resections in 33 ones.

PS parenchyma density and the diameter of the main pancreatic duct were recorded because they are risk factors for the CR-POPF, and were applied to assess an individual risk using Modified Fistula Risk Score developed by Kantor O. et al. (2017) [11]. The score is shown in Table 3.

The Cattle technique was applied to form “duct-to-mucosa” anastomoses [6], invaginational anastomoses were formed by the technique similar to that described

Table 1/ Таблица 1

Characteristics of patients included in the study Характеристики пациентов, вошедших в исследование

Показатели/Parameters	Значение/Value
Возраст, лет/Age, years (min – max; mean $\pm$ SD)/	36 – 80; 62.3 $\pm$ 9.7
Пол (мужской/женский)/Gender (males/females)	98 (56.6 %)/75 (43.4 %)
Индекс массы тела/Body mass index (min – Q25 – med – Q75 – max)	18.8 – 22.1 – 28.0 – 33.3 – 38.2
Механическая желтуха/Obstructive jaundice	112 (64.7 %)
Диагноз/Diagnosis	
Рак дистального отдела холедоха/Distal common bile duct carcinoma	7 (4.0 %)
Нейроэндокринная опухоль поджелудочной железы/Pancreatic neuroendocrine tumor	4 (2.3 %)
Рак большого дуоденального сосочка/Ampullary carcinoma	11 (6.4 %)
Рак двенадцатиперстной кишки/Duodenal carcinoma	38 (22.0 %)
Рак поджелудочной железы/Pancreatic ductal carcinoma	93 (53.8 %)
Прочие злокачественные опухоли/Other malignant tumors	3 (1.7 %)
Доброкачественные опухоли/Benign tumors	4 (2.3 %)
Панкреатит/Pancreatitis	
T (1 – 2 – 3 – 4)*	14 – 22 – 89 – 30
N (0 – 1 – 2)	99 – 53 – 3

Примечания: * – T, N представлены только для первичных периапулярных опухолей; таблица составлена авторами.

Notes: * – T, N are presented only for primary periampullary tumors; created by the authors.

Table 2/Таблица 2

Surgical details
Детали операций

Показатели/Parameteres	Значение/Value
Плотность паренхимы поджелудочной железы/PG parenchyma density	
Плотная /Firm	122* (70.5 %)
Мягкая /Soft	50 (28.9 %)
Диаметр панкреатического протока/PD diameter	
≥6 мм/mm	130 (75.1 %)
3–6 мм/mm	42 (24.3 %)
Тип панкреатического анастомоза/Pancreatic anastomosis type	
“Duct-to-mucosa”	122 (70.5 %)
Инвагинационный/Invaginal	25 (14.5 %)
Катетер-направленный/Catheter-guided	9 (5.2 %)
Муфтообразный оригинальный/Novel sleeve-shaped	16 (9.2 %)

Notes: * – in one case there was no pancreatic anastomosis and PG parenchyma density likewise a PD diameter were not taken into account; created by the authors.

Примечания: * – в одном случае не было панкреатического анастомоза. Плотность паренхимы поджелудочной железы и диаметр панкреатического протока не оценивались; таблица составлена авторами.

Table 3/Таблица 3

Modified Fistula Risk Score
Модифицированная шкала риска панкреатической фистулы

Фактор риска/Risk Factor	Отношение шансов (95 % ДИ)/ Odds Ratio (95 % CI)	Баллы риска/ Risk Score
Женский пол/Female	Референсное значение/Reference	0
Мужской пол/Male	2.15 (1.47–3.18)	2
ИМТ < 25 кг/м²/BMI < 25 kg/m²	Референсное значение/Reference	0
ИМТ ≥ 25 кг/м²/BMI ≥ 25 kg/m²	1.55 (1.04–2.32)	1
Общий билирубин ≥ 2 мг/дл/Total bilirubin ≥ 2 mg/dL	Референсное значение/Reference	0
Общий билирубин < 2 мг/дл/Total bilirubin < 2 mg/dL	2.07 (1.22–3.51)	1
Диаметр панкреатического протока/Diameter of PD		
≥ 6 мм/≥ 6 mm	Референсное значение/Reference	0
3–6 мм/3–6 mm	2.89 (1.11–7.48)	3
< 3 мм/< 3 mm	4.63 (1.77–12.10)	4
Поджелудочная железа высокой или промежуточной плотности/Firm or intermediate PG		
Мягкая поджелудочная железа/Soft PG	2.71 (1.64–2.62)	2
Всего/Total*		0–10

Notes: * – 0–2 points for negligible risk (0 % risk of CR-POPF), 3–6 points for low risk (<10 % risk of CR-POPF), 7–8 points for intermediate risk (10 % to 20 % risk of CR-POPF), and 9–10 points for high risk (>20 % risk of CR-POPF); BMI – body mass index; created by the authors.

