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Association of protocolized slow stapled pancreatic transection with clinically relevant postoperative pancreatic fistula after distal pancreatectomy

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Abstract

Purpose:

Clinically relevant postoperative pancreatic fistula (POPF) remains common after distal pancreatectomy (DP). We assessed whether a standardized very slow stapling technique (VSST) was associated with lower POPF after stapled DP.

Methods:

Consecutive patients undergoing DP/DP-CAR/SPDP (2014–2026) were reviewed. VSST (introduced January 2024) comprised no precompression, very slow firing (~ 1 cm/5 min), and avoidance of concomitant manipulation. Analyses were restricted to stapled cases; multivariable logistic regression assessed risk factors for grade B/C POPF.

Results:

Of 211 patients, 184 had stapled transection (VSST 45; conventional 139). Grade B/C POPF occurred in 2/45 with VSST versus 31/139 (22.3%) with conventional stapling ($P < 0.01$). VSST remained associated with lower POPF (adjusted OR 0.16, 95% CI 0.025–0.57; $P < 0.01$). Among patients with a thick pancreas (≥ 13 mm; n = 66), VSST was independently associated with lower POPF (adjusted OR 0.14, 95% CI 0.01–0.83; $P = 0.031$). Overall Clavien–Dindo grade ≥ III complications did not differ between groups (6/45 vs 27/139; $P = 0.35$), whereas POPF-related grade ≥ III complications were significantly less frequent with VSST (2/45 vs 23/139; $P = 0.039$).

Conclusion:

VSST was associated with lower clinically relevant POPF and fewer POPF-related major complications after stapled distal pancreatectomy; prospective multicenter validation with prespecified stratification by pancreatic thickness is warranted.

Introduction

Postoperative pancreatic fistula (POPF) remains one of the most clinically relevant complications after pancreatic resection and continues to be a major cause of postoperative morbidity, prolonged hospitalization, and increased healthcare costs. Among pancreatic procedures, distal pancreatectomy (DP) has consistently been reported to be associated with a relatively high incidence of POPF, even in the absence of a pancreaticoenteric anastomosis [1–3]. Meta-analyses and comparative studies have suggested that the incidence of clinically relevant POPF after DP is comparable to or slightly higher than that after pancreatoduodenectomy, and that procedure-specific factors, such as soft pancreatic texture,

preserved exocrine function, and the biological characteristics of the pancreatic remnant, may contribute to this vulnerability [1, 2].

Because POPF after DP originates from the transected pancreatic stump, management of the pancreatic remnant has long been a central focus of surgical innovation. A wide variety of stump closure techniques have been proposed, including hand-sewn closure, stapled transection using linear staplers, reinforcement of the staple line with bioabsorbable mesh or buttressing materials, coverage with fibrin sealants or hemostatic patches, additional suturing techniques, and conversion of the stump to a pancreaticoenteric anastomosis [4–10]. However, despite numerous randomized controlled trials and meta-analyses, no single method has demonstrated consistent and reproducible superiority, and the optimal strategy for pancreatic stump management during DP remains controversial. More recently, attention has shifted from the choice of closure materials to technical aspects of stapled pancreatic transection itself, including compression time, firing technique, and the interaction between pancreatic thickness and stapler mechanics [11–14]. These reports suggest that the manner in which the pancreas is transected may influence stump integrity and the subsequent risk of POPF; however, the clinical significance of such technical modifications has not been fully established.

In this study, we retrospectively reviewed clinical outcomes of patients who underwent DP at our institution and investigated the efficacy of our recent method for pancreatic transection.

Materials and Methods

Patient selection and evaluation

Between January 2014 and March 2026, consecutive patients who underwent distal pancreatectomy (DP), distal pancreatectomy with celiac axis resection (DP-CAR), or spleen-preserving distal pancreatectomy (SPDP) at Okayama Saiseikai General Hospital were enrolled in this retrospective study. The study protocol was approved by the Institutional Review Board of Okayama Saiseikai General Hospital (approval no. #260204). Demographic characteristics, perioperative variables, and postoperative outcomes were collected from a prospectively maintained institutional database and medical records. POPF and delayed gastric emptying (DGE) were evaluated according to the definitions of the International Study Group of Pancreatic Surgery [15, 16]. Postoperative complications were graded using the Clavien–Dindo (C-D) classification. Glucose intolerance was defined as a glycated hemoglobin (HbA1c) level >6.5% during postoperative follow-up. Pancreatic thickness at the planned transection line was measured preoperatively using contrast-enhanced computed tomography.

