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Endoscopic suturing for mucosal defect closure following endoscopic submucosal dissection: Systematic review and meta-analysis

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ABSTRACT

Background and study aims: Endoscopic submucosal dissection (ESD) is a minimally invasive and effective treatment for gastrointestinal lesions. It carries potential risks such as bleeding and perforation. This meta-analysis was conducted to assess the safety, effectiveness, and feasibility of endoscopic suturing, a promising technique for closing mucosal defects post-ESD.

Methods: We reviewed several databases, including MEDLINE/PubMed, Cochrane Library, Web of Science, and Embase up to May 1,2023. We aimed at identifying original studies that provided insightful data on the use of endoscopic suturing in reducing complications post-ESD.

Results: In our study, we evaluated 426 publications and included 10 studies involving a total of 284 patients. The pooled technical success rate of endoscopic suturing was 92.6% (95% confidence interval [CI] 0.88–0.96). The pooled rate for sustained closure of mucosal defects post-endoscopic submucosal dissection (ESD) was estimated to be 80.7% (95% CI 0.71–0.88). The pooled mean time required to perform the endoscopic suturing procedure was calculated to be 31.11 minutes (95% CI 16.01–46.21). Among the studies reviewed for the incidence of delayed perforation post-ESD, a singular event of perforation was documented, suggesting a minimal occurrence. The overall rate of delayed bleeding was 5.3% (95% CI 0.30–0.10). Within the subset of patients using antithrombotic drugs, our subgroup analysis identified a delayed bleeding event rate of 6.7% (95% CI 0.02–0.25).

Conclusions: Our results underscore the potential of endoscopic suturing as a viable and efficient technique in managing mucosal defects following ESD, highlighting the need for further large, prospective research to corroborate these findings and concentrate on establishing standard methodologies.

Introduction

Endoscopic submucosal dissection (ESD) has revolutionized treatment of early-stage gastrointestinal cancer by offering a minimally invasive approach with demonstrable superiority over endoscopic mucosal resection (EMR) in terms of en bloc resection and decreased recurrence rates [1, 2, 3, 4]. Yet the promise of ESD is not without its challenges. The procedure inherently poses a considerable risk of complications, including delayed bleeding and perforation, due to the potential for significant mucosal defects [5, 6]. Post-ESD complications contribute significantly to the patient and hospital burden, requiring additional interventions such as repeat endoscopy, hemostasis, possible blood transfusion, and extended hospitalization [7, 8]. Thus, development and implementation of effective preventive measures against these complications are necessary.

A randomized controlled trial revealed that endoscopic strategies for closing mucosal defects following ESD have been observed to effectively decrease postoperative adverse events (AEs) [9]. A variety of closure techniques have emerged, such as clip-based techniques and endoscopic suturing techniques including the overstitch device, endoscopic hand-suturing (EHS) system, and endoscopic tack-and-suture device [10, 11]. While use of clip-based techniques for closing mucosal defects post-ESD has been widespread, limitations of these techniques, including their restricted tissue grasp and associated risk of early-stage mucosal dehiscence, have necessitated exploration of alternative methods [12, 13]. These limitations have spurred exploration of alternate methods, such as endoscopic suturing. Kantsevoy et al. were at the forefront of using endoscopic suturing for closing mucosal defects nearly a decade ago, and its application has since expanded [14]. Goto et al. propose that endoscopic suturing post-ESD is both feasible and safe, even demonstrating a decrease in delayed bleeding incidents among patients undergoing antithrombotic treatment [15].

Despite these advances, there is currently a paucity of comprehensive evidence pertaining to post-ESD complication rates following application of endoscopic suturing techniques. A more nuanced understanding of indications for endoscopic suturing, as well as an assessment of its success rate, is urgently needed to guide clinical practice. This study aimed to evaluate the feasibility, safety, and effectiveness of endoscopic suturing for managing post-ESD mucosal defects, including a detailed examination of outcomes through subgroup analyses based on suturing techniques, antithrombotic drug use, and lesion location.

