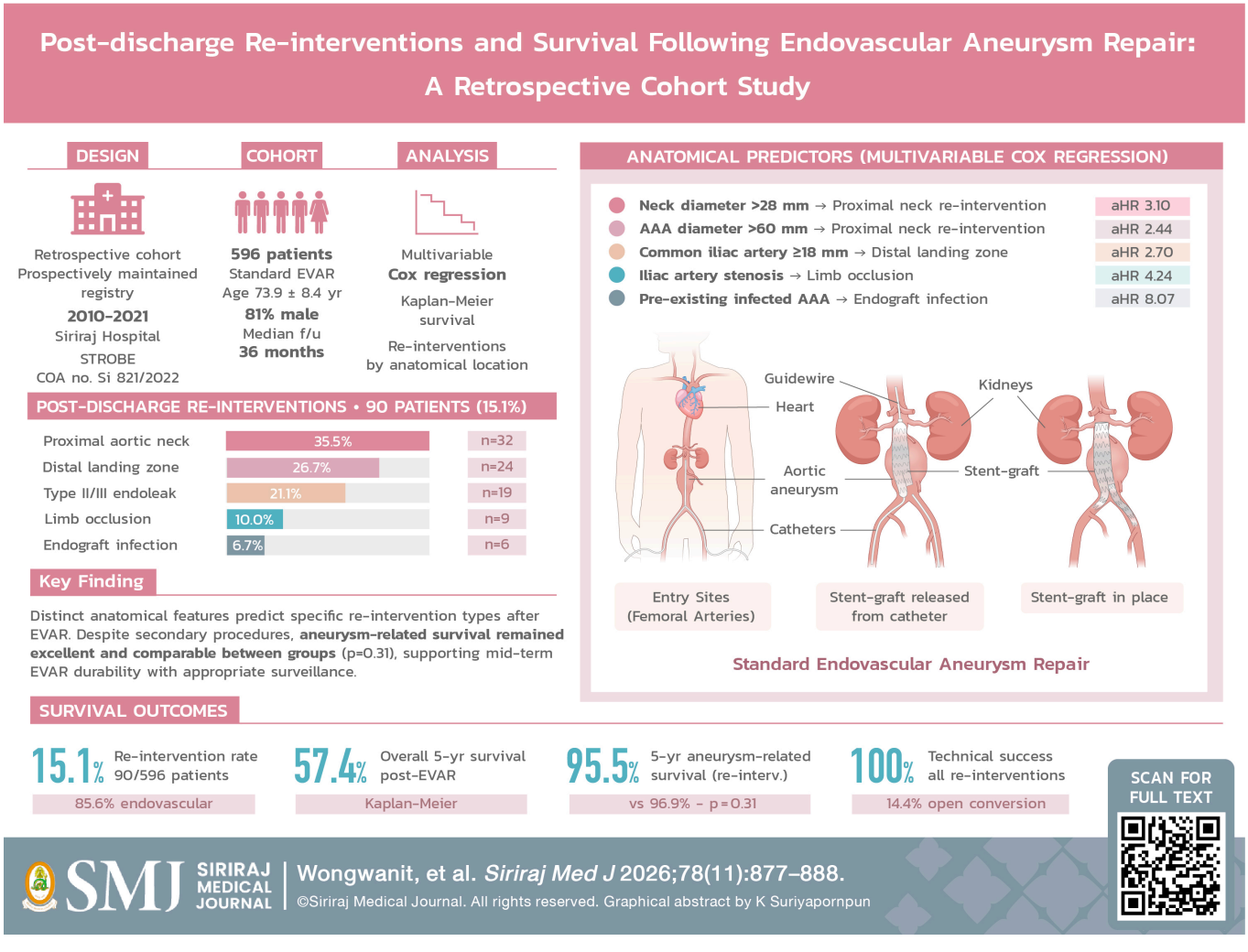
Post-discharge Re-interventions and Survival Following Endovascular Aneurysm Repair: A Retrospective Cohort Study

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ABSTRACT

Objective: To identify anatomical predictors of specific post-discharge re-intervention types following endovascular aneurysm repair (EVAR) and evaluate their association with aneurysm-related survival in an Asian cohort.

Materials and Methods: This retrospective cohort study analyzed prospectively maintained data from 596 patients who underwent EVAR at a single center between 2010 and 2021. Post-discharge re-interventions were categorized according to anatomical location. Anatomical predictors were identified using multivariable Cox proportional hazards regression. Aneurysm-related survival was evaluated using Kaplan-Meier analysis. The median follow-up duration was 36 months.

Results: Ninety patients (15.1%) underwent post-discharge re-intervention during follow-up. The most common indications were proximal aortic neck (35.5%) and distal landing zone (26.7%). Proximal complications were predicted by neck diameter >28 mm (adjusted HR 3.096, p = 0.04) and aneurysm diameter >60 mm (adjusted HR 2.439, p = 0.01). A common iliac artery diameter ≥18 mm predicted distal landing zone-related re-interventions (adjusted HR 2.703, p = 0.03). Iliac stenosis was independently associated with limb occlusion (adjusted HR 4.237, p = 0.04), whereas pre-existing infected abdominal aortic aneurysm strongly predicted endograft infection (adjusted HR 8.065, p = 0.02). Five-year aneurysm-related survival was 95.5% in the re-intervention group versus 96.9% in the non-re-intervention group (p = 0.31).