Surgical procedures

Regarding pancreatic transection, stapler closure had been our standard first-line approach. In the conventional technique, after approximately 10 minutes of precompression, the pancreas was transected using a linear stapler; the choice of stapler device and cartridge, as well as the transection speed, was left to the discretion of the operating surgeon. In cases with an extremely thick pancreas or

when it was difficult to secure an adequate margin at the pancreatic stump, the pancreas was transected using a scalpel and the stump was closed by hand suturing. To reduce the incidence of POPF, we devised a standardized technique termed the very slow stapling technique (VSST). This technique consists of the following key elements: (1) no precompression before stapler activation; (2) use of an electric linear stapler with a polyglycolic acid (PGA) sheet regardless of pancreatic thickness; (3) extremely slow stapling, with a transection speed of no faster than approximately 1 cm per 5 minutes; (4) complete avoidance of any other surgical maneuvers, such as traction, dissection, and hemostasis, during pancreatic transection; and (5) no additional procedures, such as clip application, on the resected pancreatic margin. Since January 2024, pancreatic transection during DP has been uniformly performed using VSST, irrespective of the surgeon. We evaluated the efficacy of VSST in reducing the incidence of POPF.

Statistical analysis

Continuous variables are presented as medians with ranges, and categorical variables as frequencies with percentages when the denominator was ≥50; percentages were omitted when the denominator was <50. Comparisons between groups were performed using the chi-square test or Fisher's exact test for categorical variables and the Mann–Whitney U test for continuous variables. Fisher's exact test was applied when expected cell counts were ≤5. Variables with a P value <0.05 in univariate analysis were entered into a multivariate logistic regression model to identify independent risk factors for POPF. In addition, clinically relevant variables were included in the multivariate analysis regardless of their univariate significance. Results are reported as odds ratios with 95% confidence intervals. All statistical analyses were performed using JMP® version 11 (SAS Institute Inc., Cary, NC, USA). All tests were two-sided, and a P value <0.05 was considered statistically significant.

Results

Patient characteristics

A total of 211 patients who underwent DP, DP-CAR, and SPDP during the study period were included. The patient characteristics were summarized in **Table 1**. The median age was 71 years (range, 24–89), and 99 patients were male. Pancreatic stump closure was performed using a stapler in 184 patients and by hand suturing in 27 patients. C-D grade ≥III complications occurred in 41 patients (19.4%), and clinically relevant POPF (Grade B or higher) occurred in 42 patients (19.9 %). Among patients with C-D grade ≥III complications, the distribution was grade IIIa in 31 patients, grade IIIb in 5, grade IVa in 3, and grade IVb in 2. Notably, 33 of these 41 severe complications were attributable to POPF. There was no 90-day mortality in this series.

When POPF rates were compared according to stump closure method, Grade B or higher POPF tended to be more frequent in the suture-closure group than in the stapler group (9/27 vs 33/184 [17.9%], respectively; P = 0.061). Because hand suturing was selectively used in patients with an extremely thick pancreas or in cases where securing an adequate stump margin was difficult—conditions that may

intrinsically increase the risk of POPF—subsequent analyses evaluating the efficacy of VSST were restricted to the stapler cohort (n = 184).

Clinical outcomes according to transection technique

Among the 184 patients who underwent stapled transection, 45 patients (24.4%) received VSST and 139 patients (75.6%) underwent conventional stapling. Baseline characteristics were broadly comparable between groups, including age, sex, prognostic nutritional index, glucose intolerance, primary disease, procedure type (DP/SPDP/DP-CAR), operative approach (open vs minimally invasive), lymph node dissection, intraoperative blood loss, and pancreatic thickness at the transection line (Table 2). As intended, stapler transection time was markedly longer in the VSST group than in the conventional group (median 47.0 min [37–68] vs 3.0 min [1.5–9], P<0.01). As expected, overall operating time was also longer in the VSST group (median 437 min [223–680] vs 335 min [157–635], P=0.023). Postoperative serum amylase and drain amylase levels (postoperative days 1 and 3), C-reactive protein on postoperative day 3, and drain culture results were similar between groups, whereas the incidence of Grade B or higher POPF was significantly lower in the VSST group (2/45) than in the conventional group (31/139 [22.3%], P=0.006). The incidence of Clavien–Dindo grade ≥III complications did not differ significantly between the VSST and conventional groups (6/45 vs 27/139 [19.4%], P=0.35). Among the six patients with Clavien–Dindo grade ≥III complications in the VSST group, the events comprised pleural effusion requiring thoracentesis (n=1), delayed gastric emptying requiring endoscopic intervention (n=1), subcutaneous hematoma requiring drainage (n=1), an intra-abdominal abscess unrelated to POPF requiring drainage (n=1), and POPF requiring drain exchange (n=2). Among the 27 patients with Clavien–Dindo grade ≥III complications in the conventional group, 23 complications were related to POPF; the remaining events comprised postoperative ileus (n=1), deep vein thrombosis requiring inferior vena cava filter placement (n=1), and postoperative bleeding unrelated to POPF (n=2). Accordingly, POPF-related Clavien–Dindo grade ≥III complications were significantly less frequent in the VSST group (2/45 vs 23/139; P=0.039). Although not statistically significant, re-drainage was not required in the VSST group (0/45), compared with 8/139 (5.8%) in the conventional group (P=0.20). Postoperative hospital stay was slightly longer in the VSST group (median 16 vs 14 days, P=0.046).