Methods

Data sources

To identify pertinent studies, a comprehensive exploration of the databases including MEDLINE/PubMed, Cochrane Library, Scopus, Web of Science, and Embase was executed. The investigation was confined to literature published in English from January 1, 2010 to May 1, 2023. Keywords deployed for the search strategy comprised of "Endoscopic submucosal dissection," "ESD," "suture," "Overstitch," “endoscopic tack-and-suture device,” and "Endoscopic Hand Suturing". Furthermore, to ensure no relevant research was missed, the references of each accessed article were meticulously examined to find any additional related studies that may have been initially omitted.

Study selection

Two independent reviewers sifted through titles and abstracts of the identified articles. Articles with full-text were gathered for more comprehensive evaluation if they complied with the defined inclusion criteria. The studies were determined, assessed for applicability, and included in the meta-analysis according to the following criteria.

Studies were eligible if they included: 1) patients aged ≥18 years who had a single clinically or histologically confirmed gastrointestinal lesions; 2) provided data on the role of endoscopic suturing in mitigating post-ESD complications; and 3) were published between 2010 and 2023. Studies were excluded if they were: 1) case reports; 2) not published in English; 3) not relevant to the objective of the review; 4) did not report any outcomes of interest; 5) were abstracts; or 6) investigated application of endoscopic suturing for treatment of perforations or fistulas.

Exclusion of EMR studies

To maintain a consistent study population, we excluded studies involving lesions removed via EMR. EMR typically involves superficial lesions, whereas ESD is used for deeper and larger lesions, resulting in different outcomes and complications. Our analysis specifically targeted the context of ESD, where the depth of resection is a critical factor.

Discrepancies in the selection process were addressed via discussion and consensus. This systematic review and meta-analysis adhered to the Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Definitions

Procedure definitions

EHS is a technique employed for closing post-ESD mucosal defects. It can be utilized in different gastrointestinal tract sections, including the stomach, colon, and rectum. The technique involves an absorbable barbed suture and a through-the-scope flexible needle holder, introduced through an overtube or an oblique distal attachment, based on case-specific requirements. Overstitch refers to a suturing method that involves affixing an overstitch endoscopic suturing platform to a double-channel therapeutic gastroscope and advancing it to the ESD site. The method allows suturing in an antegrade position, beginning from the defect edge most distal to the endoscope insertion site. The suturing is either continuous or uses separate stitches, depending on the specific case. The X tack device (endoscopic tack-and-suture device) comprises four surgical steel tacks linked by a polypropylene thread, which can be deployed without removing the instrument from the patient. These tacks are embedded into the target tissue near the defect and then sequentially tightened to secure the structure.

Outcome definitions

Technical success rate was defined as successful placement of the endoscopic suturing device and complete closure of the mucosal defect. Sustained closure was defined as the condition in which the mucosal defect remains closed without dehiscence during follow-up endoscopy. For the purposes of our analysis, sustained closure was assessed within a standardized follow-up period, ranging from 1 month to 3 months post-ESD, as reported by the included studies. Delayed bleeding was defined as overt active bleeding occurring within 30 days post-ESD. Delayed perforation was defined as any perforation not recognized during the procedure itself but occurring within 30 days post-ESD.

Procedure time was the duration of the procedure, commencing from the first insertion of the needle into the mucosa, and ending either with the cutting and freeing of the remaining suture and needle or with cinch deployment from the endoscopic suturing platform.

Data extraction and bias assessment

Data on study design, population characteristics, ESD suture-related information, and outcomes were extracted by one reviewer and verified by a second reviewer. In case of any discrepancies, a third reviewer was consulted to reach a final decision. The following data were collected from each study: 1) first author's name; 2) year of publication; 3) study design; 4) population characteristics including age, sex, sample size, and lesion type and size, location; and 5) outcomes.