Conclusion: Specific anatomical features predict distinct re-intervention types after EVAR and may facilitate individualized risk stratification and surveillance planning. Despite the need for secondary procedures in a subset of patients, aneurysm-related survival remained excellent, supporting the mid-term durability of EVAR when combined with appropriate monitoring.

Keywords: Abdominal aortic aneurysm; anatomical predictors; endovascular aneurysm repair; post-discharge re-intervention; survival analysis (Siriraj Med J 2026;78(11):877-888)

INTRODUCTION

Endovascular aneurysm repair (EVAR) has revolutionized the treatment of abdominal aortic aneurysms (AAA) since its introduction in the 1990s[1], offering lower perioperative morbidity and mortality compared to open surgical repair.[2] However, concerns regarding the long-term durability of EVAR persist, particularly with respect to secondary interventions.[3] Secondary interventions following EVAR occur in up to 16% of patients[4] and represent the primary threat to long-term procedural durability and cost-effectiveness.[5] Despite the well-established perioperative advantages of EVAR over open repair for AAA, post-discharge re-interventions — defined as any procedure performed after initial hospital discharge[6] — remain a significant clinical burden. Data from Asian populations have demonstrated similar findings, with reported endoleak rates of approximately 5%[7], suggesting that the risk of re-intervention is not limited to Western populations. This is further supported by a recent single-center Thai series demonstrating growing institutional experience with both open and endovascular repair of abdominal aortic aneurysms, including ruptured cases, in this region.[8]

Although EVAR outcomes have been extensively investigated, significant knowledge gaps persist. Limited data are available regarding the influence of anatomical characteristics on the type and timing of re-interventions. Furthermore, the impact of these re-interventions on aneurysm-related survival has not been fully clarified.[9]

A better understanding of the anatomical determinants of specific re-intervention types could improve preoperative patient selection, guide individualized post-EVAR surveillance and potentially reduce the need for avoidable secondary procedures. Given the increasing adoption of EVAR across Asian vascular centers, establishing region-specific anatomical risk profiles is of direct clinical relevance for optimizing both clinical outcomes and healthcare resource utilization.

This retrospective cohort study aimed to characterize the incidence and patterns of post-discharge re-interventions following standard EVAR, identify key anatomical predictors of different re-intervention types, and evaluate their association with mid-term overall and aneurysm-related survival in patients undergoing EVAR at a tertiary vascular center in Thailand.

MATERIALS AND METHODS

Study design and population

This retrospective analysis utilized prospectively maintained registry data from the Division of Vascular

Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University. Patients who underwent treatment between February 2010 and September 2021 were included, with follow-up available through June 30, 2022. All procedures were performed in compliance with relevant laws and institutional guidelines. The study was approved by the Institutional Review Board on November 29, 2022 (COA no. Si 821/2022), which waived the requirement for informed consent because of the retrospective study design. The study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Among 1,190 consecutive patients treated for AAA, 596 were included in the final analysis. Exclusion criteria comprised ruptured AAA (n = 201), isolated common iliac artery aneurysms (n = 16), open surgical repairs (n = 179), complex EVAR procedures including fenestrated, branched and chimney techniques (n = 147), in-hospital mortality (n = 14), and cases with incomplete data (n = 37).

Patient assessment and technical considerations

All patients underwent preoperative evaluation with multidetector computed tomography angiography (CTA). Anatomical measurements were performed according to the Society for Vascular Surgery reporting standards using 3D imaging software (3mensio® and OsiriX MD). Standard EVAR procedures were performed using commercially available devices. Device selection was based primarily on the manufacturer's instructions for use (IFU). In cases requiring deviation from the IFU criteria, the rationale was documented based on anatomical considerations, patient-specific risk factors, and clinical judgment. Concomitant common iliac artery aneurysms (defined as CIA diameter > 20 mm) were treated using either a bell-bottom limb configuration or a coil-and-cover methodology. Cases treated with iliac branch devices were excluded to maintain cohort uniformity.

Follow-up protocol

Post-discharge surveillance consisted of CTA imaging at 1 month, 6 months, and annually thereafter. Duplex ultrasound was used as an alternative imaging modality in patients with renal insufficiency (defined as an estimated glomerular filtration rate < 30 mL/min/1.73 m^2).

Outcome definitions

Post-discharge re-interventions were defined as secondary procedures performed after discharge from the hospital and were considered distinct from perioperative complications. Re-interventions were categorized according to anatomic location and underlying pathology[6]: proximal neck-related complications, primarily type IA endoleaks; distal landing zone issues, including type IB endoleaks; limb occlusion-related interventions; procedures performed for endograft infection; and other complications encompassing type II and III endoleaks.

