

Review Article

Impact of Surgical Technique on Reducing the Incidence of Postoperative Pancreatic Fistula: A Systematic Review and Meta-Analysis

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Abstract

Background: Postoperative pancreatic fistula (POPF), a complication frequently encountered following pancreaticoduodenectomy. Pancreaticojejunostomy (PJ) and pancreaticogastrostomy (PG) are the most frequently utilized reconstructive strategies with different anastomosis techniques. This study was conducted to evaluate the optimal surgical technique to prevent POPF. **Methods:** The study was conducted using PRISMA guidelines with PROSPERO registration No. CRD42023494393. Patients undergoing pancreaticoduodenectomy includes the use of PJ or PG with different anastomoses techniques and developed POPF were included. We conducted a systematic literature review from January 2019 to December 2023 using a comprehensive search strategy, through Web of Science, ProQuest, Science Direct, PubMed, and Google Scholar databases. Meta-analysis was utilized to analyze the outcomes. The risk of bias was assessed using the Newcastle-Ottawa scale. **Results:** Eighteen studies with 3343 patients who underwent various anastomoses (including the Modified DuVal, Heidelberg PJ, and Blumgart methods) were included. Postoperative pancreatic fistula (POPF) occurred in 27% of patients. Techniques such as modified Heidelberg, Peng, shark mouth PJ, and Kiguchi PJ were associated with lower POPF rates, whereas modified and classical Blumgart techniques exhibited higher rates. While mortality rates varied among surgical techniques, overall mortality was low. **Conclusions:** Data from this study can be used to shape future studies and direct physicians to develop strategies to reduce the risk of POPF and thereby reduce morbidity and mortality, leading to improved patient outcomes. Furthermore, this data can inform clinical decision-making and guide the development of evidence-based practice guidelines to optimize surgical outcomes.

Keywords

Pancreatic Fistula, Pancreatoduodenectomy, POPF, Systematic Review and Meta-Analysis

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1. Introduction

The International Study Group of Pancreatic Fistula (ISGPF) has established a definition for postoperative pancreatic fistula (POPF), a complication frequently encountered following pancreaticoduodenectomy (PD) [1]. Prior research has identified several factors potentially associated with an increased risk of POPF following pancreaticoduodenectomy. These factors include male gender, high body mass index (BMI), the specific anastomotic technique employed, and the use of an external drainage stent [2]. PD is a major surgical procedure associated with high rate of postoperative morbidity and mortality [3]. The optimal management of the pancreatic remnant following pancreaticoduodenectomy remains a topic of debate, with various reconstructive techniques employed. The primary objective of each approach is to minimize the risk of POPF and its subsequent impact on patient outcomes. Pancreaticojejunostomy (PJ), encompassing techniques such as pancreatic invagination or duct-to-mucosa anastomosis, and pancreaticogastrostomy (PG) represent the most frequently utilized reconstructive strategies [4]. While PJ, the surgical creation of a connection between the pancreas and the jejunum, is a necessary step during PD, it also carries a recognized risk of POPF [5]. Severe POPF can progress to abdominal infection. This infection carries a risk of eroding the gastroduodenal artery and its surrounding vasculature, potentially leading to delayed hemorrhage and mortality. Studies have reported mortality rates associated with severe POPF ranging from 20% to 50% [6]. Selecting the optimal pancreatico-enteric reconstruction following central pancreatectomy presents a crucial decision for surgeons. While PG offers a technically simpler approach and avoids the need for Roux-en-Y reconstruction, PJ may provide superior long-term exocrine function. Careful consideration of these factors is essential to optimize patient outcomes [7]. PD is associated with a significant risk of postoperative complications. These complications include POPF (occurring in 3–45% of patients), delayed gastric emptying (7–37%), anastomotic stenosis (3.3–30%), intra-abdominal infection (2.5–23.3%), and postoperative bleeding (5–12%). The overall morbidity rate remains high, ranging from approximately (65.9% to 77.5%) [8]. The Fistula Risk Score (FRS) is the most widely adopted and utilized clinical tool for predicting POPF following PD. This score incorporates several intraoperative and postoperative variables, including the surgeon-measured diameter of the main pancreatic duct, the surgeon-palpated texture of the gland, intraoperative blood loss, and histopathological analysis of the resected tissue [9].

This study was conducted to evaluate the optimal approach to preventing postoperative pancreatic fistula. We present this article in accordance with the PRISMA reporting checklist.

2. Methods

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) guidelines [10] and has been registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42023494393. Two independent reviewers L. Z., E. M., conducted the search, selection of studies, and three authors have extracted the data A. Z., N. Q., A. Q. A third reviewer resolved the disagreement by consensus E. M.

2.1. Literature Search

The electronic bibliographic databases Web of Science, ProQuest, Science Direct, PubMed, and Google Scholar were comprehensively searched for the studies published from January 2019 to December 2023. The following text and keywords were used in combination with the Medical Subject Headings (MeSH) in the search: (Preoperative OR POPF OR prevention AND pancreatic fistula AND Pancreaticojejunostomy OR Pancreaticogastrostomy OR pancreas surgery AND Risk factors OR Octreotide OR Sealant agent OR post operative Darin). A search term was identified in the title, abstract, or heading of the medical subject. In the research, only English language articles dealing with human patients were considered.

2.2. Inclusion and Exclusion Criteria

All Case-control studies, Cross-sectional studies, Retrospective and Prospective cohort studies, Case reports, and Randomized control trials were included in this study. All studies investigating adult patients undergoing pancreaticoduodenectomy that includes the use of pancreaticojejunostomy (PJ) or pancreaticogastrostomy (PG) anastomosis with different anastomoses techniques and developed postoperative pancreatic fistula (POPF) were considered for inclusion.

Studies were excluded from this study if they were not available in English, utilized distal pancreatectomy or pancreatic stent, were done on pediatrics or the elderly, letters, Systemic reviews and meta-analyses, editorials, and animal studies.

2.3. Study Selection and Data Extraction

18 studies met the inclusion criteria of this review as shown in Figure 1. The titles and abstracts of the studies were screened by two independent reviewers (L. Z. and N. Q.). The duplicate articles were eliminated using Rayyan [11]. Three independent reviewers conducted the full-text screening for all studies (A. Z. and E. M.). Discrepancies in judgments made were discussed between all the authors and resolved by consensus. All the authors independently examined the included articles and extracted the following data: study information including study design, first author name, year of

publication, country of study, sample size, and demographic data including age, sex, BMI, comorbidities, and the type of

intervention, incidence of POPF, histopathology, duct size, gland texture, blood loss, and the conclusion.