Study quality was assessed using the Newcastle-Ottawa Scale, a tool that evaluates the quality of non-randomized studies by evaluating three aspects of the study: 1) selection of study groups; 2) comparability of the groups; and 3) outcome assessment [16].

Statistical analysis

To assess the effectiveness and safety of ESD suture, a weighted pooled event rate was calculated for dichotomous outcomes and the weighted pooled mean difference (MD) for continuous outcomes. For continuous outcomes, specifically procedure times, we encountered heterogeneity in how these were reported across studies (i. e., some reported MD, whereas others reported medians and ranges). To standardize our analysis, we converted medians and ranges to means and standard deviations utilizing a validated algorithm, which then allowed us to calculate the weighted pooled means for these outcomes. Results were visually presented in forest plots. Heterogeneity was evaluated using the I^2 statistic and the Cochran Q test, with a $P < 0.1$ in the Cochran Q test suggesting heterogeneity. If the I^2 value exceeded 50%, it was interpreted as substantial heterogeneity. Statistical analyses were performed using Comprehensive Meta-analysis software (version 3.0), considering a $P < 0.05$ as statistically significant.

Publication bias

To account for the effect of concealed or unpublished studies, and effectively evaluate potential publication bias, we implemented comprehensive measures including the utilization of both funnel plots and the Egger's test. $P < 0.10$ in the Egger's test would suggest the presence of potential bias.

Sensitivity analysis

To verify result robustness, sensitivity analyses were performed. By sequentially removing individual studies, we reassessed the data to determine if the overall conclusions would alter. This allowed us to identify any variability or uncertainty sources in the results and evaluate their impact on the overall conclusions.

Results

Baseline study characteristics

A total of 426 publications were identified in the initial search, of which 375 were excluded as duplicates or irrelevant studies. (**Supplementary Fig. 1**) After applying these exclusion criteria, a total of ten full articles involving 284 patients were included in this meta-analysis [14, 15, 17, 18, 19, 20, 21, 22, 23, 24]. The majority of the included studies were conducted in the United States (n = 7), and three were conducted in Japan. Four studies were prospective studies and six were retrospective studies. All included studies performed follow-up endoscopy within a period ranging from 1 month to 3 months post-procedure to assess for sustained closure of mucosal defects. This allowed for consistent evaluation of endoscopic suturing effectiveness over a comparable timeframe. A summary of the included publications and the baseline characteristics of the participants can be found in ▶ **Table 1**. The detailed risk-of-bias assessment is shown in ▶ **Table 2**.

Primary outcomes

Nine studies, encompassing 251 lesions, presented data on the technical success rate. The pooled technical success rate was 92.6% (95% CI 0.88–0.96, Cochran Q test $P = 0.220$, $I^2 = 25.10\%$) (▶ **Fig. 1**), The funnel plot's symmetry, coupled with Egger's test outcome ($P = 0.22$), denoted no detectable publication bias for this particular estimation. (**Supplementary Fig. 2**) Subgroup analysis based on different types of endoscopic suturing was performed, the pooled rate for the EHS was at 88.0% (95% CI 0.73–0.95, Cochran Q test $P = 0.059$, $I^2 = 64.7\%$), the pooled rate for the overstitch was at 97.4% (95% CI 0. 90–0.99, Cochran Q test $P = 0.690$, $I^2 = 0\%$), and the pooled rate for the X tack was at 92.4% (95% CI 0. 85–0.96, Cochran Q test $P = 0.706$, $I^2 = 0\%$) (**Supplementary Fig. 3**).

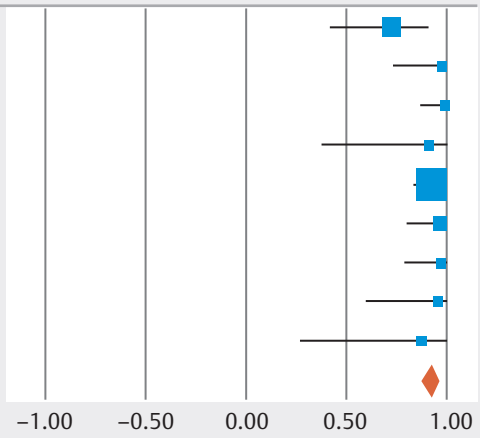
▶ **Table 1** Basic characteristics of included studies.