Statistical analysis

Continuous variables were assessed for normality using the Shapiro-Wilk test and are presented as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables are presented as frequencies and percentages. Survival analyses were performed using the Kaplan-Meier method and were truncated when the standard error exceeded 10%. Differences between groups were evaluated using the log-rank test. Predictors of re-intervention were identified using Cox proportional hazards regression analysis. Variables with $p < 0.1$ in univariable analysis were entered simultaneously into multivariable models. To minimize overfitting, the number of variables included was restricted to one variable per ten outcome events. The final adjusted models included two variables for proximal neck re-interventions (32 events), two variables for distal landing zone re-interventions (24 events), and one variable each for limb occlusion (9 events) and endograft infection (6 events). Adjusted hazard ratios (HRs) with 95% confidence intervals (CIs) were reported. All statistical analyses were performed using IBM SPSS Statistics Version 27.0. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Patient demographics and baseline characteristics

The study cohort included 596 patients who underwent EVAR, representing 50.1% of all AAA repairs performed during the study period. The mean age was 73.9 ± 8.4 years, and most patients were male (81%, n = 483). Hypertension was the most prevalent comorbidity (77.7%, n = 463), followed by dyslipidemia (34.4%, n = 205) and coronary artery disease (25.8%, n = 154). Most patients were asymptomatic at presentation (74.3%, n = 443), whereas 25.7% (n = 153) presented with symptomatic, non-ruptured AAA (Table 1).

Aneurysm morphology and operative details

Most aneurysms were fusiform in morphology (83%, n = 495), with a mean maximum AAA diameter of 57.5 ± 14.9 mm. The mean proximal neck diameter was 21.77 ± 3.85 mm, and the median neck length was

TABLE 1. Baseline demographic and clinical characteristics.

Variables	Total (*n* = 596)
Age (years), mean ± SD	73.9 ± 8.4
Sex (male), *n* (%)	483 (81%)
ASA classification	
Class 1	6 (1%)
Class 2	174 (29.2%)
Class 3	403 (67.6%)
Class 4	13 (2.2%)
Comorbidities, *n* (%)	
Coronary artery disease	154 (25.8%)
COPD	54 (9.1%)
Hypertension	463 (77.7%)
Dyslipidemia	205 (34.4%)
Renal insufficiency (Cr > 2.2 mg/dL)	69 (11.6%)
Diabetes mellitus	100 (16.8%)
Current smoker (quit < 2 weeks prior to surgery)	44 (7.4%)
Medication, *n* (%)	
Antiplatelet	334 (56%)
Statin	356 (59.7%)
Beta-blocker	189 (31.7%)
Indication for surgery	
Symptomatic (non-rupture)	153 (25.7%)
Asymptomatic	443 (74.3%)

Abbreviations: ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; Cr, creatinine; n, number; SD, standard deviation

26.75 mm (IQR 22.4-32.6 mm). The median infrarenal and suprarenal angles were 45° (range: 2°-170°) and 25.6° (range: 1°-100°), respectively. Adverse neck features included circumferential calcification involving > 50% of the neck circumference in 3.4% of patients (n = 20) and mural thrombus occupying > 50% of the neck circumference in 12.2% (n = 73). Concomitant common iliac artery aneurysms were observed in 30.5% of patients (n = 182) and were managed using either bell-bottom or coil-and-cover techniques. The most frequently implanted endografts were Endurant (51.5%, n = 307) and Zenith (27.3%, n = 163). Post-discharge re-intervention rates did not differ significantly according to device type (p = 0.40) (Table 2).

Incidence and types of post-discharge re-interventions

During a median follow-up of 36 months (IQR 14.9-63.6 months), 90 patients (15.1%) required re-interventions (Fig 1). Technical success was achieved in all cases. Endovascular management accounted for 85.6% of cases (n = 77), whereas open conversion was required in 14.4% (n = 13). The leading indications for re-interventions were proximal neck-related complications (35.5%, n = 32) and distal landing zone issues (26.7%, n = 24), followed by limb occlusion (10%, n = 9), endograft infection (6.7%, n = 6), and other complications (21.1%, n = 19) (Fig 2).

TABLE 2. Morphologic characteristics of infrarenal abdominal aortic aneurysms.

Variables	Total (*n* = 596)
Type of aneurysm	
Fusiform	495 (83%)
Saccular	100 (16.8%)
Inflammatory	1 (0.2%)
Infected AAA	33 (5.5%)
Neck diameter (mm), mean ± SD	21.77 ± 3.85
Neck length (mm), median (IQR)	26.75 (22.4-32.6)
Neck angulation	
Infrarenal angle (°), median (min, max)	45° (2°, 170°)
Suprarenal angle (°), median (min, max)	25.6° (1°, 100°)
Neck calcification > 50%, *n* (%)	20 (3.4%)
Neck thrombus > 50%, *n* (%)	73 (12.2%)
AAA diameter (mm), mean ± SD	57.5 ± 14.9
AAA length (mm), mean ± SD	116 ± 23.3
CIA diameter (mm), median (min, max)	15.3 (10, 76)
CIA length (mm), median (min, max)	38.9 (6.4, 103)
Concomitant CIA aneurysm, *n* (%)	182 (30.5%)
Iliac artery stenosis, *n* (%)	63 (10.6%)
EIA diameter (mm), median (min, max)	7.4 (4, 12.1)
EIA tortuosity, *n* (%)	171 (28.7%)
Endograft devices, *n* (%)	
Endurant	307 (51.5)
Zenith	163 (27.3)
AFX2	61 (10.2)
Treovance	29 (4.9)
Zenith LP	13 (2.2)
Nelix	12 (2.0)
Other*	11 (1.8)