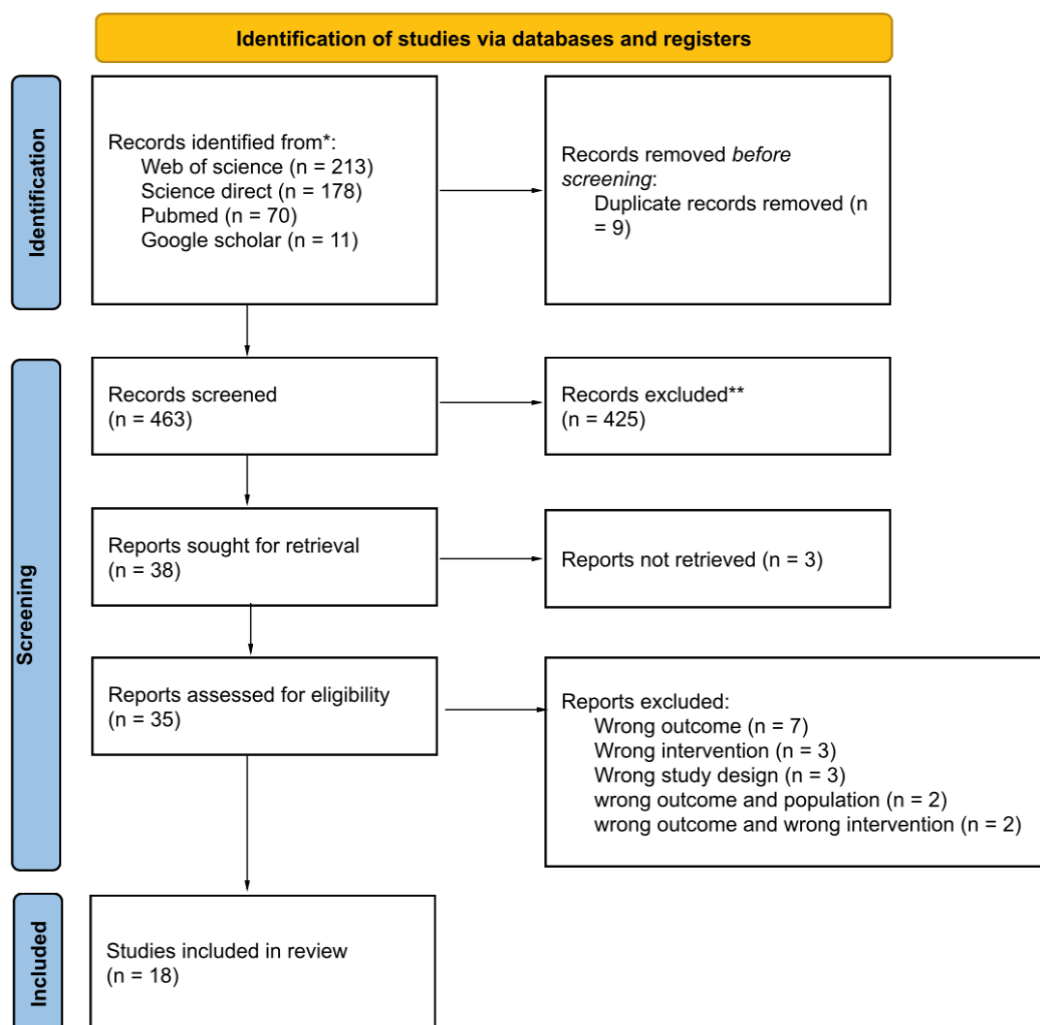


Figure 1. PRISMA flow diagram for new systematic reviews which included studies.

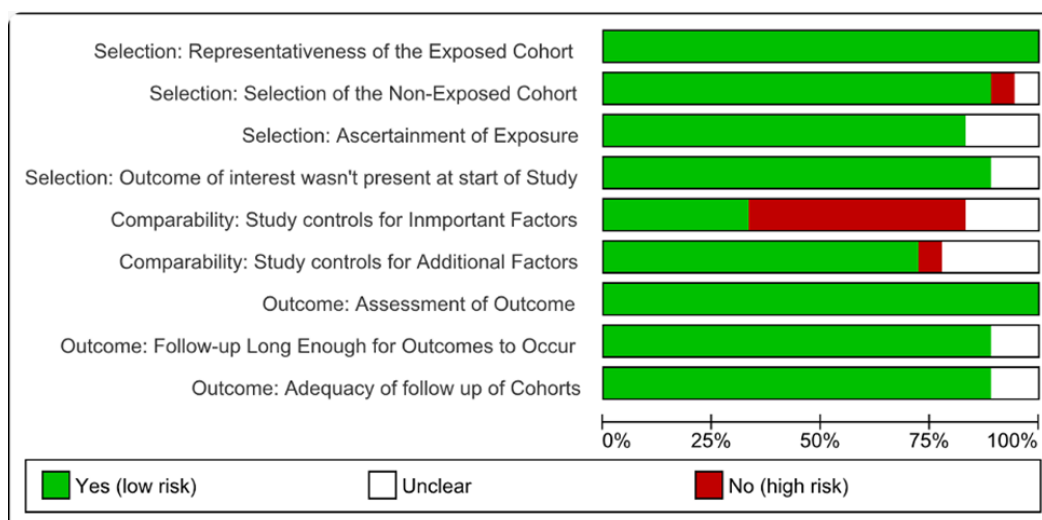


Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

	Selection: Representativeness of the Exposed Cohort	Selection: Selection of the Non-Exposed Cohort	Selection: Ascertainment of Exposure	Selection: Outcome of interest wasn't present at start of Study	Comparability: Study controls for Important Factors	Comparability: Study controls for Additional Factors	Outcome: Assessment of Outcome	Outcome: Follow-up Long Enough for Outcomes to Occur	Outcome: Adequacy of follow up of Cohorts
Ausania et al. (2021)	+	+	+	+	+	+	+	+	+
Bardol et al. (2020)	+	+	+	+	-	+	+	+	+
Capretti et al. (2021)	+	+	+	+	-	+	+	+	+
Chen et al. (2023)	+			+			+	+	+
Gupta et al. (2019)	+	+	+		-	+	+	+	+
Kawaida et al. (2020)	+	+	+	+	+		+	+	+
Kazantsev et al. (2023)	+	+	+	+	-	+	+	+	+
Kiguchi et al. (2021)	+	+	+	+	+	+	+	+	
Li et al. (2022)	+	+	+	+	-	+	+	+	+
Marino et al. (2021)	+	+	+	+		+	+	+	+
Mori et al. (2022)	+	+	+	+	-	+	+	+	+
Rentao et al. (2019)	+	+	+		+		+	+	+
Rivas et al. (2019)	+	+		+	-	+	+	+	+
Routh et al. (2018)	+	+	+	+	-	+	+	+	
Satoi et al. (2019)	+	+	+	+	+		+	+	+
Wang et al. (2021)	+	+	+	+	-	+	+	+	+
Yildirim et al. (2020)	+	+		+	+	-	+	+	+
Zimmitti et al. (2021)	+	-	+	+		+	+	+	+

Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study (Total Scores = 9).

2.4. Quality Assessment and Bias Risk

The methodological quality of the cohort study was meticulously assessed using the Newcastle-Ottawa Scale, a widely recognized tool for evaluating the quality of non-randomized studies [12]. It was conducted by three independent reviewers, ensuring a robust evaluation process. In cases where discrepancies arose, consensus was reached among the reviewers through mutual discussion. If consensus could not be achieved, a third party was involved to facilitate

conflict resolution, ensuring impartiality and accuracy in the evaluation process. The assessment encompassed three main sections, each addressing specific aspects of the study methodology: study population selection (4 scores), comparability (2 scores), and Outcome Assessment (3 scores). Within these sections, a total of nine components were evaluated, with each component consisting of 2 to 4 questions designed to gauge the risk of bias. Reviewers assigned ratings of high, low, or unclear risk of bias based on their assessment of each question.

The results of the assessment were summarized using both a risk of bias graph and a summary (Figures 2 and 3), providing a comprehensive overview of the study's strengths and weaknesses. Notably, the quality score in all domains such as the selection of studies, outcome assessment, and follow-up long enough for the outcome to occur is very high for all studies. Furthermore, certain aspects such as comparability of important factors of research and additional factors demonstrated low to medium quality scores. This underscores the importance of rigorously evaluating cohort studies' methodological quality to ensure their findings' reliability and validity.

3. Results

The characteristics of the included studies (n=18) in this review encompass a diverse range of countries including Japan, China, the USA, Italy, and others, with sample sizes varying from 24 to 975 participants. These studies span years from 2018 to 2023 and utilize a mix of retrospective studies, longitudinal cohort studies, and prospective observational clinical trials. Notable contributions include Mori's retrospective study in Japan with 24 participants (smallest sample size) [13], Rivas' large-scale retrospective study in the USA involving 975 participants (largest sample size) [14], and Kazantsev's prospective study in the USA with 309 participants [15]. This diversity in study design and geographic locations provides a broad perspective on healthcare practices and outcomes internationally (Table 1).

The median age of patients across the studies tends to hover around the 60s, with individual study median ages such as 67 years in Mori's and 69 years in Ausania's study, suggesting a predominantly older patient demographic undergoing these surgical procedures [3, 13]. Gender distribareion across these studies are nearly balanced, though slight male predominance is noted in several reports, such as in Li's 2021 study where males comprised 59.8% of the patient group [17].

Regarding interventions, the majority involve complex pancreatic surgeries such as pancreaticoduodenectomy, with specific focus on the type of anastomosis technique used, which is critical for reducing postoperative complications such as pancreatic fistulas. Techniques such as the Modified DuVal, Heidelberg PJ, and various Blumgart modifications are frequently used, reflecting their prevalence and perceived

effectiveness in clinical settings. BMI values provided in some studies indicate a general patient profile, with values as 26 in Ausania's study and 24.8 in Capretti's study, which could

influence surgical outcomes and recovery processes [3, 21] (Table 2).