Author	Year	Country	No. of patients	No. of lesions	Age	Female N/%	Lesion location	No using antithrombotics	Lesion size (mm)	Procedure time (min)	Sustained	Technical success	Perforation	Bleeding
Abe S	2020	Japan	11	11	71 (55–85)	N/A	Colorectal	0	35 (25–50)	56 (30–120)	7	8	0	1
Akimoto T	2021	Japan	20	22	74	2/10	Stomach	20	12 (2–32)	36 (24–60)	22	22	0	0
Ali O	2023	USA	55	55	67 ± 11	22/40	Gastroesophageal junction 2, stomach 30 cecum 2 sigmoid 2 rectum 13	N/A	27.4 (15)	N/A	N/A	55	0	1
Callahan Z	2019	USA	5	5	N/A	N/A	N/A	N/A	N/A	N/A	3	5	1	1
Farha J	2023	USA	82	82	65 (55.-75–72)	37/45.1	Colorectal	38	30 (25–40)	10 (6.3–17.3)	N/A	76	0	1
Goto O	2020	Japan	30	30	73 ± 9.5	6/20	Stomach	15	12.4 (7.7)	49.5 ± 16.2	25	29	0	4
Han S	2020	USA	31	31	65.6	9/29	Gastric 58.1% and rectal 41.9%	5	27.4 (16.2)	13.4 ± 5.9	N/A	30	0	0
Kantsevoy S	2014	USA	12	12	64.7 ± 11.2	7/58.3	4 stomach and 8 in colon	N/A	42.5 (14.8)	10 ± 5.8	N/A	12	0	0
Mahmoud T	2022	USA	35	35	63.6 ± 13.1	45/48.4	N/A	N/A	N/A	N/A	30	N/A	0	1
Mohapatra S	2022	USA	3	3	N/A	N/A	Colorectal	N/A	N/A	N/A	N/A	3	0	0

▶ **Table 2** Quality assessment.

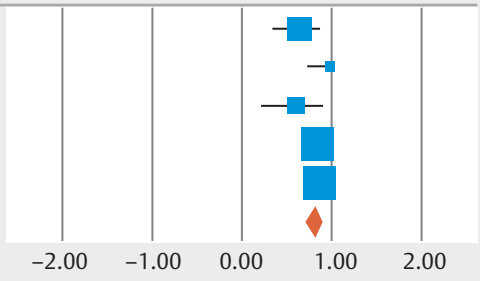
Newcastle-Ottawa Quality Assessment Scale for Non-randomized Studies									
Author	**Selection**				**Comparability**	**Outcome**			**Total**
	Representativeness of exposed cohort	**Selection of non-exposed cohort**	**Ascertainment of exposure**	**Demonstration that outcome of interest was not present at start of study**	**Comparability of cohort on the basis of the design or analysis**	**Ascertainment of o0utcome**	**Was follow-up long enough for outcomes to occur**	**Adequacy of follow-up cohorts**	
Kantsevoy S 2014	1	0	1	1	0	1	1	1	6
Goto O 2020	1	0	1	1	0	1	1	1	6
Akimoto T 2021	1	0	1	1	0	1	1	1	6
Han S 2020	1	0	1	1	0	1	1	1	6
Abe S 2009	1	0	1	1	0	1	1	0	5
Farha J 2023	1	0	1	1	0	1	1	1	6
Mahmoud T 2022	1	0	1	1	0	1	1	1	6
Ali O 2023	1	0	1	1	0	1	1	1	6
Callahan Z 2019	0	0	1	1	0	1	1	1	5
Mohapatra S 2022	0	0	1	1	0	1	1	1	5