Risk-factor analysis for POPF after DP

Univariate and multivariate logistic regression analyses were performed to identify factors associated with clinically relevant POPF (Grade B or higher) after stapled distal pancreatectomy (Table 3). In the univariate analysis, pancreatic thickness at the transection line ≥ 13 mm was significantly associated with an increased risk of POPF (odds ratio [OR] 2.23; 95% confidence interval [CI] 1.00–4.97; P = 0.046), whereas use of the VSST was strongly associated with a reduced risk of POPF (OR 0.16; 95% CI 0.037–0.71; P < 0.01). Other variables were not significant predictors in univariate testing. In the multivariate model, after adjustment for clinically relevant covariates including age, surgical approach, lymph node dissection and pancreatic thickness at transection, VSST remained independently associated with a lower risk of POPF (adjusted OR 0.16; 95% CI 0.025–0.57; P < 0.01). Pancreatic thickness ≥ 13 mm did

not retain statistical significance in the multivariate analysis, although a trend toward association persisted (P = 0.066). To further evaluate the impact of VSST in anatomically high-risk situations, an additional analysis was conducted in the subgroup of patients with a thick pancreas (≥ 13 mm; n = 66) (Table 4). In this subgroup, VSST tended to be associated with a lower incidence of POPF in univariate analysis (P = 0.09) and the difference was significant in multivariate analysis (P = 0.031), whereas other candidate factors were not independently associated with POPF.

To explore risk factors prior to VSST implementation, an additional analysis was performed limited to the conventional stapling group (n = 139) (**Table 5**). In this cohort, pancreatic thickness ≥ 13 mm was independently associated with POPF in multivariate analysis (adjusted OR 2.47; 95% CI 1.07–5.99; P = 0.033). In contrast, the use of a PGA sheet and the use of an electric stapler were not significantly associated with POPF and did not demonstrate a measurable association with reduced POPF risk. Together, these analyses highlight the impact of pancreatic thickness under conventional stapling and provide context for the observed reduction in POPF in association with VSST.

Discussion

In this retrospective single-center study, implementation of the very slow stapling technique (VSST) was associated with a marked reduction in clinically relevant POPF after stapled distal pancreatectomy. Importantly, this association was observed despite comparable baseline characteristics between groups and persisted after adjustment for clinically relevant covariates. Although overall Clavien–Dindo grade ≥III morbidity did not differ between groups, POPF-related grade ≥III complications were significantly less frequent in the VSST group. VSST required substantially longer transection time and was also associated with longer overall operating time; however, the reduction in POPF was not accompanied by an increase in overall major morbidity.

The optimal strategy for pancreatic stump management in distal pancreatectomy remains unsettled. Randomized evidence has shown that stapler closure does not consistently outperform hand-sewn closure, underscoring that “device choice alone” is unlikely to be a definitive solution [17]. In parallel, adjunctive measures such as reinforcement materials or patches have produced mixed results across trials, with some studies reporting benefit while others failed to demonstrate clinically meaningful reductions in POPF [6, 8, 18]. Contemporary syntheses similarly emphasize heterogeneity in definitions, operative technique, and patient risk profiles as major reasons why a single “best” method has not emerged [9]. Against this backdrop, our findings support the concept that technical aspects of stapled pancreatic transection—beyond the selection of closure method or materials—may be clinically relevant.