Abbreviations: AAA = abdominal aortic aneurysm; CIA = common iliac artery; EIA = external iliac artery; IQR = interquartile range; max = maximum; min = minimum; mm = millimeter; n = number; SD = standard deviation

Note: *Values are presented as mean ± SD, median (IQR), median (min, max), or n (%) as appropriate. Other* includes Excluder (n = 4), Jotec (n = 4), Aorfix (n = 2), and one other device.*

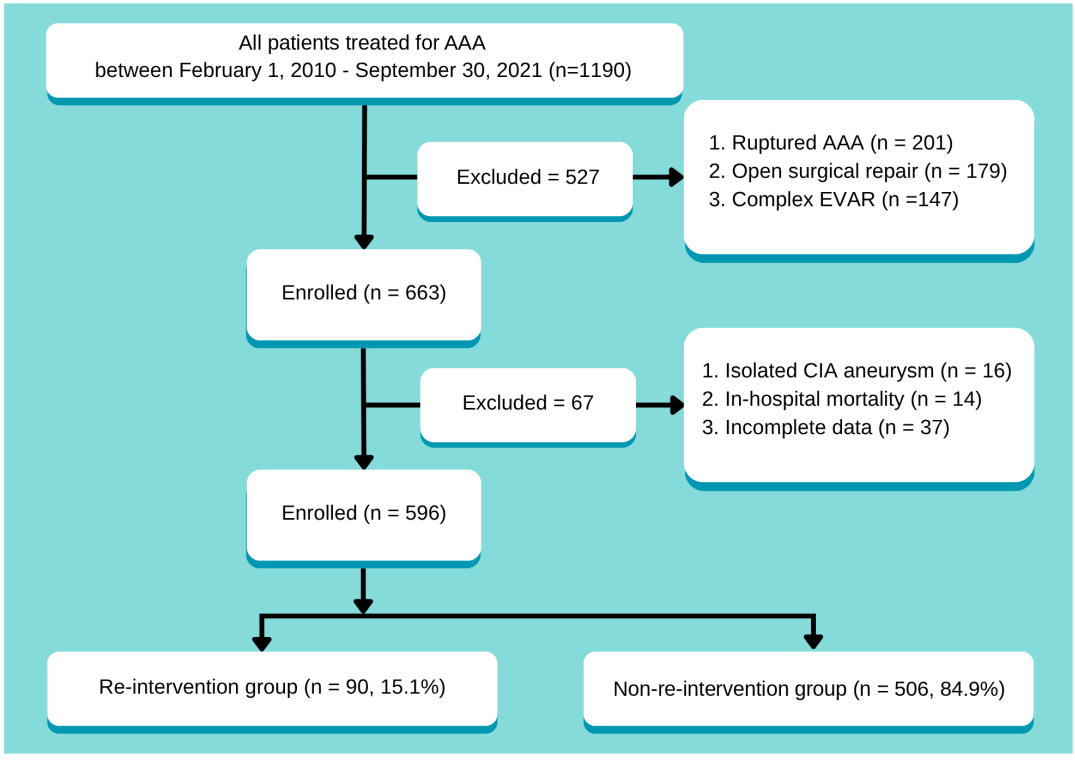


Fig 1. Flow diagram of patient selection for the EVAR outcomes study
Abbreviations: AAA, abdominal aortic aneurysm; CIA, common iliac artery; EVAR, endovascular aneurysm repair

