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REVIEW ARTICLE

Kimura's vs Warshaw's technique for spleen preserving distal pancreatectomy: a systematic review and meta-analysis of high-quality studies

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Abstract

Background: Spleen preserving distal pancreatectomy (SPDP) represents a widely adopted procedure in the presence of benign or low-grade malignant tumors. Splenic vessels preservation and resection (Kimura and Warshaw techniques respectively) represent the two main surgical modalities to avoid splenic resection. Each one is characterized by strengths and drawbacks. The aim of the present study is to systematically review the current high-quality evidence regarding these two techniques and analyze their short-term outcomes.

Methods: A systematic review was conducted according to PRISMA, AMSTAR II and MOOSE guidelines. The primary endpoint was to assess the incidence of splenic infarction and splenic infarction leading to splenectomy. As secondary endpoints, specific intraoperative variables and postoperative complications were explored. Metaregression analysis was conducted to evaluate the effect of general variables on specific outcomes.

Results: Seventeen high-quality studies were included in quantitative analysis. A significantly lower risk of splenic infarction for patients undergoing Kimura SPDP (OR = 0.14; $p < 0.0001$). Similarly, splenic vessel preservation was associated with a reduced risk of gastric varices (OR = 0.1; 95% $p < 0.0001$). Regarding all secondary outcome variables, no differences between the two techniques were noticed. Metaregression analysis failed to identify independent predictors of splenic infarction, blood loss, and operative time among general variables.

Conclusions: Although Kimura and Warshaw SPDP have been demonstrated comparable for most of postoperative outcomes, the former resulted superior compared to the latter in reducing the risk of splenic infarction and gastric varices. For benign pancreatic tumors and low-grade malignancies Kimura SPDP may be preferred.

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Introduction

Distal pancreatectomy (DP) is one of the most adopted therapeutic options for lesions of the body and tail of the pancreas. Despite the lack of clear evidence, it is well agreed that DP should be associated with splenectomy for malignant lesions due to the need of adequate lymphadenectomy, including splenic hilum (station 10).[1]

In the presence of non-malignant disease, with no need of lymphadenectomy or extensive retroperitoneal excision, spleen preserving distal pancreatectomy (SPDP) should be considered. Indeed, patients suffering from benign and low-grade pancreatic malignancies are likely to survive for a longer time, and therefore it is important to preserve their immune function. Moreover, several middle/long-term post-splenectomy complications (i.e. abdominal abscesses, thrombocytosis, pulmonary hypertension,

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venous and arterial thrombosis) have been described after splenectomy, and among them Overwhelming Post Splenectomy Infections (OPSI) are the most feared.

Indications to SPDP include neuroendocrine tumors (NET), serous and mucinous cystadenoma, and intraductal papillary mucinous neoplasms (IPMN) without clear signs of malignant degeneration, that account for 5%–10% of pancreatic neoplasms. Pancreatitis and solid pseudopapillary tumors represent other indications to SPDP.

To preserve the spleen, adequate splenic blood flow must be guaranteed. This goal can be reached in two different surgical ways: through splenic vessels preservation (called the Kimura technique - KT) or with splenic vessels resection (called the Warshaw technique – WT). Recent studies seem to favor KT, mainly due to the potential higher incidence of splenic infarction and subsequent splenectomy of the Warshaw procedure. However, preservation of the splenic vessels is more technically demanding since it needs the dissection of the pancreas from the splenic vessels, especially the splenic vein that is fragile and usually embedded in the sulcus on the posterior side of the pancreatic body.

The aim of the present study is to systematically review the current high-quality evidence regarding these two techniques and analyze their short-term outcomes.

Methods

Search strategy

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines,[2,3] and following the MOOSE recommendations. Details of the protocol for this systematic review were registered on PROSPERO and can be accessed on the relative website (ID: CRD42022335322).

The PubMed, Scopus, and Cochrane Library databases were screened without time restrictions up to May the 19th, 2022. The research also included all the MeSH Terms. The full search queries are available in supplementary materials.

Articles without free full text available were searched through the University of Milan digital library, the "Alberto Malliani" library, or direct contact with the authors. A hand-search of references of included studies and previous reviews on the topic was also performed to include additional relevant studies according to our selection criteria. Two investigators (EG, AB) carried out the literature search independently.

Inclusion criteria

All study designs were considered. Studies involving patients who underwent spleen-preserving distal pancreatectomy for benign or low-grade malignant tumors, regardless of surgical approach (open vs minimally invasive surgery) were included in the review.

A specific population (P), intervention (I), comparator (C), outcome (O), and study design (S) (PICOS) framework was specified to define study eligibility, as recommended. In particular, the following criteria were outlined:

- Population (P): patients suffering from benign or low-grade malignant tumors arising from the body and tail of the pancreas eligible for SPDP;
- Intervention (I): Splenic vessels-preserving distal pancreatectomy (Kimura's technique);
- Comparison (C): Warshaw's surgical technique;
- Outcomes (O): incidence of specific postoperative complications (see primary and secondary endpoints);
- Study design (S): all study designs.

Studies with insufficient reporting of the PICOS criteria were excluded.