Study name	Statistics for each study					Event rate and 95% CI
	Event rate	Lower limit	Upper limit	Z-Value	*P*-Value	
Abe S	0.727	0.414	0.910	1.449	0.147	
Akimoto T	0.978	0.732	0.999	2.662	0.008	
Ali O	0.991	0.873	0.999	3.315	0.001	
Callahan Z	0.917	0.378	0.995	1.623	0.105	
Farha J	0.927	0.847	0.967	5.987	0.000	
Goto O	0.967	0.798	0.995	3.311	0.001	
Han S	0.984	0.789	0.999	2.883	0.004	
Kantsevoy S	0.962	0.597	0.998	2.232	0.026	
Mohapatra S	0.875	0.266	0.993	1.287	0.198	
	0.926	0.876	0.957	8.596	0.000	



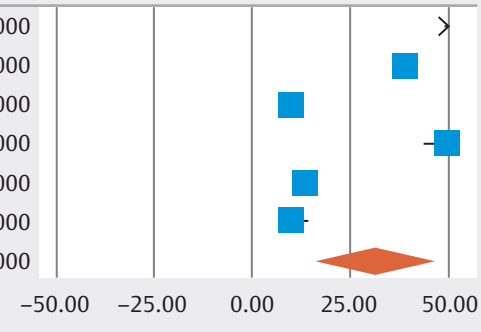
▶ **Fig. 1** Pooled technical success rates of endoscopic suturing post endoscopic submucosal dissection.

Study name	Statistics for each study				Event rate and 95% CI
	Event rate	Lower limit	Upper limit	*P*-Value	
Abe S, 2020	0.636	0.339	0.857	0.372	
Akimoto T, 2021	0.978	0.732	0.999	0.008	
Callahan Z, 2019	0.600	0.200	0.900	0.675	
Goto O, 2020	0.833	0.657	0.929	0.001	
Mohapatra S, 2022	0.875	0.700	0.939	0.000	
	0.807	0.707	0.879	0.000	



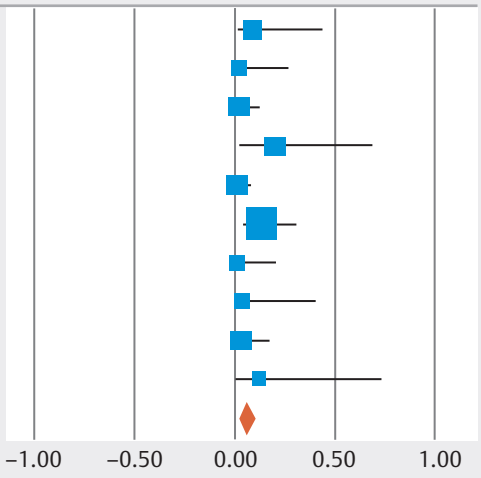
▶ **Fig. 2** Pooled rates for sustained closure of endoscopic suturing post endoscopic submucosal dissection.

Study name	Statistics for each study							Mean and 95% CI
	Mean	Standard error	Variance	Lower limit	Upper limit	Z-Value	*P*-Value	
Abe S	65.500	2.322	5.390	60.950	70.050	28.213	0.000	
Akimoto T	39.000	0.640	0.409	37.746	40.254	60.975	0.000	
Farha J	10.000	0.199	0.040	9.610	10.390	50.308	0.000	
Goto O	49.500	2.958	8.748	43.703	55.297	16.736	0.000	
Han S	13.400	1.060	1.123	11.323	15.477	12.645	0.000	
Kantsevoy S	10.000	1.674	3.803	6.718	13.282	5.973	0.000	
	31.109	7.703	59.338	16.011	46.207	4.038	0.000	



▶ **Fig. 3** Pooled procedure time of endoscopic suturing post endoscopic submucosal dissection.