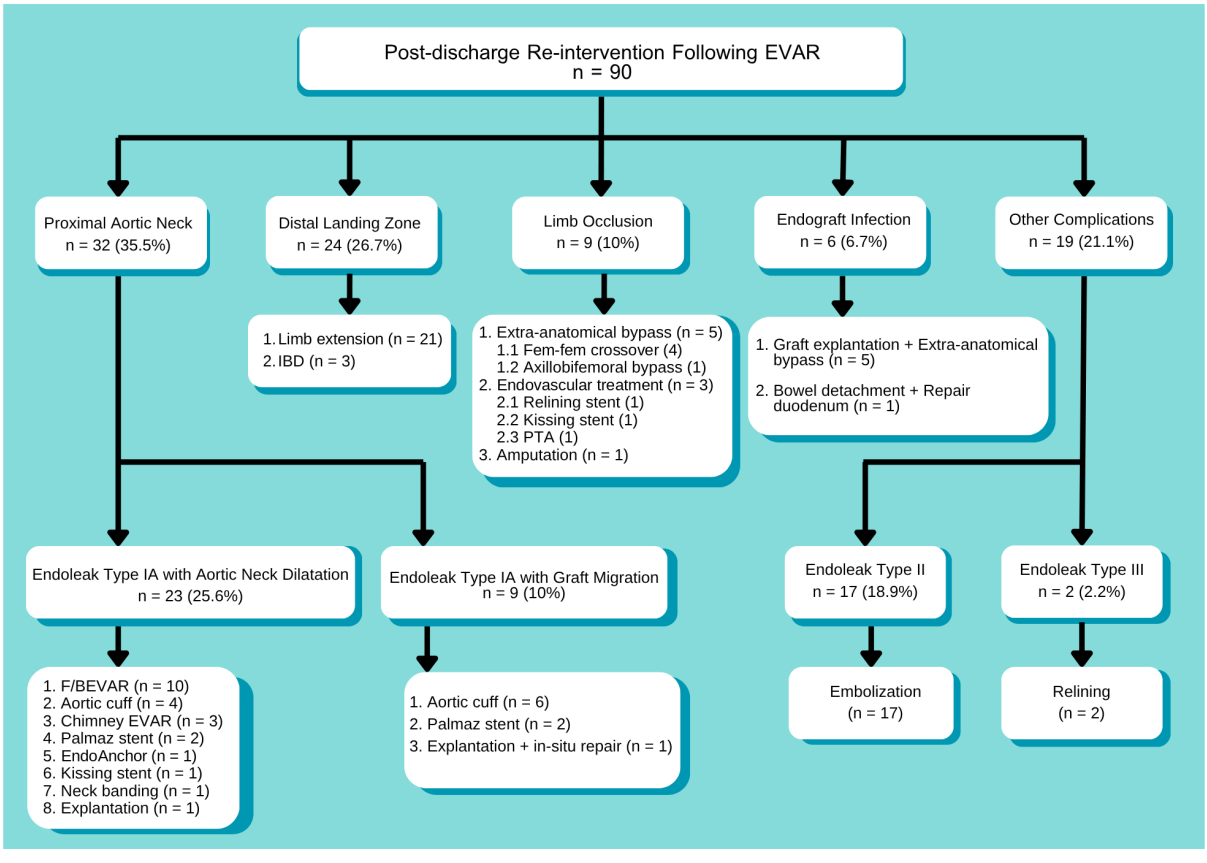


Fig 2. Distribution of post-discharge complications and re-intervention procedures after EVAR
Abbreviations: EVAR, endovascular aneurysm repair; F/BEVAR, fenestrated/branched EVAR; IBD, iliac branch device; PTA, percutaneous transluminal angioplasty

Predictive factors of re-interventions

Multivariable analysis revealed several anatomical predictors of specific re-intervention types. A proximal neck diameter > 28 mm (aHR: 3.096; 95% CI: 1.083-8.850; p = 0.04) and AAA diameter > 60 mm (aHR: 2.439; 95% CI: 1.203-4.950; p = 0.01) were independently associated with proximal neck re-interventions. A common iliac artery diameter of ≥ 18 mm (aHR: 2.703; 95% CI: 1.136-6.410; p = 0.03) was an independent predictor of distal landing zone-related re-interventions. Iliac artery stenosis independently predicted limb occlusion (aHR: 4.237; 95% CI: 1.060-16.949; p = 0.04). Pre-existing infected AAA was strongly associated with subsequent endograft infection requiring re-intervention (aHR: 8.065; 95% CI: 1.460-43.478; p = 0.02) (Table 3).

Survival analysis

Kaplan-Meier survival analysis demonstrated an overall five-year survival of 57.4% following EVAR (Fig 3). Five-year aneurysm-related survival did not differ significantly between patients who underwent re-intervention (95.5%) and those who did not (96.9%) (p = 0.31) (Fig 4).

DISCUSSION

This study demonstrates that post-discharge re-interventions following EVAR occur in approximately one in seven patients, consistent with rates reported in contemporary literature.[5] Distinct anatomical features were identified as predictors of specific re-intervention types, providing a foundation for individualized preoperative risk stratification and individualized post-EVAR surveillance strategies.

Proximal aortic neck complications were the most frequent re-intervention category, underscoring the critical importance of proximal neck anatomy for long-term EVAR durability. A neck diameter > 28 mm was independently associated with proximal neck-related re-interventions, consistent with previous research demonstrating poorer outcomes in patients with adverse neck anatomy.[10] This finding is further supported by evidence demonstrating that patients with wide infrarenal necks experience a substantially increased risk of adverse events following EVAR.[11]

Larger aneurysm diameter was also independently associated with proximal neck-related re-intervention. This relationship may be explained by greater hemodynamic

TABLE 3. Univariable and multivariable Cox regression analyses of factors associated with specific re-intervention types.