Exclusion criteria

All studies with NOS <7 were excluded from the review. Studies reporting overlapping series were excluded as well. Similarly, Non-English language papers, case reports, editorials, abstracts, unpublished studies, previously published reviews, book chapters and commentaries were deemed not eligible.

Systematic review process

Mendeley reference software (Mendeley Ltd, London, UK) was used to identify and remove duplicates among identified records. Overall, 727 articles were preliminarily identified by the literature search. After exclusion of duplicates, two independent reviewers (EG, AB) screened titles and abstracts of 460 records. An a priori developed screening form was created to guide study selection. Investigators were blinded to each other's' decisions. A third party (CC), who supervised the systematic review process, solved eventual disagreement.

Twenty-four articles were assessed for eligibility. Finally, thirteen studies fulfilling all inclusion criteria were selected for qualitative and quantitative analysis. The flow-chart depicting the overall review process according to PRISMA is reported Fig. 1.

Assessment of risk of bias

The risk of bias was assessed for individual studies according to the ROBINS-I tool provided by the Cochrane Collaboration[4] (SF). The following domains were explored: 1) bias arising from the randomization process; 2) bias due to deviations from intended interventions; 3) bias due to missing outcome data; 4) bias in measurement of the outcome; 5) bias in selection of the reported results.

Data were collected according to the methodology proposed by Higgins[5] in a computerized spreadsheet. Bar and traffic light plots were created to display the results of the risk of bias assessment graphically.

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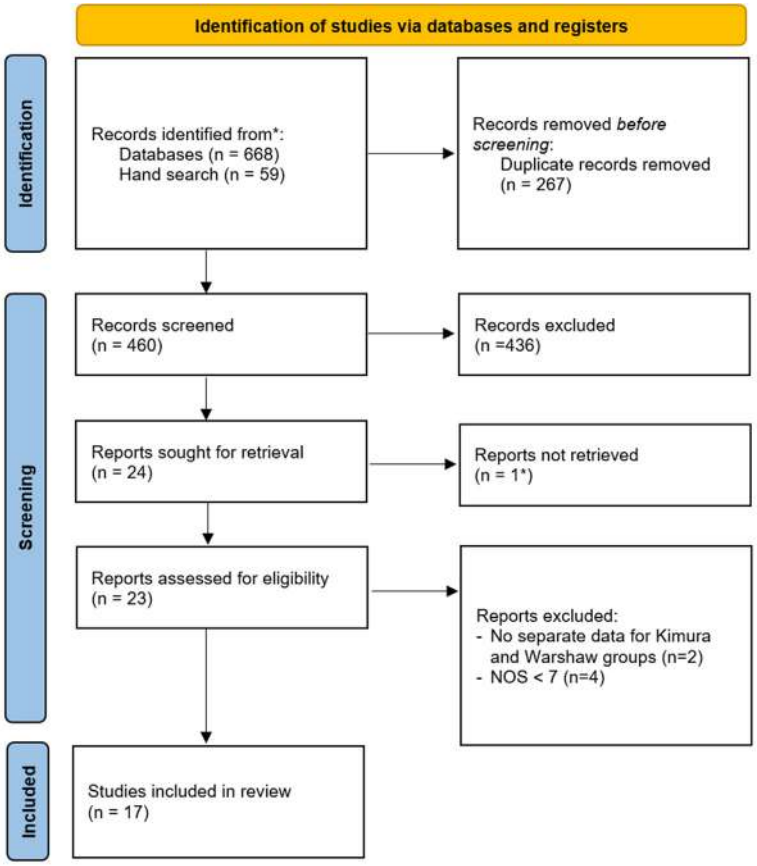

Figure 1 PRISMA flow diagram

Data extraction and assessment of included studies

Data were extracted independently by three authors (SG, AB, EG). Information about study design and methodology, participant demographics and baseline characteristics, intraoperative and postoperative outcomes were gathered in a computerized spreadsheet (Microsoft Excel 2016; Microsoft Corporation, Redmond; WA).

In case of disagreement, two further investigators (AG, CC) helped resolve it through discussion. Two authors (SF, SP) independently assessed the quality of evidence provided by each study using the Oxford Center for Evidence-Based Medicine scoring system.[6] The methodological quality of each retrospective comparative study was assessed using the validated Newcastle–Ottawa Scale (NOS)[7]; studies that scored $\geq$7 were considered of high quality.

Primary and secondary endpoints

The primary endpoint was to assess the incidence of splenic infarction and splenic infarction leading to splenectomy.

The occurrence of grade B/C postoperative pancreatic fistula (POPF) according to ISGPF's definition, Clavien-Dindo complications $\geq$3, amount of blood loss, gastric varices, length of hospital stay, surgical time, unplanned splenectomy, and conversion to open surgery (for the subgroup of patients undergoing minimally invasive DP) defined the secondary endpoint.

Statistical analysis

Odds Ratio (OR) and 95% Confidence Intervals (CI) represented the primary outcome measure. Secondary outcome measures were reported as OR and weighted mean difference with 95% CI. Meta-analyses of binary outcomes and means were developed.