Study name	Statistics for each study					Event rate and 95% CI
	Event rate	Lower limit	Upper limit	Z-Value	*P*-Value	
Abe S	0.091	0.013	0.439	−2.195	0.028	
Akimoto T	0.022	0.001	0.268	−2.662	0.008	
Ali O	0.018	0.003	0.118	−3.953	0.000	
Callahan Z	0.200	0.027	0.691	−1.240	0.215	
Farha J	0.012	0.002	0.081	−4.368	0.000	
Goto O	0.133	0.051	0.306	−3.485	0.000	
Han S	0.016	0.001	0.206	−2.907	0.004	
Kantsevoy S	0.038	0.002	0.403	−2.232	0.026	
Mahmound T	0.029	0.004	0.177	−3.476	0.001	
Mohapatra S	0.125	0.077	0.734	−1.287	0.198	
	0.053	0.027	0.104	−7.829	0.000	



▶ **Fig. 4** Pooled delayed bleeding rates of endoscopic suturing post endoscopic submucosal dissection.

The pooled sustained closure rate was 80.7% (95% CI 0.71–0.88, Cochran Q test $P = 0.156$, $I^2 = 39.81\%$) (▶ **Fig. 2**). Funnel plot symmetry, coupled with Egger's test outcome ($P = 0.73$), denoted no detectable publication bias for this particular estimation. (**Supplementary Fig. 4**) Subgroup analysis based on different types of endoscopic suturing was performed, the pooled rate for the EHS was at 82.4% (95% CI 0.56–0.95, Cochran Q test $P = 0.090$, $I^2 = 58.4\%$) and the pooled rate for the X tack was at 78.6% (95% CI 0. 62–0.89, Cochran Q test $P = 0.154$, $I^2 = 50.74\%$). Given that just one study provided data on the sustained closure rate utilizing the overstitch device, a meta-analytical computation of the pooled rate was precluded (**Supplementary Fig. 5**).

Secondary outcomes

The pooled procedure time was 31.11 minutes (95% CI 16.01–46.21, Cochran Q test $P < 0.01$, $I^2 = 99.80\ \%$) (▶ **Fig. 3**). A subgroup analysis was conducted based on method of suturing EHS or non-EHS. The pooled procedure time for the EHS group was at 51.25 minutes (95% CI 33.86–68.65, Cochran Q test $P < 0.01$, $I^2 = 98.45\%$). For the non EHS group, the pooled procedure time was 11.12 minutes (95% CI 8.75–13.48, Cochran Q test $P = 0.007$, $I^2 = 79.90\%$) (**Supplementary Fig. 6**).

Ten studies reported on the overall delayed perforation rate, with only one event of perforation noted. Ten studies reported on the overall delayed bleeding rate, with the pooled event rate at 5.3 % (95% CI 0. 30–0.10, Cochran Q test $P = 0.276$, $I^2 = 18.1\%$), showing low heterogeneity (▶ **Fig. 4**).

A subgroup analysis was conducted considering the use of antithrombotic drugs. Five studies reported data on whether antithrombotic drugs were used. Only three delayed bleeding events were noted among patients using antithrombotics with a 6.7% event rate (95% CI 0.02–0.25). Among patients not using antithrombotics, the event rate was 4.4% (95% CI 0.02–0.12) (**Supplementary Fig. 7**).

We conducted a subgroup analysis predicated on lesion location, delineating a delayed bleeding rate of 7.9% (95% CI 0.30–0.10, Cochran Q test $P = 0.451$, $I^2 = 0\%$) for gastric lesions. In contrast, lesions located in the colorectal region exhibited a pooled delayed bleeding rate of 4.1% (95% CI 0.30–0.10, Cochran Q test $P = 0.707$, $I^2 = 0\%$) (**Supplementary Fig. 8**).

Subgroup analysis based on different types of endoscopic suturing was performed, the pooled rate of delayed bleeding for the EHS was at 10.5% (95% CI 0. 05–0.22, Cochran Q test $P = 0.442$, $I^2 = 0\%$), the pooled rate of delayed bleeding for the overstitch was at 4.2% (95% CI 0.01–0.14, Cochran Q test $P = 0.304$, $I^2 = 17.44\%$), and the pooled rate of delayed bleeding for the X tack was at 3.4% (95% CI 0. 01–0.11, Cochran Q test $P = 0.572$, $I^2 = 0\%$) (**Supplementary Fig. 9**).