Variables	Crude HR (95%CI)	*p* value	Adjusted HR (95%CI)	*p* value
Proximal aortic neck				
Neck diameter > 28 mm	3.115 (1.091 – 8.896)	0.034	3.096 (1.083 – 8.850)	0.04
Maximum AAA diameter > 60 mm	2.531 (1.249 – 5.128)	0.01	2.439 (1.203 – 4.950)	0.01
Infrarenal neck angle > 60°	1.682 (0.822 – 3.443)	0.155		
Distal landing zone				
CIA diameter ≥ 18 mm	3.080 (1.318 – 7.197)	0.009	2.703 (1.136 – 6.410)	0.03
EIA tortuosity	2.464 (1.103 – 5.504)	0.03	2.012 (0.887 – 4.566)	0.09
Limb occlusion				
Iliac artery stenosis	4.237 (1.060 – 16.949)	0.04	4.237 (1.060 – 16.949)	0.04
Endograft infection				
Infected AAA	9.007 (1.648 – 49.227)	0.011	8.065 (1.460 – 43.478)	0.02

Abbreviations: AAA, abdominal aortic aneurysm; CI, confidence interval; CIA, common iliac artery; EIA, external iliac artery; HR, hazard ratio; mm, millimeter

Note: *p values <0.05 are considered statistically significant. Variables not shown in the adjusted column were excluded from the final multivariable model based on the one-variable-per-ten-events rule to prevent overfitting. The number of events for each outcome category was as follows: proximal aortic neck (n = 32 events), distal landing zone (n = 24 events), limb occlusion (n = 9 events), and endograft infection (n = 6 events).*

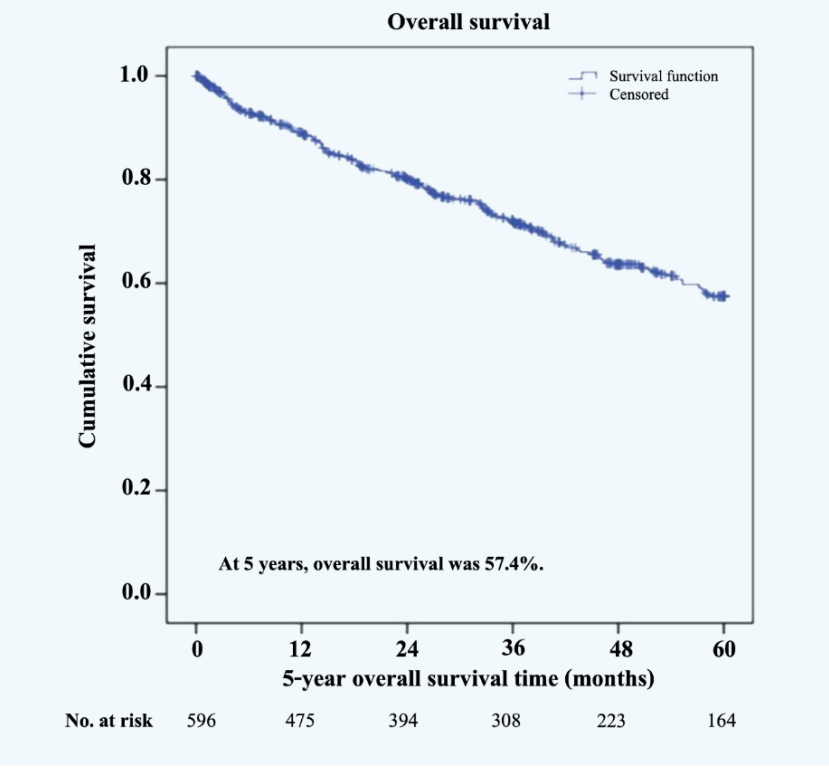


Fig 3. Kaplan-Meier curve for overall survival following EVAR. *The curve displays cumulative survival probability over a 60-month follow-up period. The number of patients at risk at each time point is shown below the x-axis. The curve was truncated when the standard error exceeded 10%.*