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Mean blood loss, surgical time and length of stay values with relative standard deviations were retrieved from each manuscript. Whenever not overtly reported, they were computed from medians, ranges, interquartile ranges (IQR) and sample sizes according to Wan's method.[8]

Fixed and random effects models based on the Mantel-Haenszel method were built to assess the impact of heterogeneity on results. In the presence of low heterogeneity (<25%), a fixed-effects model was chosen to compute the outcome. The presence of outliers was investigated, and their effect sizes were excluded. Between-studies heterogeneity was quantified by I^2 statistic and Cochran's Q test; cut-off values of 25%, 50%, and 75% were considered as low, moderate, and high, respectively.[9] Sensitivity analyses were conducted after inspecting patterns of effect sizes and heterogeneity of the included studies. In the presence of I^2 >25%, to identify studies overly contributing to heterogeneity, Graphic Display of Heterogeneity (GOSH) plots were developed, and sensitivity analysis was conducted excluding studies predominantly responsible for it. Forest plots were developed to graphically display the results.

Mixed-effects multiple meta-regression models were developed to investigate the association between general predictors (year of publication, country, journal H-index, mean age, male gender, NOS score, and total number of patients included in each study) of splenic infarction and effect size differences. Since some Authors have claimed shorter operative times and reduced intraoperative blood loss in favor of the Warshaw technique, we wanted to explore the impact of the aforementioned predictors on these outcome variables as well.

Since no prior knowledge on how general predictors are related to effect sizes, we built multiple regression models based on statistical properties in our sample. Therefore, a multi-model inference approach was adopted. The presence of multicollinearity was evaluated checking for high predictor correlations ($r \geq 0.7$) before fitting the model. Due to the limited number of studies included, the Knapp-Hartung adjustment was adopted. Model fitting was assessed using Akaike's Information Criterion coefficient.

Funnel plots were developed to explore publication bias, and Egger's test of the intercept was used to quantify funnel plots' asymmetry. Duval & Tweedie's trim-and-fill method was adopted to estimate and adjust the number and outcomes of missing studies each time Egger's test demonstrated significant asymmetry.

Statistical analysis was conducted with R statistical software (The Comprehensive R Archive Network – CRAN, ver. 4.0.0 × 64),[10] using "meta", "metafor", "metamedian", "robvis" and "dmetar" packages.[11–14]

Results

Descriptive noncomparative analysis of included studies and primary endpoint

After the literature search, 17 high-quality retrospective cohort studies[15–31] were included in the qualitative and quantitative analysis.

In total, 1999 patients were included in the meta-analysis. The median NOS value was 8. Seven studies (41.2%) were conducted in Eastern countries. All included studies were retrospective. Only 125 patients underwent open surgery; in the remaining 1867 patients SPDP was conducted with a minimally invasive approach, laparoscopic or robotic.

In the study by Dai 126 patients (103 in the Kimura and 23 in the Warshaw groups respectively) were originally included in the analysis. However, the study was burdened by substantial crossover, because 37 patients were intraoperatively switched to Warshaw procedure, whereas 13 patients required splenectomy due to intraoperative spleen infarction or uncontrollable bleeding. Eventually, 53 patients underwent Kimura SPDP, and 50 Warshaw SPDP. Unfortunately, only data in intention-to-treat analysis were reported in supplementary materials. Indeed, no information but splenic infarction and gastric varices of 51 patients (25 Kimura and 26 Warshaw) who had postoperative contrast-enhanced CT scan or MRI imaging were reported after crossover.

Further details of included studies are reported in Table 1.

Primary endpoint

Binary outcome meta-analysis of sixteen studies was performed for the primary endpoint highlighting a significantly lower risk of splenic infarction for patients undergoing Kimura SPDP (OR = 0.19; 95% CI: 0.09–0.41; p < 0.0001; I^2: 46.5%).

GOSH plots assessment identified the study by Paiella et al. as the responsible for heterogeneity: after excluding it a remarkable reduction in the risk of splenic infarction was confirmed for the Kimura's technique, with no between-studies heterogeneity (n. of studies 15; OR = 0.14; 95% CI: 0.09–0.22; p < 0.0001; I^2: 0%). Forest plots before and after sensitivity analysis are displayed in Fig. 2. GOSH plots are reported in supplementary materials.

Moreover, patients belonging to the Kimura group showed a significantly lower risk of splenic infarction requiring splenectomy (OR 0.29; 95% CI: 0.15–0.57; p = 0.0003; I^2: 0%)

Secondary endpoint

Patients undergoing Kimura SPDP had a lower risk of grade B/C POPF (n. of studies: 13; OR = 0.76; 95% CI: 0.56–1.04; p = 0.08; I^2: 0%), severe complications (Clavien-Dindo ≥ 3) (n. of studies: 10; OR = 0.85; 95% CI: 0.6–1.2; p = 0.36; I^2: 0%), gastric varices (n. of studies: 10; OR = 0.15; 95% CI: 0.05–0.4; p = 0.0002; I^2: 62.9%), and unplanned splenectomy (n. of studies: 3; OR = 0.39; 95% CI: 0.14–1.08; p = 0.069; I^2: 18.9%). Considering the subgroup of studies involving patients undergoing minimally invasive SPDP, Kimura's technique showed an increased risk of conversion to open surgery (n. of studies: 3; OR = 1.21; 95% CI: 0.67–2.18; p = 0.52; I^2: 0%).