A plausible explanation is that VSST modifies the mechanical environment at transection. Extremely slow stapling with avoidance of concurrent maneuvers may reduce abrupt compression and shear forces, potentially allowing more uniform parenchymal flattening, improved staple formation, and less micro-disruption of fragile acinar tissue at the stump. This interpretation is consistent with the broader hypothesis that stump integrity is influenced by “transection mechanics,” not only by the presence or

absence of reinforcement. However, given the retrospective design, we emphasize that these mechanistic considerations remain speculative and should be viewed as biologically plausible hypotheses rather than proven causal pathways.

Our analyses also highlight the importance of anatomical risk stratification. In the conventional stapling cohort (pre-VSST), pancreatic thickness ≥13 mm was independently associated with POPF, supporting previous observations that “thick pancreas” represents a high-risk setting under standard stapling conditions. Notably, in that same conventional cohort, neither use of a PGA sheet nor a powered stapler demonstrated a measurable association with reduced POPF risk, suggesting that incremental device-related modifications may be insufficient when the underlying mechanical challenge (e.g., thick parenchyma) is substantial. This context strengthens the interpretation that the reduction in POPF observed with VSST may reflect a technique-dependent effect rather than a simple time-period artifact of adopting particular devices or materials.

This study has several limitations. Its retrospective, single-center design is subject to selection bias and residual confounding, and the nonrandomized introduction of VSST in a later era raises the possibility of calendar-time effects, including unmeasured changes in perioperative management (e.g., drain policy, antibiotics, ERAS implementation, thresholds for imaging/intervention) and institutional learning curves. Standardization itself may also have influenced outcomes through protocol-related changes in surgeon behavior independent of the transection step. In addition, the VSST cohort was relatively small with a low event count, which may limit the stability of multivariable modeling and precision of effect estimates. Finally, external validity remains uncertain across institutions with different devices, operative techniques, and postoperative care pathways.

Conclusion

VSST was associated with a substantial reduction in clinically relevant POPF after stapled distal pancreatectomy and with fewer POPF-related Clavien–Dindo grade ≥ III complications, including among patients with thick pancreatic parenchyma who are traditionally considered high risk. Given the inherent limitations of retrospective analyses, prospective multicenter validation with standardized perioperative protocols and prespecified risk stratification (especially by pancreatic thickness) is warranted before VSST can be recommended as a new standard of care.

Abbreviations

DP
distal pancreatectomy
POPF
postoperative pancreatic fistula
VSST
very slow stapling technique

OR
odds ratio
CI
confidence interval
PNI
prognostic nutritional index.

Declarations

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Ethics approval: This retrospective study was approved by the Institutional Review Board of Okayama Saiseikai General Hospital (approval no. #260204) and was conducted in accordance with the Declaration of Helsinki and its later amendments.

Consent to participate: The requirement for individual informed consent was waived by the Institutional Review Board because of the retrospective nature of the study.

Data availability: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

Authors' Contributions:

• Study conception and design: HS, TK

• Acquisition of data: HS, YN

• Analysis and interpretation of data: HS

• Drafting of manuscript: HS, TK

• Critical revision of manuscript: HS, TK, YN, CY, TN

References

1. Eshmuminov D, Schneider MA, Tschuor C, Raptis DA, Kambakamba P, Muller X, et al. (2018) Systematic review and meta-analysis of postoperative pancreatic fistula rates using the

updated 2016 International Study Group Pancreatic Fistula definition in patients undergoing pancreatic resection with soft and hard pancreatic texture. HPB (Oxford) 20(11):992–1003. https://doi.org/10.1016/j.hpb.2018.04.003