Abbreviation: EVAR, endovascular aneurysm repair

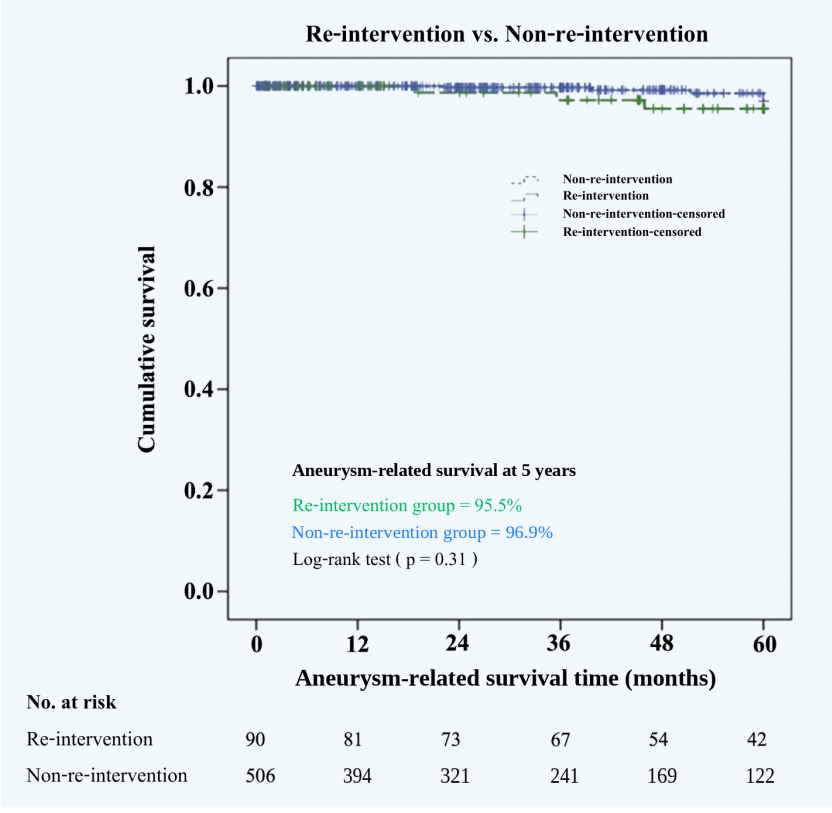


Fig 4. Kaplan-Meier curves of aneurysm-related survival according to re-intervention status following EVAR

Kaplan-Meier curves display aneurysm-related survival probability over a 60-month follow-up period for patients who underwent re-intervention (n = 90) and those who did not (n = 506). Differences between groups were assessed using the log-rank test. The number of patients at risk at each time point is shown below the x-axis. The curves were truncated when the standard error exceeded 10%.

Abbreviations: EVAR, endovascular aneurysm repair; P, probability value from log-rank test

stress and more complex flow patterns within larger aneurysms.[12] Previous studies have shown that initial aneurysm size significantly impacts both the immediate success and long-term durability of endovascular repair outcomes[13], further emphasizing the importance of preoperative aneurysm size in perioperative patient selection.

An enlarged common iliac artery diameter was identified as a key risk factor for distal landing zone-related re-interventions, underscoring the importance of achieving an adequate distal seal zone during EVAR. Contemporary studies have demonstrated that inadequate distal sealing contributes significantly to late endovascular failure.[14] Although bell-bottom and coil-and-cover techniques

provide effective treatment options for challenging iliac anatomy, careful patient selection remains essential, particularly in those with borderline iliac diameters.[15,16]

Limb occlusion represented a clinically important category of re-intervention, although its incidence in this cohort (1.5%) was lower than previously reported rates of 5.6% and 10.6%.[17,18] Recognized risk factors include severe iliac artery angulation, calcification, excessive limb oversizing, a narrow aortic bifurcation, and distal landing in the external iliac artery.[19] Notably, eight of the nine limb occlusions identified in this cohort were successfully managed without limb loss (one patient required amputation), emphasizing the value of prompt diagnosis and timely re-intervention in preserving limb viability.

A notable finding of this study was the absence of an association between severe infrarenal neck angulation and late re-intervention risk, in contrast to pooled analyses reporting a significantly increased risk among patients with hostile neck anatomy.[20] This discrepancy may reflect the proactive intraoperative management protocol employed at this institution. A substantial proportion of patients with severe neck angulation experienced intraoperative complications, predominantly type IA endoleaks, all of which were successfully managed with adjunct procedures, including additional balloon molding, proximal extension cuffs, and Palmaz stent deployment.[21] This proactive approach to intraoperative complications may explain why severe neck angulation did not emerge as a predictor of late re-intervention in this cohort, supporting the principle that anatomical challenges can be effectively mitigated through meticulous technical management and a willingness to perform adjunct procedures to achieve an optimal proximal seal.

Pre-existing infected AAA emerged as the strongest predictor of subsequent endograft infection in this study. This finding is particularly relevant in Asian populations, where infected aortic aneurysms account for approximately 13.3% of cases compared with only 0.85% in Western series, a disparity attributed largely to the higher prevalence of *Salmonella* infection in subtropical regions.[22] These findings suggest that greater caution is warranted when considering EVAR for infected AAA in Asian patients. Although the optimal management of infected AAA remains controversial, with some authors favoring open surgical repair because of concerns regarding persistent infection associated with endovascular approaches[23], the present findings support careful consideration of alternative surgical strategies in this high-risk subgroup. Given this markedly higher regional prevalence, patients with infected AAA undergoing EVAR in Asian settings should be considered for specialized, more intensive post-discharge follow-up, including closer clinical assessment and more frequent imaging surveillance for early signs of endograft infection, rather than the standard surveillance protocol applied to non-infected cases.

Survival analysis demonstrated no significant difference in five-year aneurysm-related survival between patients who underwent re-intervention and those who did not, suggesting that the requirement for secondary procedures does not necessarily compromise mid-term aneurysm-related survival when complications are appropriately managed. This represents a clinically important finding; however, the literature directly comparing aneurysm-related survival between these two groups remains limited, highlighting the need for further prospective investigation. The overall five-year survival rate observed in this cohort reflects the significant comorbidity burden associated with patients undergoing EVAR and is consistent with outcomes reported in contemporary EVAR registries.[24]

Several factors may explain the favorable aneurysm-related survival observed in this study. First, all re-interventions were technically successful, resulting in effective resolution of identified complications. Second, most re-interventions were performed using endovascular techniques, thereby minimizing additional procedural morbidity and reducing the risk of procedure-related adverse outcomes. Third, all patients with treatable complications underwent corrective intervention, suggesting that systematic surveillance and timely management protocols can preserve the long-term protective benefits of the index EVAR procedure.