On the other hand, patients undergoing Kimura SPDP had greater intraoperative blood loss (n. of studies: 12; MD = 5.08; 95% CI: −77.64-87.82; p = 0.89, I^2: 85.8%), a longer operative time (n. of studies: 13; MD: 7.28; 95%CI: −22.62-37.18; p = 0.6;

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Table 1 Studies' and patients' characteristics

Author	Year of publication	Years of enrollment	Country	NOS	Total number of patients	N° of pts undergoing Kimura technique	N° of pts undergoing Warshaw technique	Age	Male gender (%)	Surgical approach	Open approach	MI approach	Follow up (months)
Beane	2011	2002–2009	USA	8	86	45	41	55.8	33	68 (79%) Lap; 18 (21%) Open	18	68	60
Baldwin	2011	2008–2010	USA	7	9	5	4	81		9 (100%) Lap	0	9	
Butturini	2012	1999–2007	Italy	7	43	36	7	47.6	18.6	43 (100%) Lap	0	43	12
Hwang	2012	2007–2011	Korea	8	21	17	4	43.2	33.3	21 (100%) Rob	0	21	
Adam	2013	1997–2011	Multicentric	8	140	55	85	55.3	15	124 (89%) Lap; 16 (11%) Open	16	124	
Matsushima	2014	2005–2013	Japan	7	24	7	17	57.5	29.1	24 (100%) Lap	0	24	45
Worhunsky	2014	2007–2013	USA	7	55	19	31	55	32	50 (100%) Lap	0	50	18
Zhou	2014	2005–2011	Korea	8	246	206	40	49.4	27.6	246 (100%) Lap	0	246	
Boselli	2015	NR	Italy	7	8	5	3	46	62.5	Unclear			
Lee	2016	2006–2015	Korea	7	89	63	26	49.6	32.5	56 (62.9%) Lap, 33 Rob (37.1%)	0	89	
Nakamura	2016	2013–2015	Japan	8	17	11	6	48.4	58.8	14 (82.3%) Lap, 3 (17.7) Open	3	14	
Dai	2016	2004–2016	China	8	51	25	26	43		51 (100%)	0	51	
Paiella	2019	2000–2017	Multicentric	8	164	109	55	52	24.4	95 (57%) Lap, 69 (42.1%) Open	69	95	41
Yohanathan	2020	2006–2015	USA	9	82	19	63	53.1	45.1	69 (71.2%) Lap; 19 (28.8%) Open	19	69	12
Korrel	2021	2001–2019	Multicentric	9	878	634	244	56.7	35.6	Lap/rob 878 (100%)	0	878	1.5
Esposito	2021	2014–2019	Italy	7	34	24	10	48	26	Rob 34 (100%)	0	34	
Lin	2021	2016–2019	China	9	52	41	11		34.6	Rob 52 (100%)	0	52	

Author	Year of publication	Total number of patients	IPMN (%)	Cystic tumor (%)	NET (%)	Adenocarcinoma (%)	Solid pseudopapillary tumor (%)	Inflammatory/ Pancreatitis (%)	Metastases (%)	Other (%)
Beane	2011	86	29.1	25.6	11.6	2.3	0.0	0.0	0.0	8.1
Baldwin	2011	9	55.6	11.1	11.1	11.1	0.0	11.1	0.0	0.0
Butturini	2012	43	4.7	53.5	20.9	2.3	9.3	0.0	0.0	9.3
Hwang	2012	21	14.3	23.8	14.3	0.0	19.0	4.8	0.0	23.8
Adam	2013	140	15.7	37.9	31.4	0.7	5.0	5.7	0.0	3.6
Matsushima	2014	24	16.7	25.0	0.0	12.5	8.3	8.3	12.5	16.7
Worhunsky	2014	55	23.6	34.5	34.5	0.0	5.5	0.0	0.0	1.8
Zhou	2014	246	24.0	34.1	13.0	0.0	17.1	3.3	0.0	2.0
Boselli	2015	8	37.5	25.0	37.5	0.0	0.0	0.0	0.0	0.0
Lee	2016	89	18.0	29.2	19.1	0.0	21.3	0.0	0.0	12.4
Nakamura	2016	17	0.0	52.9	23.5	0.0	0.0	11.8	11.8	0.0
Dai	2016	51	2.4*	44.4*	25.4*	0.0	20.6*	4.8*	0.0	2.4*
Paiella	2019	164	13.4	27.4	32.3	0.6	7.3	7.3	0.0	13.4
Yohanathan	2020	82	0.0	24.4	47.6	0.0	4.9	14.6	4.9	0.0
Korrel	2021	878	18.2	34.1	47.6	5.1	0.0	0.0	0.0	19.7
Esposito	2021	34	0.0	29.4	52.9	0.0	14.7	0.0	0.0	2.9
Lin	2021	52	0.0	51.9	19.2	0.0	13.5	0.0	0.0	15.4

IPMN: Intraductal papillary mucinous neoplasia; NET: Neuroendocrine tumor; *Percentages extracted from the whole sample of 126 patients.
NOS: Newcastle–Ottawa scale; MI: minimally invasive.

