

Association between prophylactic pancreatic stent length and post-ERCP pancreatitis: a propensity score-matched cohort study

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Abstract

Background and study aims

Prophylactic pancreatic duct stenting is an established strategy for reducing the risk of post-ERCP pancreatitis in high-risk patients, but the optimal stent length remains uncertain. We evaluated the association between 5 cm and longer (6–9-cm) 5 Fr prophylactic pancreatic stents and the incidence of post-ERCP pancreatitis.

Patients and methods

We conducted a retrospective cohort study at a tertiary referral center from 2015 to 2025, including 466 high-risk patients who underwent ERCP with prophylactic 5 Fr pancreatic stents of 5 cm or longer lengths. Patients were stratified according to stent length. Propensity score matching was performed to balance baseline characteristics and procedural factors between groups, and the incidence of PEP and available data on recorded stent-related complications were analyzed.

Results

PEP occurred in 15.7% of patients (73/466). In the propensity score–matched cohort, the incidence was significantly higher in patients with a 5-cm stent compared with those who received longer stents (22.2% vs 10.2%, $P = 0.003$). In multivariable conditional logistic regression, placement of a stent longer than 5 cm remained statistically associated with lower odds of PEP compared with placement of a 5-cm stent. No bleeding, perforation, or infection was documented in either group.

Conclusion

In this single-center retrospective cohort, longer prophylactic pancreatic stents (6–9 cm) were associated with a lower incidence of PEP than 5-cm stents after propensity score matching. Given the non-random selection of stent length and potential residual confounding, these findings should be interpreted as hypothesis-generating rather than as evidence of an independent or causal effect of stent length.

Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) is widely performed for the diagnosis and treatment of pancreatobiliary diseases but carries the risk of post-ERCP pancreatitis (PEP), one of its most common and clinically important adverse events¹. According to previous studies, PEP occurs in approximately 8% of average risk and 16% of high risk procedures^{2–4}. Prophylactic pancreatic stent

placement has long been established as an effective mechanical strategy to reduce the incidence of PEP, particularly in high-risk patients^{5,6}. A meta-analysis of 10 randomized controlled trials involving 1,176 patients showed that prophylactic pancreatic duct stenting significantly reduced the incidence of PEP in high-risk patients compared with no stenting (OR 0.25, 95% CI 0.17–0.38; $P < 0.001$)⁷. By maintaining ductal drainage and relieving transient outflow obstruction caused by papillary trauma or edema, pancreatic stents reduce intraductal hypertension, thereby reducing the incidence and severity of pancreatitis². In accordance with national guideline recommendations and based on our center's clinical practice, prophylactic pancreatic stent placement is routinely recommended in patients in whom the guidewire unintentionally enters the pancreatic duct more than once during biliary cannulation⁸.

While the utility of prophylactic stents in PEP prevention is well recognized, the optimal characteristics of these stents—particularly their length—remain a subject of ongoing debate. Current guidelines generally recommend the use of small-caliber plastic stents, but lengths vary considerably in clinical practice, with stents of 5 cm, 6 cm, 7 cm, or even longer being employed^{3,9}. Some studies suggest that shorter stents may be preferable, given their higher likelihood of spontaneous dislodgement and reduced need for follow-up endoscopy^{10,11}. In contrast, other studies have reported that longer stents may provide more stable drainage and better protection against PEP.¹² Despite decades of clinical experience, the evidence for defining the ideal stent length remains limited and no consensus has been reached regarding the most appropriate pancreatic stent length for PEP prophylaxis.

Therefore, we conducted a retrospective cohort study to evaluate the association between pancreatic stent length and the incidence of PEP in high-risk patients receiving prophylactic 5 Fr pancreatic stents.

Methods

Study design and patients

In this retrospective, single-center cohort study, we reviewed ERCP cases performed between January 2015 and January 2025 at a tertiary referral hospital. The study was approved by the hospital's ethics committee, with a waiver of informed consent due to its retrospective nature (BFHHZS20250218).

Patients were included if they met all of the following criteria: (1) Adult patients underwent ERCP at our center for the planned management of biliary disease (e.g., choledocholithiasis, biliary stricture, biliary mass/space-occupying lesion) or lesion of the duodenal papilla or ampulla without structural abnormalities of the pancreatic duct (e.g., pancreatic duct stones, strictures, space-occupying lesions or pancreatic cancer); (2) Patients who underwent successful placement of a 5 Fr prophylactic pancreatic duct stent due to inadvertent guidewire cannulation of the pancreatic duct and/or unintentional contrast opacification during attempted biliary cannulation; (3) No history of acute pancreatitis within 1 month prior to the procedure.