Примечания: * – 0–2 балла, отсутствие риска (незначительный), 3–6 баллов, низкий риск, <10 %, 7–8 баллов, промежуточный риск, 10–20 %, и 9–10 баллов, высокий риск, >20 %; ИМТ – индекс массы тела; таблица составлена авторами.

by B.V. Sigua et al. (2021) [12]. When forming a catheter-guided anastomosis the PS was fixed “to the side” of the small intestine using U-shaped sutures, the catheter was inserted 1.5–2 cm into the PD and was fixed by a U-shaped suture. The catheter was delivered to the skin in the form of external pancreaticostomy.

Statistical analysis

All the statistical calculations were implemented using the freely distributable “R” programming language (v. 4.4.1), integrated developer’s environment “RStudio” 2024.09.1 Build 394 © 2009–2024 Posit

Software, PBC, and statistical package “JASP” (v. 0.18.3, Built on Jan 11 2024, © 2013–2024 University of Amsterdam). The probability of the type I error of $p=0.05$ was regarded as the threshold of statistical significance. Descriptive statistics were represented as a mean, median, quartiles (Q25, Q75), standard deviation (SD), and a standard error (SE); a 95 % confidence interval (95 % CI) was used. Fisher’s exact test and Pearson’s χ^2 test were applied to analyze contingency tables. We performed Bayesian regression analysis using the R library “brms” (Bayesian Regression Models using “Stan”, v. 2.21.0, <https://github.com/>

Table 4/Таблица 4

The rate of CR-POPF by the type of a pancreatic anastomosis
Частота КЗ-ПОПФ при различных типах панкреатических анастомозов

Тип анастомоза/Type of anastomosis	КЗ-ПОПФ/CR-POPF		Всего/Total
	Нет/No	Есть/Yes	
«Duct-to-mucosa»	114	8 (6.6 %)	122
Инвагинационный/Invaginal	21	4 (16.0 %)	25
Муфтообразный оригинальный/Novel sleeve-shaped	16	0	16
Без анастомоза/No anastomosis	0	1	1
Катетер-направленный/Catheter-guided	7	2 (22.2 %)	9
Всего/Total	158	15	173

Notes: CR-POPF – clinically relevant postoperative pancreatic fistula; created by the authors.

Примечания: КЗ-ПОПФ – клинически значимая послеоперационная панкреатическая фистула; таблица составлена авторами.

Table 5/Таблица 5

The individual risk of CR-POPF by groups of pancreatic anastomoses
Индивидуальный риск КЗ-ПОПФ при различных типах панкреатических анастомозов

Тип анастомоза/Type of anastomosis		Степень риска/Degree of Risk				Всего/Total
		Высокий/High	Промежуточный/Intermediate	Низкий/Low	Незначительный/Negligible	
«Duct-to-mucosa»	Кол-во/Count	0.00	1.00	56.00	65.00	122.00
	% по строке/within row	0.00 %	0.82 %	45.90 %	53.28 %	100.00 %
Инвагинационный/Invaginal	Кол-во/Count	3.00	9.00	9.00	4.00	25.00
	% по строке/within row	12.00 %	36.00 %	36.00 %	16.00 %	100.00 %
Муфтообразный оригинальный/Novel sleeve-shaped	Кол-во/Count	2.00	5.00	7.00	2.00	16.00
	% по строке/within row	12.50 %	31.25 %	43.75 %	12.50 %	100.00 %
Катетер-направленный/Catheter-guided	Кол-во/Count	0.00	7.00	2.00	0.00	9.00
	% по строке/within row	0.00 %	77.78 %	22.22 %	0.00 %	100.00 %
Всего/Total	Кол-во/Count	5.00	22.00	74.00	71.00	172.00
	% по строке/within row	2.91 %	12.79 %	43.02 %	41.28 %	100.00 %

Notes: CR-POPF – clinically relevant postoperative pancreatic fistula; created by the authors.