Table 1. Characteristics of the included studies.

Author	Year of publication	Country	Sample size	Study design
Mori [13]	2022	Japan	24	Retrospective study
Ausania [3]	2021	Spain	212	Longitudinal cohort study
Rentao Li [16]	2019	China	229	Retrospective study
Kawaida [2]	2020	Japan	237	Retrospective study
Chen [1]	2023	China	144	Single-center retrospective cohort study
Li [17]	2022	China	233	Prospective single-arm observational clinical trial
Kiguchi [18]	2021	Japan	83	Retrospective study
Marino [4]	2021	Italy	60	A retrospective case matched comparative study
Zimmitti [19]	2021	Italy	102	Retrospective and prospective study
Rivas [14]	2019	USA	975	Retrospective study
Satoi [20]	2019	Japan	246	Retrospective study
Capretti [21]	2021	Italy	35	Retrospective and prospective study
Yildirim [22]	2020	Turkey	144	Retrospective study
Wang [23]	2021	China	74	Retrospective study
Routh [24]	2018	India	97	Prospective observational study
Kazantsev [15]	2023	USA	309	Prospective study
Gupta [25]	2019	India	81	Retrospective study
Bardol [26]	2020	France	58	Retrospective cohort study

Table 2. Demographics of patients and interventions.

Author	Age (Median Years)	Gender n (%)	BMI (kg/m ²)	Intervention	Anastomosis Technique
Mori [13]	67	MDPJ; F=15 (62.5%), M=9 (37.5%)	20.7	DP	Modified DuVal
Ausania [3]	MH: 67, PJ: 69	MH; M=19 (57.6%), PJ; M=18 (62.1%)	26	PD	Heidelberg PJ Cattell-Warren PJ
Rentao Li [16]	CB: 60 MB: 62.5	CB; F=36 (44.44%), M=45 (55.55%), MB; F=53 (35.8%), M=95 (64.18%)	NM	PD	Classical Blumgart Modified-Blumgart
Kawaida [2]	Conventional PJ: 70 Modified PJ: 71	PJ; F (Conventional PJ = 23, Modified PJ = 20), M (Conventional PJ = 44, Modified PJ = 36)	PJ: 21.8, Trian- gular mattress suite method: 23	PD	PJ triangular mattress suite
Chen [1]	PJ: X=62	PJ; F=55 (38.2%), M=89 (61.8%)	No CR-POPF: 40, CR-POPF: 26	PD	PJ

Author	Age (Median Years)	Gender n (%)	BMI (kg/m ²)	Intervention	Anastomosis Technique
Li [17]	PJ; X=61 SMPJ: X=62	PJ; F=33 (40.2%), M=49 (59.8%), SMPJ; F=69 (45.7%), M=82 (54.3%)	SMP cohort: 23.15, PJ cohort: 22.97	PD	SMP PJ
Kiguchi [18]	PJ: 72.5, KMPJ: 70	PJ; M=15 (45.5%), KMPJ; M=24 (48.0%)	PJ: 21.9, Kiguchi method: 21.3	PD	PJ Kiguchi method
Marino [4]	PJ: 63.2 PG: 61.9	PJ; F=13 (32.5%), M=27 (67.5%) PG; F=7 (35%), M=13 (65%)	25	PPPD	PJ PG
Zimmitti [19]	NM	PG; M=40 (39.2%), F=62 (60.8%)	NM	PD	PG
Rivas [14]	PJ; X = 63.9 Invagination: X=62.8)	PJ; F (Duct to mucosa = 454 (53%), Invagination = 55 (45%))	NM	PD	PJ Invagination technique
Satoi [20]	MB; 72 MK: 69	MB; F=38 (32%), M=80 (68%) MK; F=55 (43%), M=73 (57%)	NM	PD	Blumgart PJ Kakita
Capretti [21]	PJ; M=64	PJ; F=12 (34%), M=23 (66%)	24.8	PD	PJ
Yildirim [22]	PJ; X=64.46, PT; X=61.89 DMWJ; X=62.17,	PJ; F=21 (42%), M=29 (58%), PT; F=2 (22.2%), M=7 (77.8%), DMWJ; F=31 (36.5%), M=54 (63.5%)	NM	Proximal PD	DMWJ Peng's Telescopic PJ
Wang [23]	45	PJ; F=14 (63.6%), M=8 (36.4%)	Rong's group: 24.1, PJ group: 24.8	Central pan- createctomy	Rong's PJ
Routh [24]	X=55.4	PG; F=37 (38.14%), M=60 (61.85%)	22.6	PD	PG
Kazantsev [15]	PJ: 69 PG: 65	PJ; F=85 (42.7%), M=114 (57.3%), PG; F=51 (46.4%), M=59 (53.6%)	26	PD	PJ
Gupta [25]	X=48.04	CB; F=33 (40.7%), M=48 (59.3%)	NM	PD	Blumgart PJ
Bardol [18]	74	PJ; F=21 (36%), M=37 (64%)	24.5	PD	PJ

4. Meta-Analysis

Our meta-analysis investigated the incidence of postoperative pancreatic fistula (POPF) across various surgical techniques. A total of 18 studies with 3027 observations and 780 events were included. The random effects model estimated an overall proportion of POPF at 27% (95% CI: 19% to 35%) (Figure 4). The high heterogeneity among studies was indi-

cated by a tau² of 0.0433 and an I² of 99, reflecting substantial variation between studies. When examining specific surgical techniques, the proportion of POPF varied significantly. Techniques such as the modified Heidelberg, peng technique, shark mouth PJ and the Kiguchi method for PJ exhibited lower incidences of POPF at 12% (95% CI: 3% to 28%), 11% (95% CI: 0% to 48%), 7% (95% CI: 4% to 13%) and 6 % (95% CI: 1% to 20%), respectively. Conversely, the Modified Blumgart and Classical Blumgart technique demonstrated a higher incidence of POPF at 28% (95% CI: 0%

to 64%), 37% (95% CI: 3% to 71%). Notably, Techniques like Pancreaticojejunostomy (PJ) were assessed across 12 studies, showing a pooled incidence of 34.00% (95% CI: 20% to 48%) with significant heterogeneity. Other techniques such as Pancreaticogastrostomy (PG) across four studies had a pooled incidence of 16% (95% CI: 1% to 31%). The test for subgroup differences revealed a significant variation in the incidence of POPF between the different surgical techniques (d.f. = 12, $p <$

0.0001), emphasizing the influence of surgical method on the outcome. Thus, the incidence of postoperative pancreatic fistula (POPF) varies significantly across different surgical techniques, with methods like the modified Heidelberg, peng technique, shark mouth PJ, and Kiguchi method demonstrating lower incidences compared to Modified and Classical Blumgart techniques.