The unit of analysis was defined on a per-patient basis. For patients who underwent multiple ERCP procedures during the study period and received prophylactic pancreatic duct stent placement on more than one occasion, only the first ERCP that met the inclusion criteria was included in the primary analysis, in order to avoid correlated observations from repeated procedures within the same individual.

Rectal indomethacin

Rectal indomethacin, when used, was administered at a dose of 100 mg before ERCP. The decision to use rectal indomethacin was made by the treating physician according to the patient's risk profile for post-ERCP pancreatitis, including the presence of established high-risk factors described in current guideline recommendations¹³. Routine universal rectal NSAID prophylaxis was not fully implemented during the earlier years of the study period and was gradually incorporated into institutional practice over time. Contraindications included NSAID allergy, renal dysfunction, active gastrointestinal bleeding, and other conditions associated with an increased bleeding risk.

ERCP procedures

Selective biliary cannulation was routinely attempted using a sphincterotome-assisted guidewire technique. A 0.035-inch hydrophilic guidewire, typically a Zebra guidewire (Boston Scientific, Marlborough, MA, USA), was used for cannulation. All prophylactic pancreatic stents included in the study were 5 Fr single-pigtail plastic stents without an internal pancreatic flange. The stents were manufactured by Boston Scientific (Marlborough, MA, USA), Micro-Tech (Nanjing) Co., Ltd. (Nanjing, China), or Cook Medical (Bloomington, IN, USA), and were available in lengths of 5, 6, 7, 8, and 9 cm. Inadvertent pancreatic guidewire cannulation was defined as unintentional passage of the guidewire into the pancreatic duct during attempts at selective biliary cannulation. Pancreatic guidewire access occurring as part of subsequent planned therapeutic maneuvers was not considered inadvertent pancreatic guidewire cannulation for the purpose of this study. All prophylactic pancreatic stents used in this study had a diameter of 5 Fr. Stent length was selected at the discretion of the endoscopist according to pancreatic duct configuration, papillary anatomy, estimated intraductal cannulation length, procedural difficulty, and device availability. No standardized institutional algorithm mandating a specific stent length was used during the study period. Consequently, the choice of stent length was non-random and may have been influenced by anatomical and procedural factors that were not systematically recorded in the retrospective database. When pancreatic duct stent placement was indicated, the specifications of the stent (diameter and length) were clearly recorded, and the rationale for prophylactic placement was provided.

High-risk status for PEP was operationally defined as the occurrence of more than one unintended pancreatic duct guidewire cannulation and/or unintentional contrast opacification of the pancreatic duct during attempted biliary cannulation. These procedure-related factors are recognized in current ESGE and ASGE guidelines as indications for prophylactic pancreatic duct stent placement^{3,13}. In our

institution, prophylactic pancreatic duct stents are placed only in patients who experience repeated unintended pancreatic duct cannulation or pancreatic duct opacification during ERCP. Accordingly, all included patients met at least one established procedure-related high-risk criterion for PEP.

Post-ERCP care

All patients who underwent biliary or pancreatic duct interventions during ERCP were admitted for post-procedural observation. Lactated Ringer's solution was administered intraoperatively and postoperatively according to patient hemodynamic status and cardiopulmonary or renal comorbidities. Laboratory tests, including complete blood count, liver and renal function, serum amylase, and lipase, were routinely performed immediately after the procedure, as well as at 6 hours and 24 hours post-ERCP. Post-procedural nursing and monitoring protocols were standardized across all patients. Clinical monitoring focused on abdominal signs and symptoms, including pain, distention, nausea, and vomiting. Patients were routinely kept nil per os and received intravenous fluid therapy after the procedure, primarily Lactated Ringer's solution or normal saline, for hydration and supportive care. Imaging tests were performed when clinically indicated.