Примечания: КЗ-ПОПФ – клинически значимая послеоперационная панкреатическая фистула; таблица составлена авторами.

Table 6/Таблица 6

Comparison of the efficiency of NSSP with the efficiency of other types of anastomoses
Сравнение эффективности муфтообразного оригинального анастомоза с эффективностью других типов анастомозов

Тип анастомоза для сравнения/Type of anastomosis to compare	ОШ (95 % ДИ)/OR (95 % CI)
«Duct-to-mucosa»	1.19 (0.65–2.38)
Инвагинационный/Invaginal	3.44 (2.63–11.11)
Катетер-направленный/Catheter-guided	5.54 (3.41–8.22)

Notes: OR (95% CI) – odds ratio and 95% confidence interval; created by the authors.

Примечания: ОШ (95 % ДИ) – отношение шансов и 95 % доверительный интервал; таблица составлена авторами.

paul-buerkner/brms). For bootstrap testing (calculation of OR) R-package “fwb” (Fractional Weighted Bootstrap, v. 0.5.1, <https://ngreifer.github.io/fwfb/>, <https://github.com/ngreifer/fwfb> Maintainer: Noah Greifer <noah.greifer@gmail.com>) was applied.

Results

In total, 15 (8.7 %) CR-POPF of types B and C have been registered after 173 PDE. The rate of CR-POPF by the variant of a pancreatic anastomosis is presented

in Table 4. The differences in Table 4 are statistically significant (Pearson’s $\chi^2=16.5$, $df=4$, $p=0.002$).

The study used a Modified Fistula Risk Score to assess the risk of CR-POPF. The individual risk of CR-POPF by groups of pancreatic anastomoses is presented in Table 5.

The differences in Table 5 are statistically significant (Pearson’s $\chi^2=90.6$, $df=9$, $p<0.001$). It should be noted that the soft parenchyma of the PG was observed in 8.2 % in the group of DTMA (10 out of 122),

Table 7/Таблица 7

Results of regression modeling of the expected rate of a CR-POPF
in different types of pancreatic anastomoses

Результаты регрессионного моделирования ожидаемой частоты КЗ-ПОПФ при различных типах
анастомозов

Family: bernoulli; Links: mu=logit; Formula: fistula ~ 1 + (1|anastomosis); Data: df (Number of observations: 172)/
Распределение Бернулли; Функция связи: логит-преобразование; Модель: fistula ~ 1 + (1|anastomosis);
Количество наблюдений: 172

Draws: 4 chains, each of iter=2000; warmup=1000; thin=1; total post-warmup draws=4000/
Аргументы функции моделирования brm пакета brms: количество цепей=4; количество итераций в цепи=2000;
период прогрева=1000 итераций; толщина цепи=1; выбрано после прогрева=4000 итераций

Multilevel Hyperparameters: ~anastomosis (Number of levels: 4)/Многоуровневые гиперпараметры:
~anastomosis (Количество уровней: 4)

	Estimate/ Оценка	SE	l-95 %	u-95 %	$\hat{R}$	Bulk_ESS	Tail_ESS
sd (Intercept)/sd(Константа)	1.23	1.02	0.05	3.82	1.00	805	1181
Individual intercepts/Индивидуальные константы:							
Intercept (type 1 “duct-to-mucosa”)/ Константа (тип 1 «duct-to-mucosa»)	-2.63	0.34	-3.34	-2.00			
Intercept (type 2 “invaginalational”)/ Константа (тип 2 «инвагинационный»)	-1.95	0.53	-2.96	-0.92			
Intercept (type 3 “catheter guided”)/ Константа (тип 3 «катетер-направленный»)	-1.86	0.76	-3.31	-0.34			
Intercept (type 4 “sleeve-shaped”)/ Константа (тип 4 «муфтообразный»)	-3.41	1.52	-7.43	-1.74			
Regression coefficients/Коэффициенты регрессии:							
Intercept/Константа	-2.24	0.80	-3.88	-0.31	1.00	904	680

Notes: SE – standard error; l-95 % – lower border of the 95 % CI; u-95 % – upper border of the 95 % CI; $\hat{R}$ – potential scale reduction factor;
Bulk_ESS – effective sample size for the central part of the posterior distribution; Tail_ESS – effective sample size for the tail parts of the posterior
distribution; created by the authors.