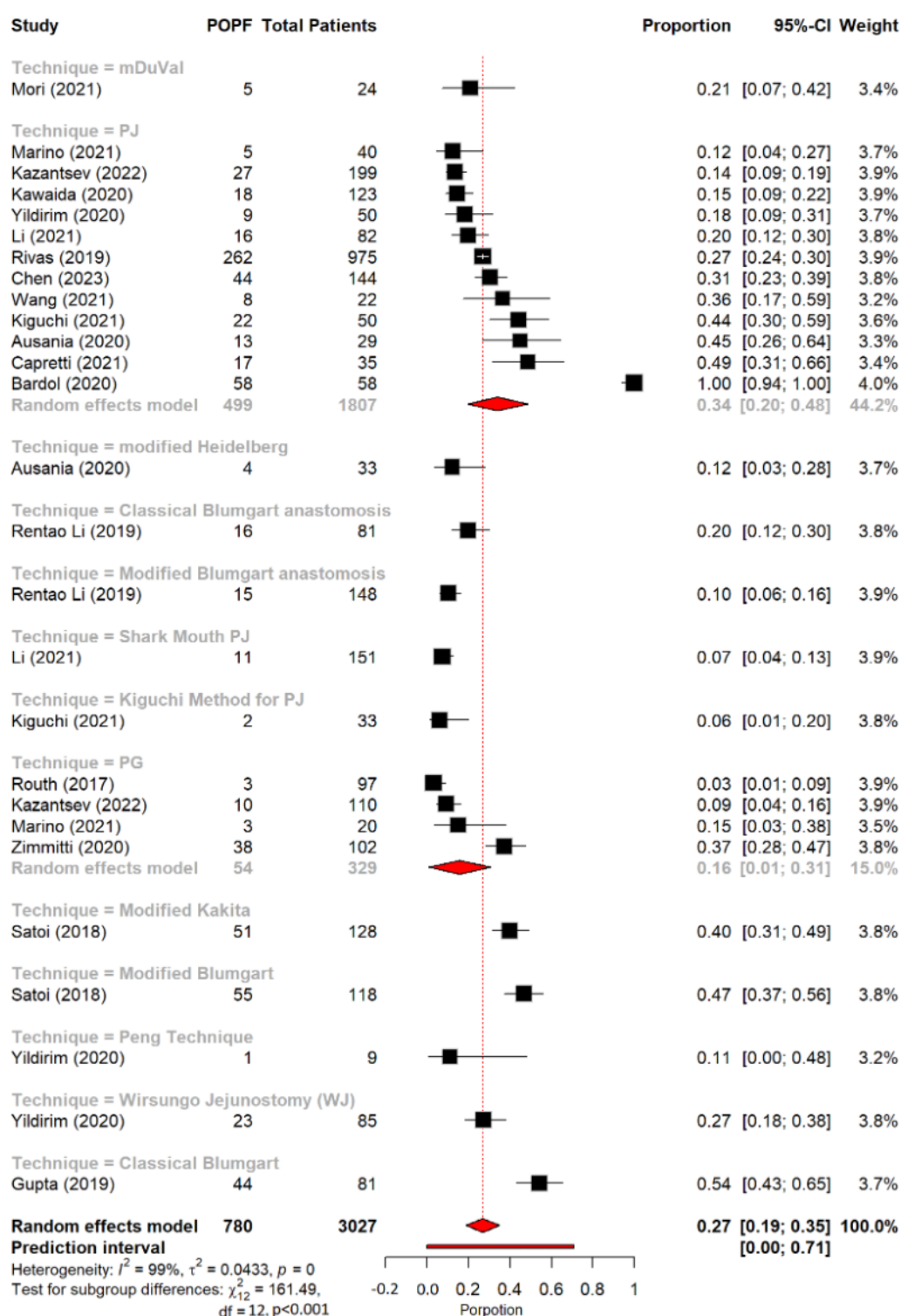


Figure 4. Incidence of Post Operative Pancreatic Fistula (POPF) among different techniques.

Figure 5 assessed blood loss across various pancreatic surgery techniques in 18 studies with 1600 observations. The random effects model estimated mean blood loss at 334.18 mL (95% CI: 250.84 to 445.21 mL), with substantial heterogeneity ($I^2 = 99.8\%$). Techniques with lower blood loss included the Shark Mouth PJ (200.00 mL, 95% CI: 170.51 to

234.58 mL) and Kiguchi Method for PJ (213. mL, 95% CI: 142.71 to 317.90 mL). The Modified Kakita (834.00 mL, 95% CI: 677.57 to 1026.54 mL) and Modified Blumgart (778.00 mL, 95% CI: 631.44 to 958.58 mL) techniques exhibited higher blood loss. Subgroup differences were significant ($Q = 407.73$, $p < 0.0001$).

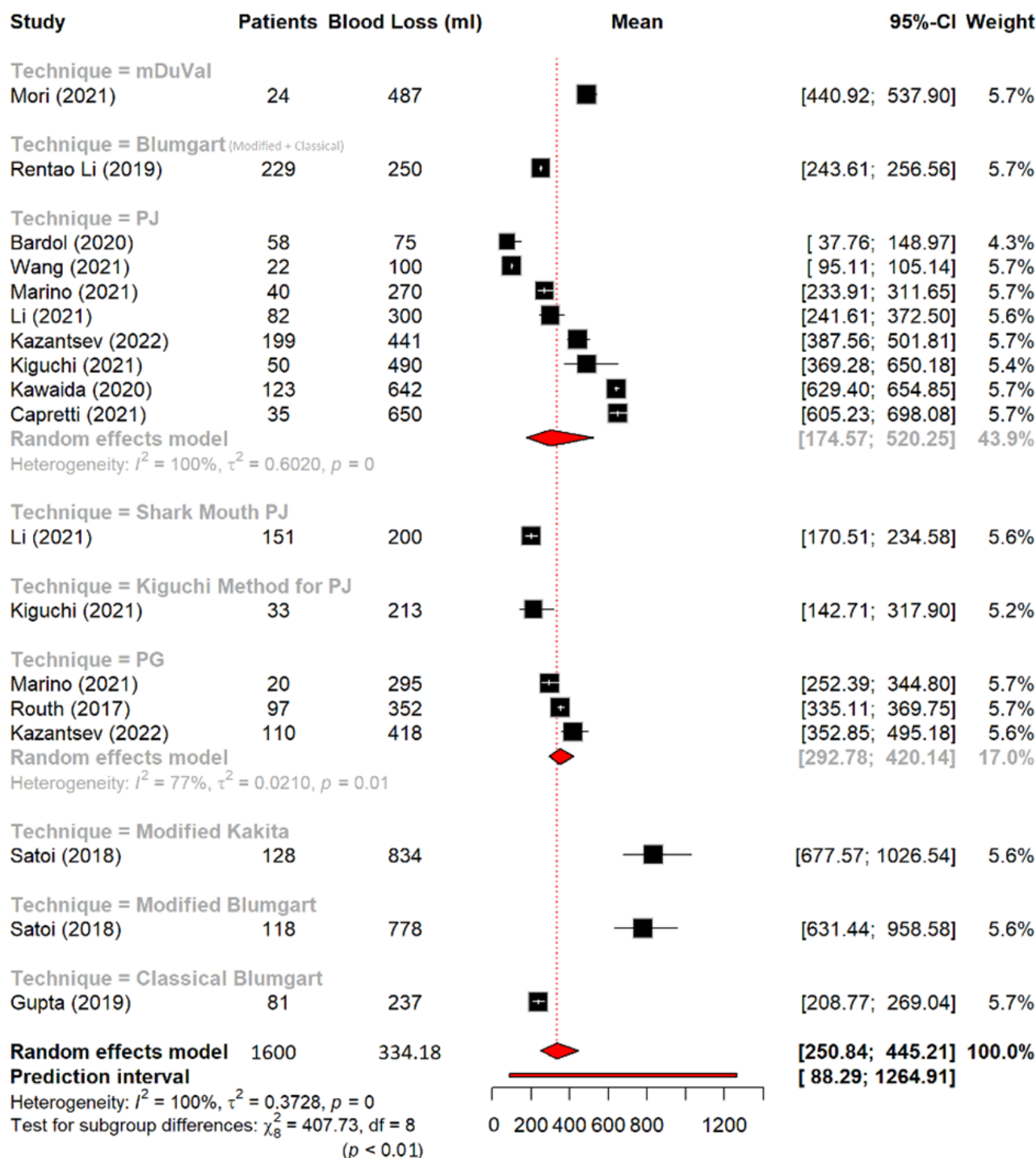


Figure 5. Comparison of Blood Loss among different techniques.

Figure 6 shows the post-operative complications (like pancreatic leak, post-pancreatectomy hemorrhage, delayed gastric emptying, intra-abdominal abscess, and wound infection) across various surgical techniques. The random effects model estimated an overall complication proportion of 38% (95% CI: 29% to 49%), with significant heterogeneity ($I^2 = 98.3\%$, $\tau^2 = 0.0513$). Subgroup analysis revealed varying complication rates, mDuVal (25%), PJ (42%), modified Heidel-

berg (45%), Classical Blumgart (38%), Modified Blumgart (46%), Shark Mouth PJ (27%), Kiguchi Method for PJ (27%), PG (27%), and Modified Kakita (54%). Notably, modified Kakita had the highest complication proportion (54%), while mDuVal had the lowest observed proportion (25%). The test for subgroup differences was significant ($p < 0.0001$), indicating technique-dependent variations in complication rates.