Outcome

The primary outcome was post-ERCP pancreatitis, diagnosed according to the Cotton consensus criteria¹⁴. Under this definition, the diagnosis required new or worsening upper abdominal pain, serum amylase or lipase levels at least three times the upper limit of normal more than 24 hours after ERCP, and hospitalization for at least 2 nights. The outcome was independently adjudicated by three ERCP experts at our center (who were not involved in the index procedure) based on review of the medical records of the included patients. The secondary outcome was the severity of PEP, classified according to the Cotton consensus criteria¹⁴. The primary and secondary outcomes were adjudicated if there was agreement between at least 2 of the 3 adjudicators. Besides, other kinds of adverse events including perforation, bleeding, infections will also be considered as secondary outcome.

Matching of patients

Propensity score matching (PSM) was performed to balance baseline differences between groups. Propensity scores were estimated using multivariable logistic regression, including age, sex, body mass index, treatment indication, rectal indomethacin use, periampullary diverticulum, removal of an existing stent, pancreatic duct opacification, balloon dilation, brush cytology or biopsy, stone extraction balloon use, stone retrieval basket use, biliary stent placement, endoscopic sphincterotomy, and procedure time. Nearest-neighbor matching was conducted in a 1:1 ratio without replacement, using a caliper width of 0.2 and a fixed random seed of 123456. Covariate balance before and after matching was assessed using standardized mean differences (SMDs), with an absolute SMD < 0.10 considered indicative of adequate balance. **Statistical analysis**

All statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA) and R version 4.3.0. Continuous variables were summarized as median (interquartile range) and compared using the Mann–Whitney U test. Categorical variables were expressed as counts (percentages) and compared using the chi-square. After propensity score matching, covariates with an absolute standardized mean difference greater than 0.10 were included in the multivariable model. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. A two-sided $P < 0.05$ was considered statistically significant.

Results

Patients and propensity score matching

Between January 2015 and January 2025, 466 patients who underwent ERCP with placement of a prophylactic 5 Fr pancreatic duct stent were included in the study. The median age was 63 years, and 208 patients (44.64%) were male. Overall, 73 patients (15.7%) developed post-ERCP pancreatitis (Fig. 1).

Before propensity score matching, patients receiving 5 cm and longer pancreatic stents differed in treatment indication and several procedure-related characteristics, including the use of a stone extraction balloon and a stone retrieval basket (Tables 1 and 3). Propensity score matching substantially improved the balance of the measured baseline and procedural covariates. Residual imbalance remained for rectal indomethacin use and biliary stent placement, and these variables were therefore included in the subsequent multivariable conditional logistic regression model (Tables 2 and 4).

Table 1
Baseline characteristics (Before PSM)

Variables*	Total (n = 466)	Longer stent (n = 240)	5-cm stent (n = 226)	P
Body mass index, kg/m ² †	24.24 (20.94, 27.55)	23.88 (20.20, 27.55)	24.61 (22.04, 27.55)	0.395
Age, years†	63.00 (52.00, 72.00)	63.00 (51.00, 72.00)	63.00 (53.00, 72.00)	0.433
Length of hospital stay, days†	11.00 (7.00, 14.00)	11.00 (8.00, 14.00)	10.50 (7.00, 14.00)	0.333
Gender, male	208 (44.64)	116 (48.33)	92 (40.71)	0.098
Rectal indomethacin	159 (34.12)	79 (32.92)	80 (35.40)	0.572
Treatment Indication				< 0.001
Biliary stricture (benign and malignant)	79 (16.95)	52 (21.67)	27 (11.95)	
Common bile duct stone(s) and/or acute cholangitis	328 (70.39)	147 (61.25)	181 (80.09)	
Lesion of the duodenal papilla or ampulla	59 (12.66)	41 (17.08)	18 (7.96)	
*: Variables are presented as n (%), unless otherwise specified				
†: BMI, age and length of hospital stay are presented as median (interquartile range, IQR)				

Table 2
Baseline characteristics (After PSM)