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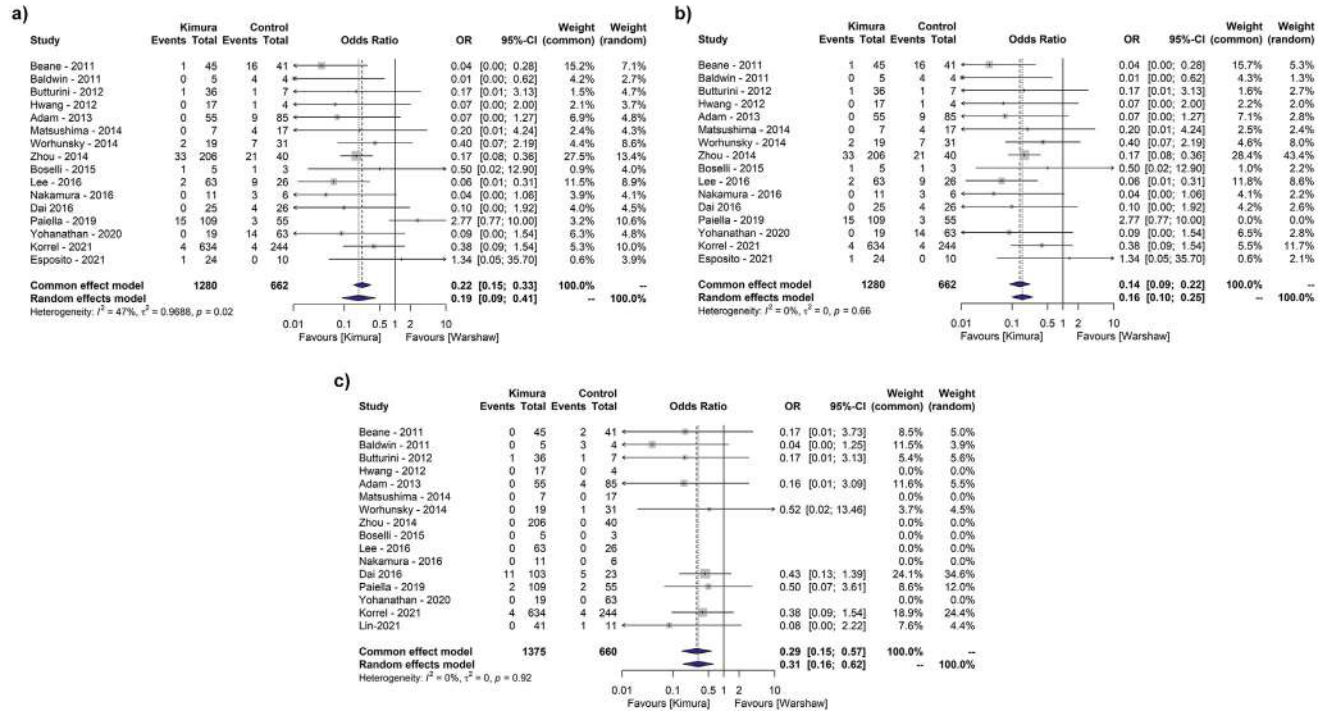

Figure 2 Meta-analysis of binary outcome: splenic infarction. Forest plots a) before and b) after sensitivity analysis. c) Forest plot of splenic infarction requiring splenectomy

I^2: 74.4%), but a lower length of hospital stay (n. of studies: 13; MD = −0.62; 95% CI: −2.13-0.89; p = 0.39, I^2: 78.4%).

For secondary outcome variables for whom moderate-to-high heterogeneity was detected (>25%), sensitivity analysis was conducted. Regarding intraoperative blood loss, GOSH plots assessment identified the studies by Paiella and Korrel as overtly contributing to heterogeneity: after their exclusion, an increased blood loss was confirmed for patients undergoing Warshaw SPDP (MD = 32.27; 95% CI: −79.14-143.69; p = 0.53; I^2: 80.1%). About gastric varices, sensitivity analysis detected the studies by Paiella as the one responsible for heterogeneity: after its exclusion a significant risk reduction was confirmed for patients undergoing Kimura SPDP (OR = 0.1; 95% CI: 0.04–0.26; p < 0.0001; I^2: 45.6%). Regarding operative time, after excluding the studies by Adam, Worhunsky, Lee, and Korrel a shorter length of surgery was pointed out for Kimura patients (MD = −4.46; 95% CI: −28.04-19.11; p = 0.67, I^2: 17.2%). Finally, a reduced length of hospitalization was confirmed for Kimura patients (MD = −0.38; 95% CI: −1.49-0.72; p = 0.45, I^2: 36.7%) after excluding the studies of Lee, Yohanathan and Korrel.

Forest plots of secondary outcomes are displayed in Fig. 3. For meta-analysis of binary outcomes or means burdened by a moderate-to-high heterogeneity forest plots before sensitivity analysis are reported in supplementary materials.

GOSH plots of secondary outcome variables for whom moderate-to-high heterogeneity was identified are reported in supplementary materials.

Metaregression analysis

Correlation analysis identified Journal H-index as significantly correlated with the total number of patients included in each study (r = 0.73), therefore, it was excluded from the model. Year of publication and NOS score, as well as NOS score and the total number of patients included in each study were correlated, but not at a significant level (r = 0.5 and 0.49 respectively). Correlation plot is displayed in supplementary materials. In multi-model inference analysis, the model with the lowest AICc (47.8) was the one based only on year of publication and male gender. No independent predictors of splenic infarction among the covariates included in the model were identified.