Примечания: SE – стандартная ошибка оценки; l-95 % – нижняя граница 95 % ДИ; u-95 % – верхняя граница 95 % ДИ; $\hat{R}$ – потенциальный
коэффициент уменьшения масштаба; Bulk_ESS – эффективное количество выбранных значений для центральной части апостериорного
распределения; Tail_ESS – эффективное количество выбранных значений для «хвостов» апостериорного распределения; таблица составлена
авторами.

68.0 % in the group of IAs (17 out of 25), 87.5 % in the group of NSSPs (14 out of 16), and 100.0 % in the group of CGAs (9 out of 9).

The efficacy of the NSSP was compared pairwise with other variants of pancreaticojejunostomies. As the invaginalational, catheter-guided and novel sleeve-shaped anastomosis groups had limited observations, classical mathematical statistical methods were not applied. Bootstrap machine learning was used, the odds ratio (OR) was estimated as a measure of differences between groups. The result of the comparative analysis is shown in Table 6.

As the last analysis, a regression model of the expected rate of CR-POPF was fitted for different anastomosis variants. The result of regression modeling is presented in Table 7.

This was a multilevel Intercept-only model, the type of the anastomosis played the role of the grouping variable. Based on the regression coefficients and confidence intervals, the following expected rates of CR-POPF for different types of anastomoses were calculated: 1) for the DTMA – 6.7 % (3.4–11.9); 2) for the IA – 12.6 % (4.9–28.5); 3) for the CGA – 13.6 % (3.5–41.6), 4) for the NSSP – 3.2 % (+0.00–14.9).

The computed CR-POPF rates were relevant to the observed ones (Table 4).

Discussion

The best results (the lowest CR-POPF rates) were observed in the DTMA and NSSP anastomosis groups, with no statistically significant differences between them (Table 6). However, it should be noted that the individual risk of the fistula in the DTMA group was significantly lower than in the NSSP group, and the soft parenchyma of the PG as the main risk factor for CR-POPF in the NSSP group was found 10 times more often. All CR-POPF in the DTMA group were observed in patients with soft parenchyma of the PG. Thus, DTMA is well-proven only in dense parenchyma cases and it should not be recommended in soft parenchyma ones.

Catheter-guided and invaginalational anastomoses were applied primarily in patients with high risk of the CR-POPF as a possible alternative to the DTMA anastomosis. Unfortunately, these variants of junctions proved ineffective, the chance of the CR-POPF was 3.5–5.5 times higher than in the NSSP. Just the first empirical evaluation of short series of these anastomo-

ses demonstrated an unacceptable rate of CR-POPF (Table 4). This was a reason to completely abandon their use. As technological shortcomings of CGA and IA one may note: 1) easy breaking of sutures passed through a soft parenchyma of the PG and dislocation of the PG from the small intestine sleeve of any design, 2) complexity to control the PD catheter position and unexpected migration of the catheter. All this inevitably resulted in a complete dehiscence of the pancreatic anastomosis.

NSSP has been developed specifically for the soft PG in order to prevent the technical problems mentioned above. Therefore, some technical requirements for the intestine to a soft PG anastomosis have been formulated a priori: 1) the pancreatic duct should be sewn into the intestine separately and precisely, 2) the PS should always be surrounded by a dense small bowel sleeve that prevents pancreatic juice leakage in the case of PD anastomosis insufficiency, 3) the fixing sutures between the pancreas and the intestine must not cut themselves through, which prevents the dislocation of the PS from the intestinal sleeve and the dehiscence of the anastomosis.

We believe, the proposed design of the NSSP largely meets these requirements. Passing the PS through the mesentery greatly facilitated the technical implementation of the whole design: we did not consider the mesentery to be an additional barrier for pancreatic juice and did not fix it. This trick had been used before, for example in the structure of the esophageal anastomosis. The key technical point of the NSSP is U-shaped fixing sutures. On both sides they are supported by intestinal walls which play the role of “ideal natural viable” supporting pads, excluding cutting the sutures through. The transpancreatic passing of U-shaped sutures at a distance from the edge of the PS allowed reducing their number to 2 and at the same time preventing dislocation of the gland from the intestinal sleeve. The possibility of precise suturing of the PD in all the cases, for example, if its diameter is less than 3 mm, seems to be debatable. In our series of 16 operations with NSSP, we always managed to identify the PD applying a 4-fold optical magnification and sew it into the bowel lumen.