Variables*	Total (n = 334)	Longer stent (n = 167)	5-cm stent (n = 167)	SMD
Body mass index (kg/m ²)†	24.24 (20.20, 27.55)	24.24 (20.20, 27.55)	24.52 (21.30, 27.55)	-0.010
Age (year)†	65.50 (53.75, 76.00)	66.00 (52.00, 76.00)	65.00 (54.25, 75.00)	-0.018
Length of hospital stay (day)†	11.00 (8.00, 12.75)	11.00 (8.00, 13.00)	11.00 (8.00, 12.00)	-0.011
Gender, male	140 (41.92)	70 (41.92)	70 (41.92)	0.000
Indomethacin	124 (37.13)	56 (33.53)	68 (40.72)	-0.147
Treatment Indication				
Biliary stricture (benign and malignant)	49 (14.67)	26 (15.57)	23 (13.77)	-0.032
Common bile duct stone(s) and/or acute cholangitis	250 (74.85)	123 (73.65)	127 (76.05)	-0.012
Lesion of the duodenal papilla or ampulla	35 (10.48)	18 (10.78)	17 (10.18)	0.051
*: Variables are presented as n (%), unless otherwise specified				
†: BMI, age and length of hospital stay are presented as median (interquartile range, IQR)				

Table 3
Procedure-related risk factors (Before PSM)

Variables*	Total (n = 466)	longer stent (n = 240)	5-cm stent (n = 226)	P
Periampullary diverticulum	77 (16.52)	40 (16.67)	37 (16.37)	0.932
Removal of existing stent	25 (5.36)	12 (5.00)	13 (5.75)	0.719
Pancreatic duct opacification	25 (5.36)	11 (4.58)	14 (6.19)	0.440
Balloon dilation	45 (9.66)	17 (7.08)	28 (12.39)	0.130
Brush cytology or biopsy	122 (26.18)	58 (24.17)	64 (28.32)	0.308
Stone extraction balloon	256 (54.94)	115 (47.92)	141 (62.39)	0.002
Stone retrieval basket	99 (21.24)	35 (14.58)	64 (28.32)	< 0.001
Biliary stent placement	110 (23.61)	58 (24.17)	52 (23.01)	0.769
Endoscopic sphincterotomy	351 (75.32)	181 (75.42)	170 (75.22)	0.961
Procedure time†	35.00 (29.00, 45.00)	36.00 (30.50, 46.00)	35.00 (28.00, 43.00)	0.143
*: Variables are presented as n (%), unless otherwise specified				
†: Procedure time is presented as median (interquartile range, IQR)				

Table 4
Procedure-related risk factors (After PSM)

Variable*	Total (n = 334)	longer stent (n = 167)	5-cm stent (n = 167)	SMD
Periampullary diverticulum	54 (16.17)	26 (15.57)	28 (16.77)	0.032
Removal of existing stent	18 (5.39)	9 (5.39)	9 (5.39)	0.000
Pancreatic duct opacification	17 (5.09)	9 (5.39)	8 (4.79)	-0.028
Balloon dilation	31 (9.28)	15 (8.98)	16 (9.58)	0.020
Brush cytology or biopsy	77 (23.05)	37 (22.16)	40 (23.95)	0.042
Stone extraction balloon	188 (56.29)	91 (54.49)	97 (58.08)	0.073
Stone retrieval basket	66 (19.76)	31 (18.56)	35 (20.96)	0.059
Biliary stent placement	65 (19.46)	27 (16.17)	38 (22.75)	0.157
Endoscopic sphincterotomy	244 (73.05)	122 (73.05)	122 (73.05)	0.000
Procedure time †	35.00 (34.00, 41.00)	35.00 (34.00, 41.50)	35.00 (34.00, 39.00)	0.021
*: Variables are presented as n (%), unless otherwise specified				
†: Procedure time is presented as median (interquartile range, IQR)				

Study outcomes

Primary and secondary outcomes

In the propensity score–matched cohort, PEP occurred more frequently among patients receiving a 5 cm pancreatic stent than among those receiving a longer stent. According to the matched analysis, PEP occurred in 37/167 (22.16%) for the 5 cm group and 17/167 (10.18%) for the longer stent group, respectively (P = 0.003) (Table 5).

Table 5
Study outcome

Variables*	Total (n = 334)	longer stent (n = 167)	5-cm stent (n = 167)	P
PEP	54 (16.17)	17 (10.18)	37 (22.16)	0.003
Severity				/
Mild/Moderate	54/54 (100)	17/17 (100)	37/37 (100)	
Severe	0	0	0	
Dislodgement				0.474
Endoscopic removal	159 (47.60)	74 (44.31)	85 (50.90)	
Spontaneous dislodgement	10 (2.99)	5 (2.99)	5 (2.99)	
Missing data	165 (49.40)	88 (52.69)	77 (46.11)	
*: Variables are presented as n (%)				
PEP severity was graded according to the Cotton consensus criteria.				