Sensitivity analysis

We conducted leave-one-out sensitivity analyses to assess the robustness of our findings. These analyses involved removing individual studies one by one and reanalyzing the data, and we found that the results remained consistent regardless of which studies were included or excluded (**Supplementary Fig. 10**).

Discussion

Our meta-analysis, the first to explore the feasibility, safety, and efficacy of endoscopic suturing for managing post-ESD mucosal defects, reveals several noteworthy findings for future clinical practice. To begin with, the data provide a robust technical success rate of 92.6%, underscoring the procedural viability of endoscopic suturing. In addition, we observed a commendable rate of sustained closure following the procedure. Equally noteworthy was the significantly diminished risk of postoperative

complications in patients undergoing endoscopic suturing with colorectal lesions. Notably, those patients on antithrombotic therapy manifested markedly decreased rates of delayed bleeding after endoscopic suturing. Lastly, procedure time for endoscopic suturing was found to be reasonably efficient.

Our study highlighted the high technical success rate and sustained closure rate as primary advantages of endoscopic suturing. Previous research reported a 52% mucosal dehiscence rate with defects closed using hemoclips [12, 25]. The challenge of closing stomach ESD defects using endoclips, primarily due to the anatomically thick wall leading to the formation of submucosal spaces, often results in mucosal dehiscence. Our study, on the other hand, reported an 80.7% sustained closure rate, signifying a marked improvement over traditional clip-based closure method. We attribute this improvement to endoscopic suturing techniques, which incorporate wider bites and sufficient depth, and, if required, an additional stitch at the center of the mucosal defect [15, 18]. These findings emphasize the robust suturing capabilities of EHS, overstitch, and tack suture system.

This study underscores a remarkably low incidence of post-procedural complications with endoscopic suturing. The proactive closure of larger mucosal defects, despite inherent technical challenges, could lower the risk of post-ESD AEs [9, 25]. Animal studies have substantiated that the EHS group shows comparable growth of new blood vessels and fibroblasts in the submucosal layer - key contributors to gastric ulcer healing - to that observed in normal submucosal layers [26]. Therefore, it is plausible that proficient endoscopic suturing could hasten the healing of iatrogenic gastrointestinal mucosal defects post-ESD, and limit complications among high-risk patients.

Perforation, another notable concern after ESD, has rates of approximately 4.5% after gastric ESD and 4.8% after colorectal ESD [27, 28]. Most ESD-related perforations occur intra-procedurally and can be immediately managed with clip closure. However, a small subset of patients may experience delayed perforations, which can necessitate emergent surgery. Notably, our study observed only one instance of delayed perforation after endoscopic suture. In the course of our examination, it was found that endoscopic suturing was utilized to manage intra-procedural perforations in two of the studies. Specifically, two instances were reported in the study by Ali O et al. and three instances in the study by Farha J et al [19, 21]. In all these cases, the intra-procedural perforations were successfully managed with endoscopic suturing. This additional finding underscores the potential versatility and effectiveness of endoscopic suturing not just for prevention of post-procedural complications, but also for managing complications that may arise during the procedure itself.

Our subgroup analysis indicated a significant decrease in delayed bleeding rates among patients receiving anticoagulant or antiplatelet therapy who underwent endoscopic suturing. The increased prevalence of anticoagulant use among ESD patients necessitates meticulous management to mitigate the risk of delayed bleeding. While performing ESD without interrupting anticoagulant therapy is an option for individuals at high risk of thromboembolic events, it is worth noting that anticoagulant use inherently increases the risk of delayed bleeding [29]. Specifically, we noted a mere three occurrences, a substantial decrease when compared with the previous 22.5% to 26.1% incidence rates reported in patients with untreated mucosal defects on antithrombotic therapy, as indicated in earlier studies [30, 31, 32]. Our data suggest that endoscopic suturing could help reduce complications tied to antithrombotic use in ESD procedures.