2. Nahm CB, Alzaabi S, Sahni S, Gill AJ, Samra JS, Mittal A (2021) Increased postoperative pancreatic fistula rate after distal pancreatectomy compared with pancreatoduodenectomy is attributable to a difference in acinar scores. J Hepatobiliary Pancreat Sci 28(6):533–541. https://doi.org/10.1002/jhbp.934
3. Alvikas J, Dahiya S, Dubrovsky G (2025) A review of post-operative pancreatic fistula following distal pancreatectomy: risk factors, consequences, and mitigation strategies. Cancers (Basel) 17(17):2741. https://doi.org/10.3390/cancers17172741
4. Kawai M, Hirono S, Okada K, Sho M, Nakajima Y, Eguchi H, et al. (2016) Randomized controlled trial of pancreaticojejunostomy versus stapler closure of the pancreatic stump during distal pancreatectomy to reduce pancreatic fistula. Ann Surg 264(1):180–187. https://doi.org/10.1097/SLA.0000000000001395
5. Park JS, Lee DH, Jang JY, Han Y, Yoon DS, Kim JK, et al. (2016) Use of TachoSil® patches to prevent pancreatic leaks after distal pancreatectomy: a prospective, multicenter, randomized controlled study. J Hepatobiliary Pancreat Sci 23(2):110–117. https://doi.org/10.1002/jhbp.310
6. Jang JY, Shin YC, Han Y, Park JS, Han HS, Hwang HK, et al. (2017) Effect of polyglycolic acid mesh for prevention of pancreatic fistula following distal pancreatectomy: a randomized clinical trial. JAMA Surg 152(2):150–155. https://doi.org/10.1001/jamasurg.2016.3644
7. Aoki T, Mansour DA, Koizumi T, Matsuda K, Kusano T, Wada Y, et al. (2020) Preventing clinically relevant pancreatic fistula with combination of linear stapling plus continuous suture of the stump in laparoscopic distal pancreatectomy. BMC Surg 20(1):223. https://doi.org/10.1186/s12893-020-00876-8
8. Mungroop TH, van der Heijde N, Busch OR, de Hingh IH, Scheepers JJ, Dijkgraaf MG, et al. (2021) Randomized clinical trial and meta-analysis of the impact of a fibrin sealant patch on pancreatic fistula after distal pancreatectomy: CPR trial. BJS Open 5(3):zrab001. https://doi.org/10.1093/bjsopen/zrab001
9. Hajibandeh S, Hajibandeh S, Hablus MA, Bari H, Pathanki AM, Ali M, et al. (2024) Meta-analysis and trial sequential analysis of pancreatic stump closure using a hand-sewn or stapler technique in distal pancreatectomy. Ann Hepatobiliary Pancreat Surg 28(3):302–314. https://doi.org/10.14701/ahbps.24-015
10. de Oliveira Silva Nascimento A, Silva ODC, Duarte BN, de Carvalho Baptista Barbosa I, Bajou CMO, Taba JV, et al. (2025) Suture versus stapler in distal pancreatectomy and its impact on postoperative pancreatic fistula. Sci Rep 15(1):6052. https://doi.org/10.1038/s41598-025-90617-9
11. Nakamura M, Ueda J, Kohno H, Aly MY, Takahata S, Shimizu S, et al. (2011) Prolonged peri-firing compression with a linear stapler prevents pancreatic fistula in laparoscopic distal

pancreatectomy. Surg Endosc 25(3):867–871. https://doi.org/10.1007/s00464-010-1285-6

12. Matsumoto I, Kamei K, Satoi S, Murase T, Matsumoto M, Kawaguchi K, et al. (2022) Efficacy of the slow firing method using a reinforced triple-row stapler for preventing postoperative pancreatic fistula during laparoscopic distal pancreatectomy. Surg Today 52(2):260–267. https://doi.org/10.1007/s00595-021-02344-z
13. Naito K, Shinmura K, Suzuki T, Maeda S, Kuboki S, Ohtsuka M (2024) Appropriate linear stapler selection for avoiding postoperative pancreatic fistula after distal pancreatectomy: a retrospective cohort study. Medicine (Baltimore) 103(40):e39954. https://doi.org/10.1097/MD.0000000000039954
14. Yoshii H, Izumi H, Fujino R, Nomuraa E, Mukai M (2024) Intraoperative video analysis of pancreatic stump and stapler closure-induced pancreatic fistula in laparoscopic distal pancreatectomy: a retrospective study. Cureus 16(4):e58959. https://doi.org/10.7759/cureus.58959
15. Wente MN, Bassi C, Dervenis C, Fingerhut A, Gouma DJ, Izbicki JR, et al. (2007) Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS). Surgery 142(5):761–768. https://doi.org/10.1016/j.surg.2007.05.005
16. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, et al. (2017) The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 161(3):584–591. https://doi.org/10.1016/j.surg.2016.11.014
17. Diener MK, Seiler CM, Rossion I, Kleeff J, Glanemann M, Butturini G, et al. (2011) Efficacy of stapler versus hand-sewn closure after distal pancreatectomy (DISPACT): a randomised, controlled multicentre trial. Lancet 377(9776):1514–1522. https://doi.org/10.1016/S0140-6736(11)60237-7
18. Montorsi M, Zerbi A, Bassi C, Capussotti L, Coppola R, Sacchi M (2012) Efficacy of an absorbable fibrin sealant patch (TachoSil) after distal pancreatectomy: a multicenter, randomized, controlled trial. Ann Surg 256(5):853–859; discussion 859–860. https://doi.org/10.1097/SLA.0b013e318272dec0

Tables

Tables 1 to 5 are available in the Supplementary Files section.

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