All adjudicated cases of PEP were mild or moderate, and no severe PEP occurred¹⁴. No bleeding, perforation, or infection was documented in either group. However, proximal pancreatic stent migration was not systematically captured and could not be compared between groups.

Multivariable analysis in the matched cohort

In the multivariable conditional logistic regression model accounting for the matched-pair design, placement of a longer pancreatic stent remained associated with lower odds of PEP compared with placement of a 5-cm stent (adjusted OR 0.38, 95% CI 0.20–0.72; P = 0.003). Rectal indomethacin use was not significantly associated with PEP in this model (adjusted OR 1.14, 95% CI 0.40–3.28; P = 0.805), and biliary stent placement was also not statistically significant (adjusted OR 0.24, 95% CI 0.04–1.35; P = 0.105) (Table 7).

Table 7
Multivariable conditional logistic regression analysis of factors associated with post-ERCP pancreatitis in the propensity score-matched cohort

Variable	Adjusted OR	95% CI	P value
Longer stent (> 5 cm vs 5 cm)	0.38	0.20–0.72	0.003
Rectal indomethacin	1.14	0.40–3.28	0.805
Biliary stent placement	0.24	0.04–1.35	0.105
OR, odds ratio; CI, confidence interval.			

Dislodgement

Among the 334 cases, endoscopic removal was performed in 159/334 (47.6%), including 74/167 patients (44.3%) in the longer stent group and 85/167 patients (50.9%) in the 5-cm stent group. Spontaneous dislodgement occurred in 10/334 (3.0%), with 5/167 (3.0%) in each group. Dislodgement status could not be determined in 49.4% of cases due to loss to follow-up or lack of radiographic documentation, with 88 (52.7%) in longer stent group vs 77(46.1%) in 5-cm stent group. Among the remaining patients with available data, there was no significant difference between the two groups regarding dislodgement-related outcomes ($P = 0.474$) (Table 5).

Subgroup Analysis

The association between stent-length group and PEP did not differ significantly according to rectal indomethacin use (P for interaction = 0.337; Supplementary Table S1).

Exploratory analysis according to individual stent length

The distribution of pancreatic stent lengths in the full unmatched cohort was as follows: 5 cm in 226 patients, 6 cm in 101, 7 cm in 119, 8 cm in 13, and 9 cm in 7. The corresponding PEP incidences were 20.8% (47/226), 8.9% (9/101), 13.4% (16/119), 7.7% (1/13), and 0% (0/7), respectively. The overall difference across the five stent-length categories was statistically significant (Fisher's exact test, $P = 0.043$) (Table 6).

Table 6
Exploratory logistic regression analysis according to individual pancreatic stent length

Stent length	Patients, n	PEP, n (%)	Adjusted OR*	95% CI	P value
5 cm	226	47 (20.8)	Reference	—	—
6 cm	101	9 (8.9)	0.31	0.13–0.64	0.003
7 cm	119	16 (13.4)	0.48	0.24–0.93	0.035
8 cm	13	1 (7.7)	Not estimable†	—	—
9 cm	7	0 (0)	Not estimable†	—	—
Overall comparison across the five stent-length categories: Fisher's exact test, P = 0.043.					
*: Adjusted for rectal indomethacin use and biliary stent placement.					
†: The effect estimate for the 8 cm and 9 cm group were not considered interpretable because of sparse data.					

Discussion

In this single-center retrospective cohort of high-risk ERCP patients receiving prophylactic 5 Fr pancreatic stents, the use of longer stents (6–9 cm) was associated with a lower observed incidence of PEP than the use of 5-cm stents after propensity score matching. However, stent length was selected non-randomly, and the observed difference may reflect residual or unmeasured confounding related to pancreatic duct anatomy, procedural difficulty, and endoscopist decision-making. Therefore, these findings should be interpreted as hypothesis-generating rather than as evidence of an independent or causal effect of stent length.