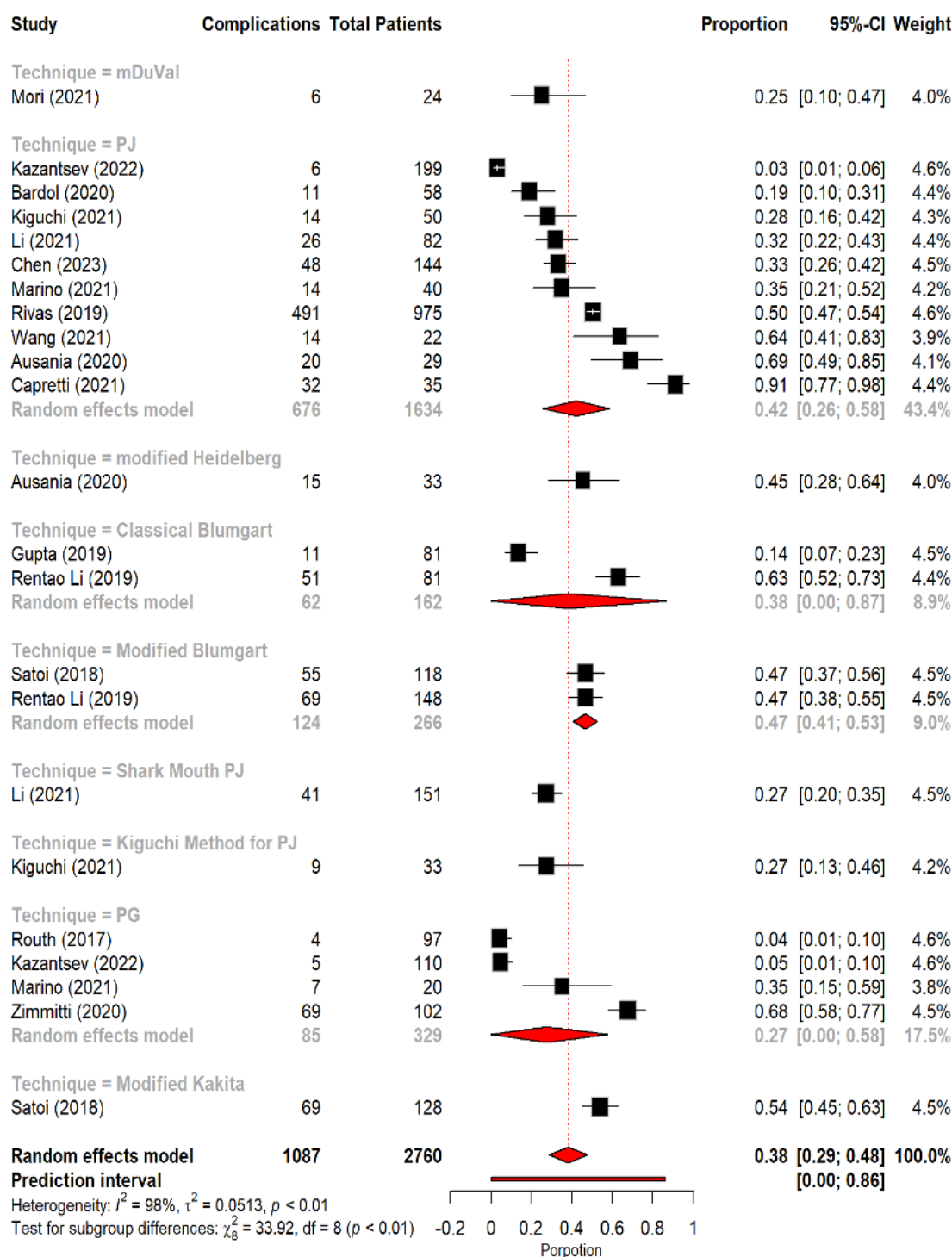


Figure 6. Comparison of postoperative complications among different techniques.

Figure 7 shows the proportion of Diabetes Mellitus (DM) among different surgical techniques. The random effects model estimated an overall DM proportion of 17% (95% CI: 10% to 24%), with considerable heterogeneity ($I^2 = 95.7\%$, $\tau^2 = 0.0169$). Subgroup analysis revealed varying DM proportions across techniques: Classical Blumgart (17%), Modified Blumgart (19%), Shark Mouth PJ (1%), PJ (12%),

Kiguchi Method for PJ (24%), PG (31%), and Modified Kakita (27%). PG (27%) had the highest observed proportion technique done in DM, while Shark Mouth PJ had the lowest proportion among the techniques analyzed (1%). The test for subgroup differences was significant ($Q = 72.50$, $p < 0.0001$), indicating technique-specific prevalence in DM patients.

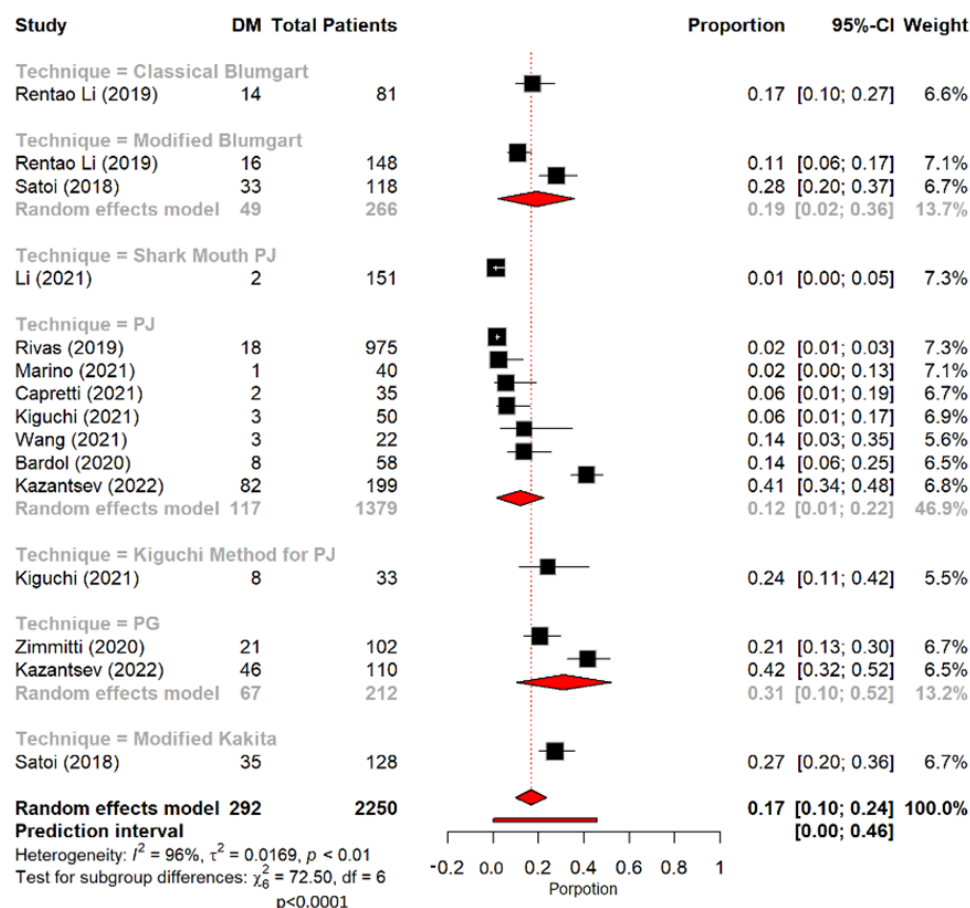


Figure 7. Proportions of different technique among Diabetes Patients.