Regarding blood loss, the best five models had almost identical AICc values (around 118.7) and all of them involved a maximum of four covariates at a time. Neither for blood loss, independent predictors were detected.

Finally, multi-model interference analysis was conducted to identify independent variables related to operative time. Even in this case, the best five models had overlapping AICc values (around 101.8), and no independent predictors were outlined.

Risk of bias assessment

Fig. 4 summarizes the risk of bias evaluation according to the latest version of the Cochrane Collaboration handbook.[5] The largest amount of "serious" risk of bias was found in the domain: "bias due to deviation from intended interventions". In the domain "bias in measurement of outcomes" 15 out of 17 studies

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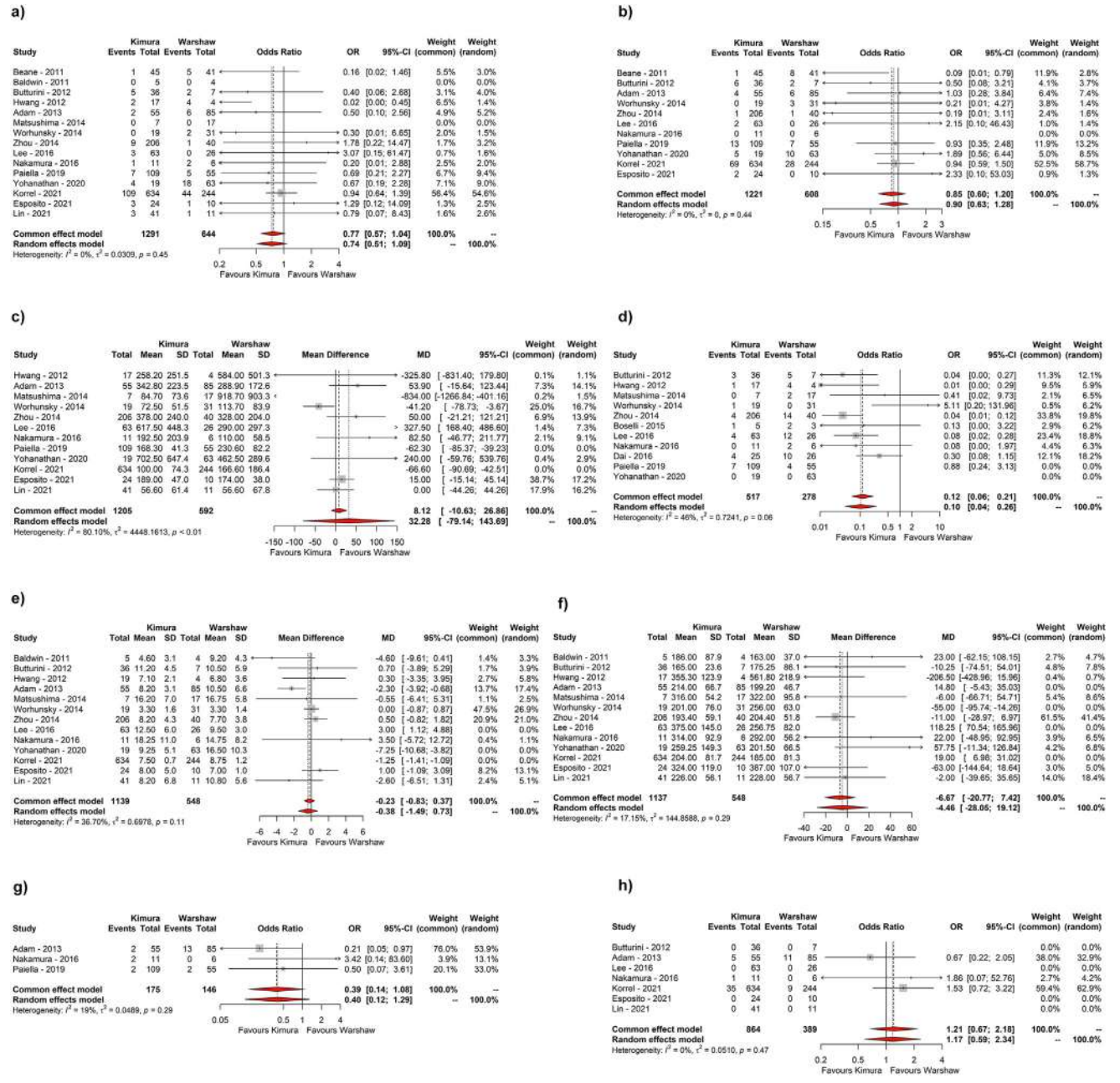

Figure 3 Forest plots of secondary outcomes variables: a) grade B/C POPF; b) Clavien-Dindo complications ≥3; c) blood loss (after sensitivity analysis); d) gastric varices (after sensitivity analysis); e) length of hospital stay (after sensitivity analysis); f) operative time (after sensitivity analysis); g) unplanned splenectomy; h) conversion to open surgery

were burdened by moderate risk of bias, whereas in the remaining two serious risk of bias was detected. A traffic light plot showing a detailed risk of bias assessment for individual studies is reported in supplementary materials.

Assessment of publication bias

Egger's test for the primary endpoint failed to point out significant asymmetry (p = 0.371). Contour enhanced funnel plots of publication bias is showed in Fig. 5.