The relatively high overall PEP rate deserves specific consideration. This was not an unselected ERCP cohort but a high-risk population in whom prophylactic pancreatic stents were placed after repeated unintended pancreatic duct guidewire cannulation or pancreatic duct opacification during cannulation. In these patients, mechanical papillary or pancreatic duct irritation may have already occurred before stent placement, and pancreatic stenting may reduce but cannot eliminate the risk of PEP^{15,16}. In addition, rectal indomethacin was used in only a subset of patients because the study period covered years during which routine NSAID prophylaxis was not fully implemented in our center. Its use was selectively determined according to perceived PEP risk and contraindications, which may have introduced confounding by indication. These factors may explain why the observed PEP rate was higher than that reported in some contemporary cohorts with universal NSAID prophylaxis.

Because 3 cm pancreatic stents were not routinely used at our center during the study period, our analysis focused on comparing outcomes between 5-cm stents and longer stents (6–9 cm). Within this context, our study addresses a more specific question regarding the optimal stent length.

The multivariable model included rectal indomethacin use and biliary stent placement because both variables showed residual imbalance after propensity score matching. Placement of a longer stent remained associated with lower odds of PEP after this additional adjustment. In this retrospective cohort, indomethacin was selectively administered according to clinical risk, contraindications, and evolving institutional practice. Patients perceived to be at greater risk may therefore have been more likely to receive indomethacin, creating confounding by indication. The study was not designed or powered to estimate the independent preventive efficacy of rectal NSAIDs.

Pancreatic stents are thought to prevent PEP by maintaining pancreatic outflow across an edematous or traumatized papilla^{17,18}. It is biologically plausible that a longer stent could provide more stable intraductal positioning or drainage in selected patients. Nevertheless, the present data cannot establish such a mechanism. Dislodgement status was unavailable in approximately half of the matched cohort, spontaneous dislodgement was uncommon, and exact stent dwell time was not systematically recorded. In addition, proximal stent migration, an important length-related adverse event, was not reliably captured. Therefore, the study can neither support nor refute the hypothesis that longer stents reduce PEP through prolonged retention or more sustained drainage.

The most important limitation of this study is confounding by indication. Pancreatic stent length was not randomly assigned but was selected by the endoscopist according to pancreatic duct configuration, papillary anatomy, estimated cannulation depth, procedural difficulty, operator preference, and device availability. These same factors may also influence the risk of PEP. Patients with a small-caliber, tortuous, or technically difficult pancreatic duct may have been more likely to receive a 5-cm stent while simultaneously having a higher intrinsic risk of PEP. Because these anatomical and technical determinants were not systematically recorded, they could not be incorporated into the propensity score model; therefore, propensity-score matching could not eliminate residual or unmeasured confounding. Accordingly, the observed association should be regarded as hypothesis-generating and should not be interpreted as evidence that shorter stents independently or causally increase the risk of PEP. Another important limitation is that 3 cm pancreatic stents were not used in our center during the study period. Because 3 cm stents are commonly used for PEP prophylaxis in many centers, our findings should not be extrapolated to comparisons involving 3 cm stents. The present study only addresses the comparison between 5 cm and 6–9 cm 5 Fr pancreatic stents.

Despite these limitations, the study addresses a clinically relevant question for which evidence remains limited. The findings suggest that the relationship between prophylactic pancreatic stent length and PEP warrants further investigation. Future prospective studies should standardize stent design, diameter, length-selection criteria, pharmacological prophylaxis, and post-procedural imaging. Ideally, adequately powered randomized trials should directly compare commonly used 5 Fr stent lengths while systematically recording pancreatic duct anatomy, procedural difficulty, spontaneous dislodgement, dwell time, proximal migration, and the need for endoscopic removal.

Conclusion

In this single-center retrospective cohort of high-risk ERCP patients, the use of prophylactic pancreatic duct stents longer than 5 cm was associated with a lower observed incidence of PEP than the use of 5-cm stents. Because stent length was selected non-randomly and important anatomical and technical determinants were not measured, these findings should be regarded as hypothesis-generating. Adequately powered prospective randomized studies are required to determine whether stent length itself influences PEP risk and to identify the optimal prophylactic pancreatic stent length.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Ethics Committee of Beijing Friendship Hospital, Capital Medical University (BFHHZS20250218). The requirement for informed consent was waived because of the retrospective nature of the study and the use of de-identified clinical data. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Conflict of interest statement

The authors declare that they have no competing interests.

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Author Contribution

M.W. conceived and designed the study, developed the methodology, collected and curated the data, performed the statistical analyses, prepared the visualizations, and drafted the manuscript. Y.C. and Y.Z. collected and validated the clinical data, contributed to the interpretation of the results, and critically revised the manuscript. W.W. conceived and supervised the study, provided clinical oversight, administered the project, and critically revised the manuscript. All authors read and approved the final manuscript.