Procedure time for endoscopic suturing was 31.11 minutes, potentially extending anesthesia time and associated risks. However, we observed a decrease in post-procedural AEs, suggesting that the benefits of endoscopic suturing may outweigh these potential risks. As endoscopic procedures continue to evolve and mature, we anticipate further improvements in efficiency.

EHS, Overstitch, and the tack suture system all aim to close mucosal defects following ESD, although they utilize different tools and procedures. Despite the complexity of EHS, its powerful suturing capabilities make it a viable option for large defects. Overstitch, although requiring a specific device and potentially impacting maneuverability and cost-effectiveness, remains widely used. The X tack device offers a simplified approach for gastrointestinal defect closure [18, 21, 22]. However, balancing simplicity, time-effectiveness, and cost-effectiveness is critical for these techniques to be widely adopted.

Our subgroup analysis, focused on varying types of endoscopic suturing, yielded key insights into the technical success rate of each method. The overstitch technique emerged as particularly successful from a technical success standpoint. Regarding the sustained closure rate, both the EHS and X tack procedures demonstrated substantial effectiveness. However, the study was constrained by the lack of available data to compute a meta-analytical pooled rate of sustained suture for the overstitch device. An analysis of the delayed bleeding rates associated with different suturing techniques revealed that both the overstitch and X tack techniques exhibited lower rates than the EHS, contributing to their favorable safety profiles in relation to post-procedural bleeding.

Endoscopic suturing in ESD shows promise but poses certain limitations. First, risk of inadvertently embedding tumor components into the submucosal layer reinforces the need for astute patient selection [33]. In addition, limited clinical data regarding sustained closure rates beyond postoperative Day 7 impedes our capacity to evaluate long-term effectiveness of these suturing techniques. Therefore, long-term follow-up studies are needed to validate these findings in endoscopic suturing. While we observed a single event of delayed perforation, which matches the general rate post-ESD, this does not conclusively prove the preventive efficacy of endoscopic suturing against delayed perforation. This highlights the need for larger-scale studies to further investigate this potential. Some anatomical regions like the cardia or pyloric ring may be unsuitable for closure. In such cases, suturing of large mucosal defects should aim towards the organ's longitudinal direction to minimize post-suturing stenosis severity. Furthermore, our study does not provide cost-effectiveness data for endoscopic suturing and further studies are warranted on this area. Selection of

studies for this analysis, six of which were retrospective, introduces the potential for selective bias. In addition, the analysis lacked direct comparisons among the overstitch, EHS, and X tack suturing techniques. As such, future research should prioritize conducting head-to-head comparative studies to better understand the relative merits and limitations of these methods.

In our analysis, we converted medians and ranges to means and standard deviations using a validated algorithm to harmonize the available estimates. However, this method assumes a normal distribution, which may not accurately reflect the skewness of the data, particularly for procedure time. This assumption may introduce some bias in the results. Future studies should consider reporting both mean and median values to better represent the data distribution and ensure a more robust statistical analysis.

We acknowledge the inclusion of studies with incomplete datasets on lesion size and location, notably the Callahan et al. study. This decision was made to encompass a broad spectrum of available evidence on endoscopic suturing post-ESD. However, we recommend interpreting the pooled results with caution, considering these limitations. Future research should aim for more detailed reporting to enhance the comparability and interpretation of findings across studies.

Conclusions

In conclusion, endoscopic suturing offers a promising solution for managing post-ESD mucosal defects in patients with antithrombotic therapy. Despite challenges and limitations related to technique, lesion location, and cost, techniques such as EHS, overstitch, tack suturing system hold potential for enhancing patient outcomes. The findings call for further large-scale, prospective studies to validate these outcomes and focus on developing standardized methodologies.

Conflict of Interest

The authors declare that they have no conflict of interest.

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