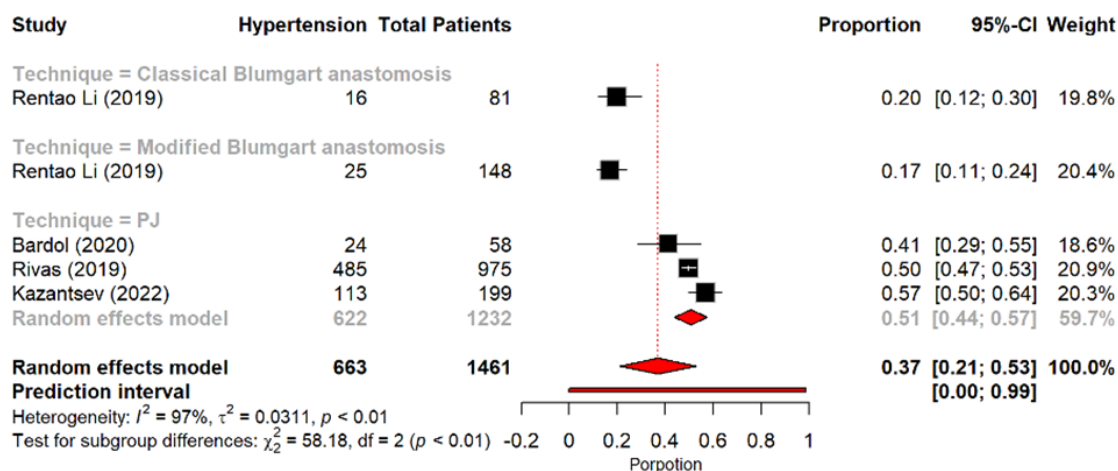


Figure 8. Shows the proportion of hypertension among different surgical techniques.

Figure 8 shows the proportion of hypertension among different surgical techniques. The random effects model estimates an overall hypertension proportion of 37% (95% CI: 21% to 53%), with significant heterogeneity ($I^2 = 97.0\%$, $\tau^2 = 0.0311$). Subgroup analysis reveals varying proportions across techniques: Classical Blumgart anastomosis (20%), Modified Blumgart anastomosis (17%), and PJ (%1%). PJ shows the highest observed proportion among hypertension, while Modified Blumgart anastomosis and Classical Blumgart anastomosis demonstrate lower proportions among the techniques analyzed. The test for subgroup differences is significant ($Q = 58.18$, $p < 0.001$), indicating technique-specific differences in hypertension prevalence.

Figure 9 shows the length of hospital stay (HS) across different surgical techniques. The random effects model esti-

mates a slightly lower mean of 15.1 days (95% CI: 12.90 to 17.88) due to significant heterogeneity ($I^2 = 99.9\%$, $\tau^2 = 0.1378$). Subgroup analysis under the random effects model reveals varied mean HS across techniques: mDuVal (20.0 days), Classical Blumgart (17.8 days), Modified Blumgart (13.0 days), PJ (15.9 days), Shark Mouth PJ (13.0 days), Kiguchi Method for PJ (22.0 days), PG (11.49 days), and Modified Kakita (14.0 days). Specifically, PG shows the shortest mean HS (11 Days Almost), while Kiguchi Method for PJ exhibits the longest mean HS (20 Days Almost) among the analyzed techniques. The test for subgroup differences is statistically significant ($Q = 50.98$, $p < 0.0001$), indicating that different techniques are associated with varying lengths of hospital stay.

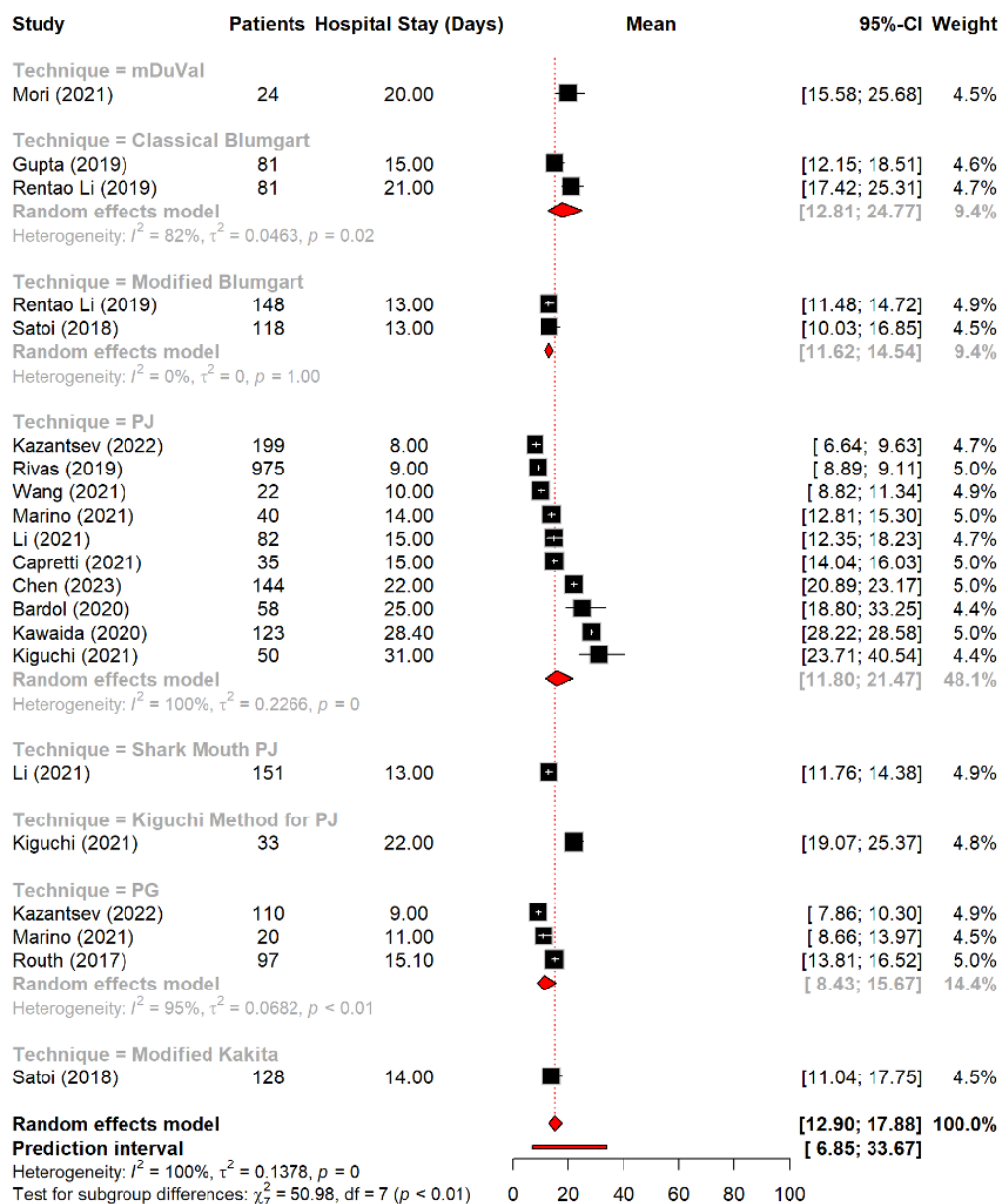


Figure 9. Length of Hospital Stay after different techniques.

Figure 10 shows the mortality rates across different techniques. The random effects model estimates an overall mortality proportion of 2% (95% CI: 1% to 2%), indicating generally low mortality risk across the techniques studied. Subgroup analyses reveal varied mortality rates: mDuVal reported no mortalities, Classical Blumgart and Modified Blumgart had rates of 3% and 1%, respectively. PJ showed 1%, Kiguchi Method for PJ and PG had 33% and 3%, Modified Kakita reported 2%, Wirsungo Jejunostomy (WJ) had 5%, and Peng Technique showed the highest at 11%. However, differences between subgroups were not statistically significant ($p =$

0.4851), suggesting observed variations in mortality rates may be due to random chance rather than systematic differences between techniques. Overall, despite some variability, mortality rates remain generally low across the evaluated surgical techniques.

Publication bias and Heterogeneity

The visual inspection of the funnel plot in our meta-analysis revealed a notable presence of significant publication bias regarding POPF in patients undergoing different techniques as shown in Figure 11.