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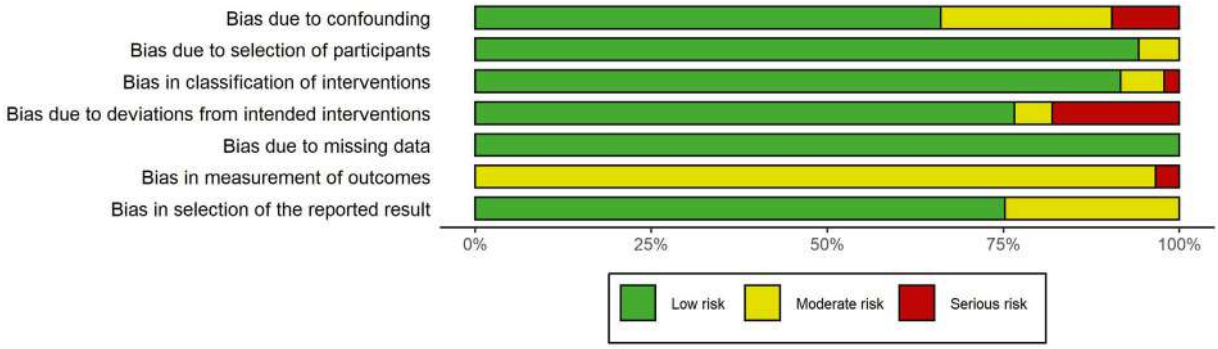

Figure 4 Risk of bias assessment through barplot

Discussion

The spleen plays a well-known key role in the regulation of the immune system as well as in hematopoiesis. Since splenectomy correlates to an increased risk of malignancies[32–34] and several middle/long-term complications, a growing body of evidence supports its preservation during distal pancreatectomy in case of benign or low grade malignant tumors of the body and tail of the pancreas. Over the years two different SPDP techniques have progressively gained popularity: the Kimura's and the Warshaw's techniques. The former, originally proposed by Mallet-Guy in 1946 and revised at the end of the 90's by Professor Wataru Kimura involves the ligation of all the tiny vessels arising from the splenic artery and veins and entering the body/tail of the pancreas. The latter, developed in 1988 by Dr Andrew Warshaw, encompasses the resection of major splenic vessels and allows the spleen to be vascularized by short gastric and gastroepiploic vessels.

Both techniques are characterized by strengths and pitfalls: despite the risk of splenic vein thrombosis, splenic vessel preservation in Kimura's technique has been reported to provide a