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None.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available because they contain institutional clinical data, but are available from the corresponding author upon reasonable request and with appropriate institutional approval.

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Figures

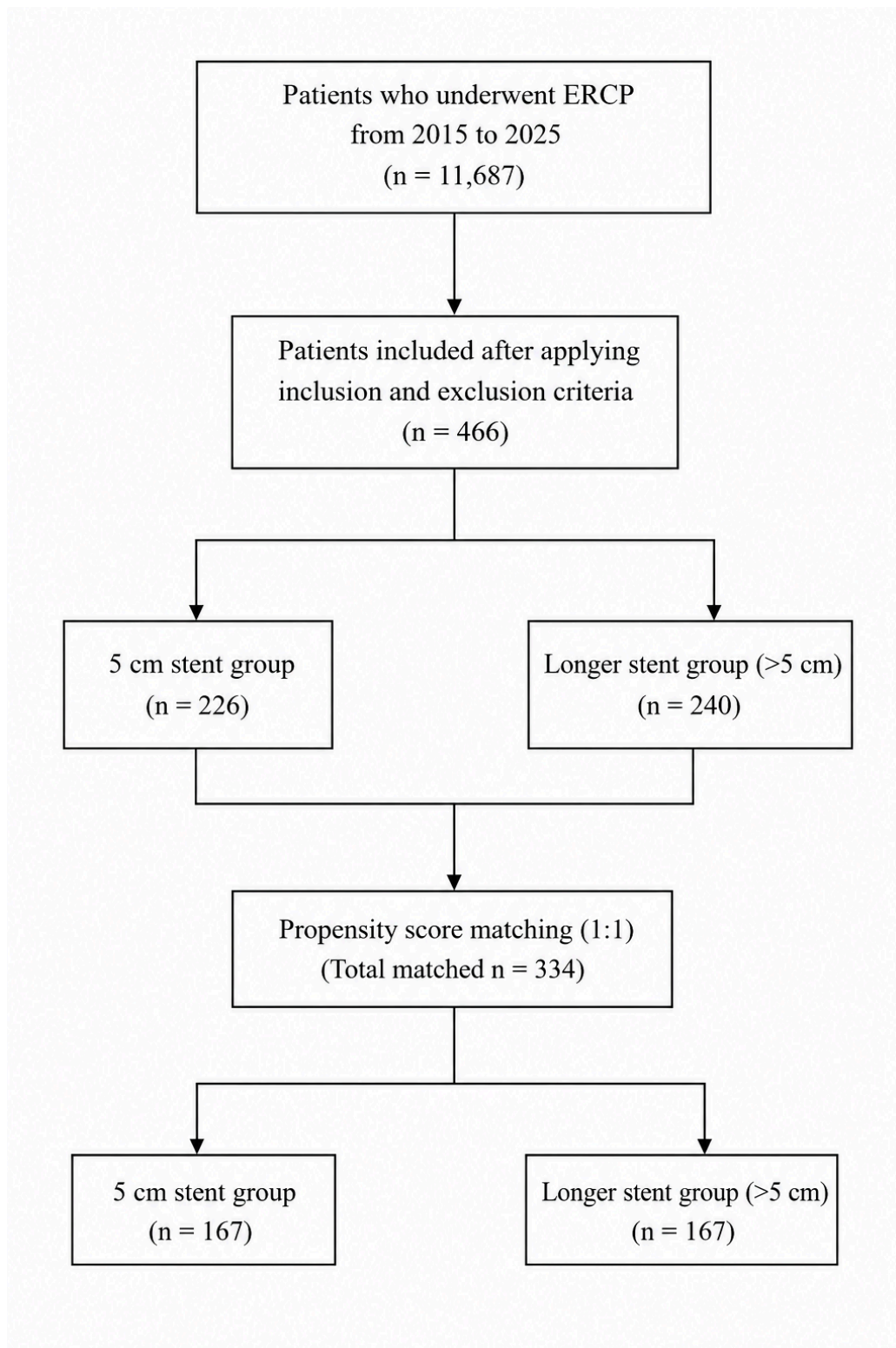


Figure 1

Study flowchart

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