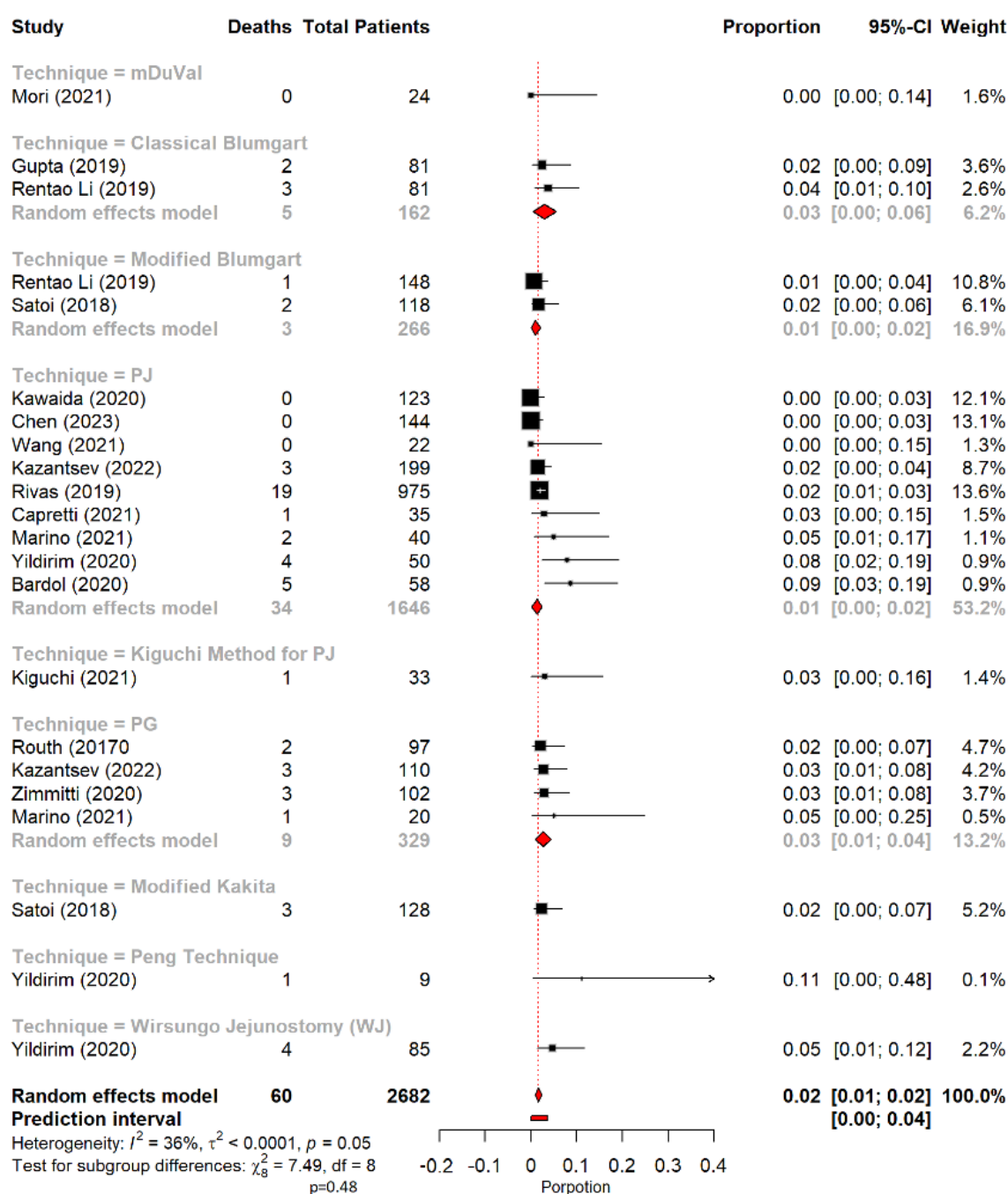


Figure 10. Mortality Rate among different techniques.

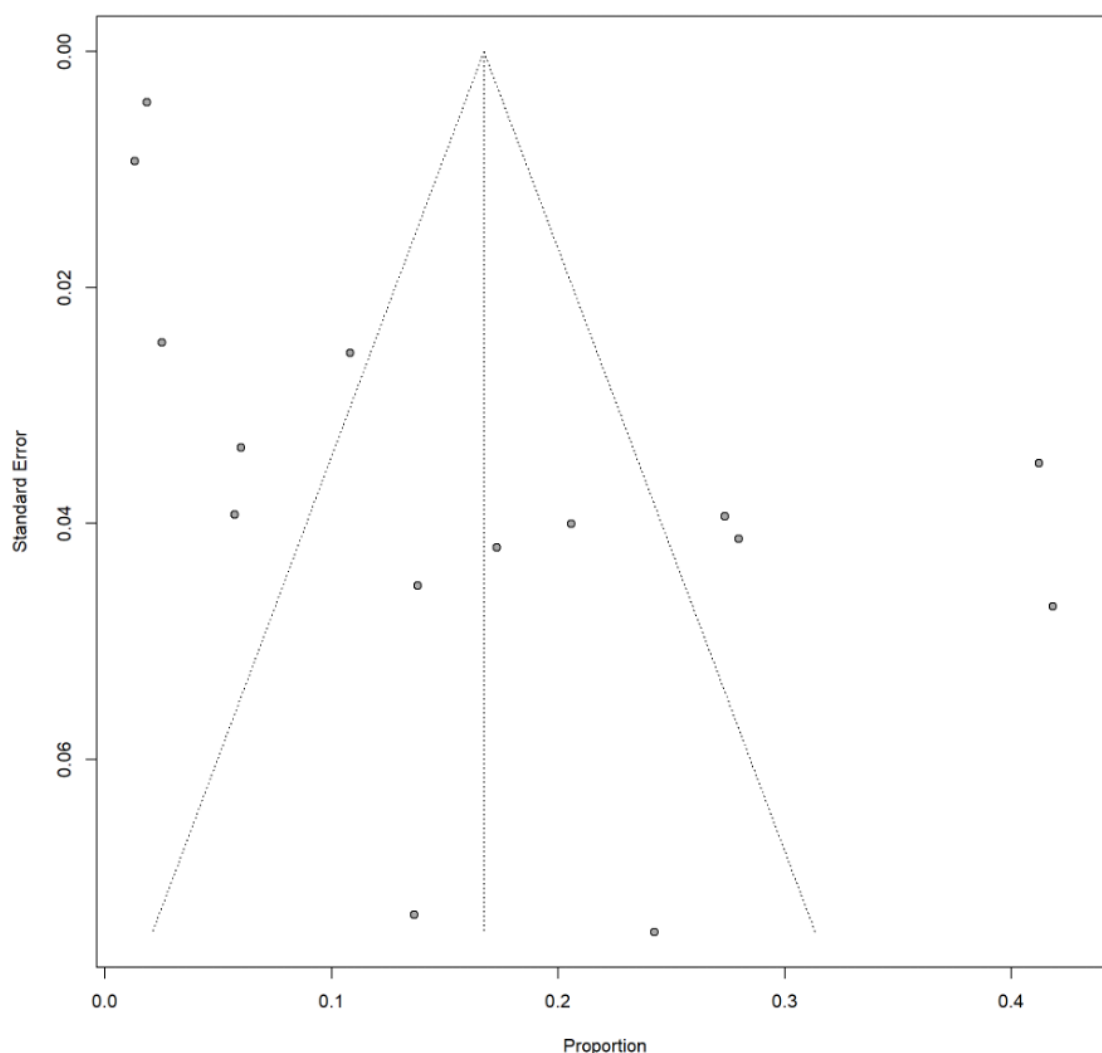


Figure 11. Funnel Plot showing Publication bias and Heterogeneity.

5. Discussion

Despite numerous surgical techniques for pancreatic reconstruction, the optimal approach to prevent postoperative pancreatic fistula remains unclear. Previous studies have explored various methods, but inconsistent findings and methodological heterogeneity limit definitive conclusions. A comprehensive systematic review and meta-analysis is necessary to evaluate the relative effectiveness of these techniques, identify best practices, and inform evidence-based guidelines for pancreatic reconstruction. The study found that the overall occurrence of POPF after surgery is around 27%. However, there's a wide variation in this rate depending on the specific surgical technique used. Some methods, like the modified Heidelberg, peng techniques, shark mouth PJ and the Kiguchi method have lower POPF rates, while others, such as the Modified Blumgart and Classical Blumgart technique, have higher rates. This suggests that the surgical approach significantly impacts the risk of developing POPF.