No significant association was observed between device type and re-intervention rates across major endograft platforms, suggesting that anatomical factors, rather than device-specific characteristics, are the primary determinants of re-intervention risk. This finding supports the generalizability of the anatomical predictors identified in this study across contemporary endograft platforms, reinforcing their potential utility in preoperative risk stratification regardless of device selection.

The findings of this study have several important clinical implications. First, the identified anatomical predictors should be incorporated into preoperative EVAR evaluation, with patients exhibiting multiple high-risk anatomical features considered for alternative treatment strategies, including fenestrated EVAR, branched endovascular repair, or open surgical repair. Second, post-EVAR surveillance protocols should be individualized according to anatomical risk profiles, with more frequent imaging recommended for patients at increased risk of complications to enable early detection of complications.

Specifically, patients with a proximal neck diameter >28 mm or a common iliac artery diameter ≥18 mm, given their demonstrated risk of proximal neck- and distal landing zone-related re-intervention, may benefit from closer surveillance intervals, such as contrast-enhanced CTA at 6-month intervals during the first two postoperative years, rather than the standard annual protocol. Third, incorporation of these anatomical risk factors into institutional decision-making frameworks may help standardize patient selection and optimize procedural planning. Finally, the comparable aneurysm-related survival outcomes observed between groups reinforce the importance of early complication detection and timely intervention in maintaining the long-term effectiveness of EVAR.

Several limitations of this study warrant consideration. First, the single-center retrospective design may introduce selection bias and limit the generalizability of the identified anatomical predictors to other institutions and patient populations, potentially leading to an overestimation of the precision of these predictors due to operator-dependent measurement variability. Second, the relatively limited follow-up period may be insufficient to capture very late complications or re-interventions, potentially resulting in an underestimation of the true cumulative re-intervention burden over time. Third, as with all retrospective analyses, the possibility of residual confounding from unmeasured variables cannot be fully excluded. Nevertheless, this study has several strengths, including the use of a prospectively maintained registry, a large and well-characterized Asian cohort, comprehensive preoperative anatomical measurements, and a standardized surveillance protocol applied consistently throughout the study period. Future prospective multicenter studies with longer follow-up periods are needed to validate these anatomical predictors across diverse Asian populations. Further investigation is also warranted to determine whether newer endograft designs or modified surveillance protocols can mitigate the identified anatomical risk factors and further advance individualized patient management. In addition, cost-effectiveness analyses incorporating re-intervention rates and surveillance burden may provide valuable guidance for healthcare resource allocation.

CONCLUSIONS

Post-discharge re-interventions following EVAR are relatively common and most frequently involve proximal aortic neck and distal landing zone complications, with distinct anatomical features predicting specific re-intervention types. Patients with enlarged aortic necks, larger AAA diameters, and enlarged common iliac arteries are at increased risk of re-intervention and may benefit from consideration of alternative treatment strategies, including fenestrated or branched endovascular repair, or open surgical repair. Despite the need for secondary procedures, aneurysm-related survival remains excellent when rigorous surveillance and timely re-intervention are employed. Notably, all re-interventions in this cohort were technically successful, and only one patient with limb occlusion required amputation, supporting an "EVAR-first" approach in which endovascular re-intervention is favored as the initial strategy for managing post-EVAR complications when prompt diagnosis and meticulous technique are ensured. These findings underscore the importance of anatomical risk factor-based patient selection and individualized post-EVAR surveillance protocols to optimize long-term outcomes.

Data Availability Statement

The data supporting the findings of this study are not publicly available due to privacy and ethical restrictions under Thailand's Personal Data Protection Act (PDPA). Data may be made available by the corresponding author (Khamin Chinsakchai) upon reasonable request and approval from the Siriraj Institutional Review Board.

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DECLARATIONS

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Conflict of Interest

The authors report no competing interests related to this work.

Registration Number of Clinical Trial

Not applicable. This study was a retrospective review

of existing medical records and was not registered as a clinical trial.

Author Contributions

Conceptualization and methodology: K.C., V.C., C.W.; Investigation: K.C., V.C., C.W.; Formal analysis: S.T., V.C.; Visualization and writing – original draft: V.C.; Writing – review and editing: K.C., V.C., C.W., K.H., N.S., S.H., N.P., T.P., K.P., C.R.; Supervision: K.C. All authors have read and agreed to the published version of the manuscript.

Use of Artificial Intelligence

Artificial intelligence language tools (Claude Opus 5.5; Anthropic, San Francisco, CA, USA) were used exclusively to improve the grammatical accuracy, textual clarity, and stylistic presentation of this manuscript. All aspects of the research process, including data collection, statistical analysis, interpretation of findings, and preparation of figures and tables, were performed solely by the authors without AI assistance. All content was thoroughly reviewed and edited by the authors, who bear full responsibility for the scientific integrity of this work.

Institutional Review Board Statement

This study was approved by the Institutional Review Board (Siriraj Institutional Review Board), Faculty of Medicine Siriraj Hospital, Mahidol University (COA no. Si 821/2022, approved November 29, 2022). The requirement for informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

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