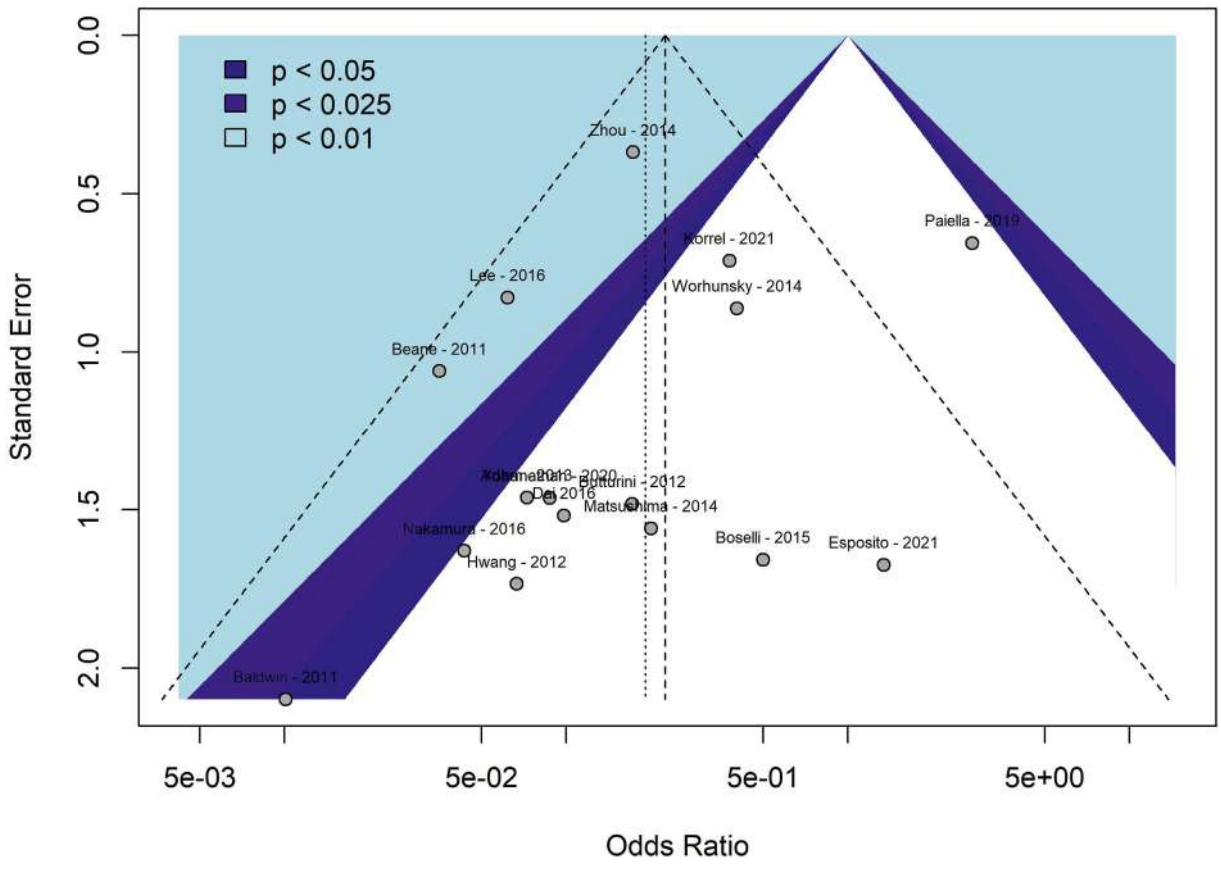

Figure 5 Contour enhanced funnel plot of publication bias

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better blood supply of the spleen preventing the hazard of splenic infarction. Nevertheless, splenic vessel preservation is more technically demanding and on the other hand Warshaw's technique has been claimed to be easier and more rapid.

Our results highlight a significant reduction in the risk of splenic infarction (OR: 0.14; $p < 0.0001$) and gastric varices (OR = 0.1; $p < 0.0001$) for patients undergoing Kimura SPDP confirming that splenic vessels preservation leads to better organ perfusion and limits the development of portal hypertension. Furthermore, our results highlight how splenic hypoperfusion in the Warshaw group translates in a higher incidence of clinically relevant splenic infarction leading to a 71% increase in the risk of splenectomy (OR: 0.29; $p = 0.0003$). Such a postoperative complication involved only 52 over 1999 patients (2.6%), but still represents a major issue.

Regarding all secondary outcome variables but the incidence of gastric varices, no differences between the two techniques were noticed. In particular, based on similar incidences of Clavien-Dindo ≥ 3 complications, intraoperative blood loss, and clinically relevant POPF both techniques can be retained safe. However, it is worth noticing that a near-significant lower trend of grade B/C POPF was pointed out for patients belonging to the Kimura group (OR: 0.76; $p = 0.08$).

Similarly, a reduced risk of unplanned splenectomy, although not significant, was noticed for patients undergoing splenic vessels preservation (OR = 0.39; $p = 0.069$). At this regard, it is worth mentioning that six studies reported information about this secondary outcome variable, but only three of them separate data was available. In the study by Adam et al. patients who received unplanned splenectomy were 2 (3.6%) and 13 (15.3%) in the Kimura and Warshaw groups respectively. Interestingly, in a pan-European retrospective study of high-volume centers, Korrel et al. reported an unplanned splenectomy rate of 19.8% (217 over 1095 total patients) and at multivariable analysis, tumor size and intraoperative blood loss were independent predictors.

For patients undergoing minimally invasive SPDP, those operated with Warshaw technique showed a trend towards an augmented risk of conversion to open surgery, but no significant differences were highlighted (OR = 1.21; $p = 0.52$).

Metaregression analysis failed to identify independent predictors of splenic infarction, blood loss, and operative time among general variables. Looking at such results, one may argue that technological advancement and the improvement of pancreatic surgeons' skills have no impact on the above-mentioned outcomes. Similarly, the sample size of each study may appear not to be relevant in predicting splenic infarction, intraoperative blood loss and surgical time; thus, apparently, similar results may be achieved in high- and low-volume centers.

All these may be interesting topics of discussion, but some consideration should be done. Although meta regressions were built respecting the rule of parsimony and applying statistical methods to adjust for the small number of studies and multicollinearity, eventually, six predictors were entered in the three models. This may have hindered the possibility to achieve a satisfying goodness of fit as confirmed by the high AICc values of all models. Therefore, the results of metaregression analysis should be interpreted with caution.

The strict methodology adopted represents the major strength of our study. Furthermore, the identification of outliers and studies overtly contributing to heterogeneity through advanced techniques such as GOSH plot analysis, and publication bias through Egger's test and contour-enhanced funnel plots, allowed us to select only studies truly contributing to the effect estimate.

Among the limitations that burden the present work, the retrospective nature of included studies is the main one. In the attempt to overcome this issue, we selected only high-quality studies with NOS score ≥ 7. This reflects in a limited proportion of serious risk of bias in all domains. Another major drawback is represented by the enrollment of a widely heterogeneous number of patients ranging from 8 to 878 with 7 out of 17 studies including <50 patients. However, it should be noticed that metaregression analysis failed to demonstrate any correlation between the sample size of each study and splenic infarction, blood loss and surgical time.

Conclusion

Although Kimura and Warshaw SPDP have been demonstrated comparable for most of postoperative outcomes, the former resulted superior compared to the latter in reducing the risk of splenic infarction and gastric varices. For benign pancreatic tumors and low-grade malignancies Kimura SPDP may be preferred over Warshaw technique, unless a clear or highly likely splenic vessels involvement is suspected. Multicentric randomized control trials may clarify some aspects regarding short- and long-term outcomes that still remain controversial.

Founding

No founding was received for this work.

Data availability

All data, template data collection forms, analytic code, and any other materials used for the purpose of the present review are available from the corresponding Author under reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hpb.2023.02.009.

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