Notably, techniques involving pancreaticojejunostomy (PJ) had a high POPF rate with considerable variation between studies, while pancreaticogastrostomy (PG) demonstrated a lower POPF rate.

A previous study reported no significant difference in the incidence of POPF between PJ and PG techniques. However, a notable disparity in overall POPF rates was observed, with patients exhibiting intermediate and high scores in the 10-point Fistula Risk Score for Pancreatic Fistula (CRS-PF) demonstrating significantly higher POPF incidence compared to those with negligible or low scores [27]. While comparisons between modified Blumgart anastomosis (m-BA) and modified Heidelberg anastomosis (m-HA) did not reveal statistically significant differences in overall POPF rates, a notable reduction in POPF incidence was observed with m-BA specifically among patients with soft pancreas. Additionally, a trend towards lower POPF rates was identified in high and intermediate risk patients undergoing m-BA, although this finding did not achieve statistical significance. These results suggest a potential advantage of m-BA in mitigating POPF risk, particularly in patients with soft pancreatic

tissue [28].

Our analysis of blood loss aligns with the established range observed in prior research. We found an estimated blood loss of 200 mL, which is consistent with the findings reported by Li et al. (200 mL) [17] and within the range observed by Li et al. (182.9 mL) [29]. These findings further substantiate the notion that blood loss during this procedure typically falls within this range.

Two key findings emerge regarding blood loss with the modified Blumgart technique. Studies report an average of 778 mL, while a recent study showed a much lower average (112 mL) [30]. This intriguing difference might be explained by the adoption of Three-Dimensional laparoscopic system. The superior visualization provided by 3D technology could potentially lead to more precise surgery and minimized blood loss. In our review, the Modified Kakita technique exhibited the highest complication rate at 54%. In contrast, a previous study reported an overall complication rate of 51% (301/596) following pancreaticoduodenectomy without specifying the anastomosis technique employed [31]. This discrepancy may be attributed to the relatively limited research focused specifically on the Modified Kakita technique, as compared to more established methods. It is important to note that our review reported complications from only one study utilizing the Modified Kakita technique. This is significant because drawing a comparison based on a single study may not provide a comprehensive understanding of the technique's true complication rate, potentially skewing the results when juxtaposed with data derived from multiple studies using other techniques.

Diabetes mellitus (DM) is commonly linked to adverse outcomes following surgery [32]. Nevertheless, more comprehensive research is needed on the impact of surgical techniques on POPF in patients with DM. Our meta-analysis revealed that among patients with POPF, the PG technique had the highest prevalence rate (31%), and the Shark Mouth PJ technique had the lowest prevalence rate (1%) among the investigated procedures.

The impact of DM on POPF after PD is a subject of debate. Elmelegy et al. [33] investigated 120 patients with periampullary lesions who underwent PD and found that patients with DM had a higher risk of developing POPF. Conversely, Williamsson et al. [34] suggested that DM has protective effects against POPF. In this nationwide register study in Sweden, the characteristics that can predict the occurrence of POPF were examined, and the study concluded that DM had a protective effect on the development of POPF. Perhaps this is due to the fact that these patients have lower levels of pancreatic fat and higher levels of pancreatic fibrosis.

Several studies have indicated that hypertension is correlated with various postoperative problems [35]. Xu et al. discovered that preoperative hypertension was identified as a risk factor for POPF. Out of the 15 patients in the group with POPF, 10 patients had preoperative hypertension. The univariate analysis indicated a significant difference in the rates

of POPF between patients with preoperative hypertension and those without ($P < 0.05$). This suggests that patients with a known history of hypertension have a higher risk of developing a POPF after PD [36]. Our meta-analysis revealed distinct variations in the prevalence of hypertension among different techniques. PJ had the lowest observed proportion (1%), while Classical Blumgart anastomosis had the highest proportion (20%). The causal relationship between hypertension and pancreatic fistula may not be readily apparent. One probable explanation is that individuals with hypertension often have stiff blood vessels and weakened blood flow, which increases the risk of blood clot formation. This is not ideal for the healing of surgical anastomosis after an operation. This contributes to the development or worsening of POPF [37].

Research has indicated that POPF has a negative impact on the outcome of patients after PD, leading to more extended hospital stays (HS) and increasing the cost of treatment [38]. Our findings indicate that different procedures are linked to varied durations of hospital stay. PG had the shortest average HS (almost 11 days), while the Kiguchi Method for PJ resulted in the longest average HS (almost 20 days). Several studies have found that the duration of PG in their samples is similar, which further strengthens the effectiveness of PG [39]. Ratnayake et al. performed a network meta-analysis to evaluate the effectiveness of different procedures for pancreatic anastomosis after PD. They directly compared five techniques in 15 randomized controlled trials involving 2428 patients. The study found that PG duct-to-mucosa was linked to the shortest HS after surgery and the lowest amount of blood loss during the operation [40].

The optimal anastomotic approach in pancreas surgery has been a subject of prolonged disagreement and has sparked significant discussion among researchers. In recent years, a multitude of surgical anastomotic techniques have been recorded [2]. Specialized surgeons focusing on the pancreas have consistently worked to tackle the issue of pancreatic fistula using different methods over many years. These efforts involve the site of anastomosis and the anastomotic technique. The literature's multitude of research indicates the absence of consensus regarding a specific approach to management, further contributing to the prevailing state of confusion. Hence, the amassed knowledge derived from this information reservoir required scientific assessment to determine the optimal anastomotic approach.

6. Conclusion

In conclusion, a pooled analysis of 18 studies comprising 3343 patients who underwent diverse pancreatic anastomosis techniques (including Modified DuVal, Heidelberg PJ, and Blumgart procedures) revealed a postoperative pancreatic fistula (POPF) incidence of 27%. Significant heterogeneity among studies indicated substantial variability in POPF rates across different surgical approaches. Our anal-

ysis revealed a clear correlation between surgical technique and POPF incidence. Techniques such as modified Heidelberg, Peng, shark mouth PJ, and Kiguchi PJ were associated with lower POPF rates, whereas modified and classical Blumgart techniques exhibited higher rates. While mortality rates varied among surgical techniques, overall mortality was low. Data from this study can be used to shape future studies and direct physicians to develop strategies to reduce the risk of POPF and thereby reduce morbidity and mortality, leading to improved patient outcomes. Furthermore, this data can inform clinical decision-making and guide the development of evidence-based practice guidelines to optimize surgical outcomes.

7. Limitations

This study represents the most extensive literature review on the optimal approach to preventing postoperative pancreatic fistula. However, there are some limitations to this study. To begin, potential publication bias was determined using the funnel plot symmetry. Additionally, poor-quality studies were included in the meta-analysis, increasing the probability of bias. A diverse array of pancreatic surgical procedures was included in this review (pancreaticoduodenectomy, distal pancreatectomy, pylorus-preserving pancreaticoduodenectomy, and central pancreatectomy), encompassing procedures with varying rates of postoperative pancreatic fistula, clinical significance, severity, and overall patient survival. Combining these disparate procedures into a single analysis limits the findings' depth of interpretation and generalizability. Moreover, the absence of detailed patient data in some of the studies, such as cancer stage, adjuvant/neoadjuvant therapy details, and comorbid conditions, constitutes a methodological limitation that may introduce bias into the study results. Furthermore, the impact of specific patient characteristics on treatment effects was not reported in some of the included studies.

Abbreviations

X	Mean
M	Median
R	Range
F	Female
M	Male
BMI	Body Mass Index
NM	Not Mentioned
CR-POPF	Clinically Relevant Postoperative Pancreatic Fistula
MDPJ	Modified DuVal PJ
MH	Modified Heidelberg
CB	Classical Blumgart
MB	Modified-Blumgart
SMPJ	Shark Mouth PJ

KMPJ	Kiguchi Method For PJ
MK	Modified Kakita
PT	Peng Technique
DMWJ	Ducto-Mucosal Wirsung Jejunostomy
PD	Pancreaticoduodenectomy
PPPD	Pylorus Preserving Pancreaticoduodenectomy
DP	Distal Pancreatectomy

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Conflicts of Interest

The authors declare no conflicts of interest.

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