Pancreatic anastomoses of similar design had been developed earlier. For example, the options proposed

by V.F. Kasatkin et al. (1999) [13], A.J. Barannikov et al. (2016) [14] are known. The authors applied a purse-string suture and a semipurse-string sutures running along the mesenterial margin of the intestine to ensure the tight adherence of the sleeve with extra-organ (outside the PG) fixation of these sutures. In our opinion, purse-string sutures deteriorate the blood supply of the intestine, and their extra-organ fixation may be unreliable in case of inflammatory or necrotic tissue changes, such as pancreatitis/ pancreonecrosis or a fistula of type A. In our series of 16 NSSP, pancreatitis/ pancreonecrosis was recorded in 4 observations, with no anastomosis failure. In addition, with the unchanged soft PG, there are usually no strong tissues suitable for fixation around it. Therefore, we preferred the fixing of the intestinal sleeve on the PG itself. However, the obvious advantage of the anastomoses proposed by the authors is in the complete absence of sutures passed through the parenchyma of the PG, which undoubtedly reduces the trauma of the organ.

Limitations

The small size of the groups in which the IA, CGA and NSSP were used did not allow for the application of classical mathematical statistics and resulted in large enough confidence intervals for estimates of central tendencies in the groups. For ethical reasons, we stopped recruitment of patients into the IA and CGA groups because the unacceptable rate of CR-POPF was obvious. The application of machine learning helped to overcome the problem of small size samples.

Conclusion

Clinically relevant post-operative pancreatic fistulas remain a key problem of modern surgical pancreatology. Despite the large number of developed pancreatic anastomoses the search for new techniques and designs continues. The anastomosis proposed in this study is adapted for prevention of pancreatic fistulas in the most difficult circumstances, with a high risk of complications against a soft parenchyma pancreas. The novel sleeve-shaped pancreaticojejunostomy proved effective and in a short series of surgeries demonstrated the lowest rate of CR-POPF compared to other known types of anastomoses. For more strong inference further studying is necessary.

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Dmitry A. Chichevatov: the conception and design of the study, analysis and interpretation of data.

Artem E. Glukhov: acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content.

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Conflict of interest

The authors declare that they have no conflict of interest.

Compliance with Ethical Standards

The study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki approved by Ethics Committee of Penza State University (40, Krasnaya St., Penza, 440026, Russia), protocol No. 10 dated June 27, 2025.

Voluntary informed consent

Written informed voluntaries consents were obtained from the patients for the publication of data and photographs in medical journal.

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ВКЛАД АВТОРОВ

Калентьев Вячеслав Викторович: концепция и дизайн исследования, сбор данных, анализ и интерпретация данных, написание статьи и ее критический пересмотр на предмет важного интеллектуального содержания.

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Все авторы одобрили финальную версию статьи перед публикацией, выразили согласие нести ответственность за все аспекты работы, подразумевающую надлежащее изучение и решение вопросов, связанных с точностью и добросовестностью любой части работы.

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Информированное согласие

Все пациенты подписали письменное информированное согласие на публикацию данных и фотоматериалов в медицинском журнале, включая его электронную версию.

Примечание. По мнению рецензентов и редколлегии, статья представлена как первый опыт применения оригинальной методики формирования панкреатоеюноанастомоза. В дальнейшем ее эффективность должна быть доказана на большей выборке больных. Также необходимо провести сравнительный анализ с методикой «duct-to-mucosa». При этом группы для сравнения должны быть сопоставимы по структуре ткани поджелудочной железы и диаметру панкреатического протока.

Note. According to the reviewers and editors, this article represents the first attempt at using an original technique for forming a pancreatojejunostomy. Its effectiveness should be further demonstrated in a larger patient sample. A comparative analysis with the “duct to mucosa” technique is also necessary. The comparison groups should be comparable in terms of pancreatic tissue structure and pancreatic duct diameter.