Hostile neck anatomy (HNA) and its variation as a prognostic factor of endovascular aneurysm repair (EVAR) complication in abdominal aortic aneurysm (AAA)

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Abstract

Background: To determine the factors affecting early type 1A endoleak (T1aEL) in AAA patients receiving conventional EVAR. Methods: This was a prognostic factor study using the PROGRESS II framework. A retrospective cohort design included consecutive cases of AAA. Potential risk factors for T1aEL after EVAR were collected. Results: 19.1% (25/131) of AAA patients receiving conventional EVAR experienced T1aEL. Patients with T1aEL had larger aortic neck diameters, shorter neck lengths, longer operative times, more blood loss, and higher 1-year mortality. Multivariable risk ratio regression revealed that the prognostic factors for early T1aEL were a neck length < 10 mm (mRR 2.68, 95% CI 1.05 – 6.88, p-value = 0.039) and infrarenal angulation > 60 degrees (mRR 1.98, 95% CI 1.08 – 3.63, p-value = 0.027). Conclusion: Patients treated with conventional EVAR who developed T1aEL had a statistically significant increase in 1-year mortality compared to those without T1aEL. The factors contributing to T1aEL include neck length and neck angulation.

Keywords

endovascular aneurysm repair; aortic aneurysm, abdominal; endoleak; perigraft leak

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Repair of abdominal aortic aneurysm (AAA) can be performed using traditional open surgery or the endovascular technique. The endovascular aneurysm repair (EVAR), due to better short-term outcomes and lower perioperative mortality, has emerged as a preferred approach[1]. Nonetheless, However, EVAR carries inherent risks, with endoleaks being a significant predictor of adverse outcomes following endovascular treatment of infrarenal AAAs.

One such complication, type 1a endoleak (T1aEL), occurs at the proximal neck of the aneurysm post-EVAR and necessitates vigilant prevention strategies, frequent monitoring, and potentially additional interventions to enhance long-term prognosis and decrease mortality [2].

Risk factors for T1aEL include unfavorable or hostile aortic neck anatomy (HNA), which is characterized by any attribute of the aneurysmal neck that renders it unsuitable for conventional EVAR. While fenestrated and chimney techniques have been explored to diminish the incidence of T1aEL in specific infrarenal AAA populations, their high costs and the level of technical skills required limit their widespread adoption, thereby continuing to pose challenges in endovascular repair [3]. Despite being considered off-label, conventional EVAR remains a viable option for HNA patients deemed at high risk for open repair, as supported by some studies [4]. This study aims to elucidate if neck anatomy, favorable or hostile, impacts outcomes, including the occurrence of T1aEL, in patients with infrarenal AAA undergoing conventional EVAR.

MATERIALS AND METHODS

Study Population

All patients with infrarenal AAA who were adequately detected by preoperative computed tomography (CT) scan and underwent conventional EVAR between January 2016 and December 2020 in the vascular unit were included and retrospectively analyzed. Only patients with adequate preoperative CT aortography (CTA), which extended from the neck to the groin, had a slide thickness ≤ 1mm, and had appropriate contrast enhancement, were included in the study. The clinical data of the patients with AAA were analyzed for demographic characteristics, comorbidities, clinical and laboratory characteristics, operative details on aortic morphology, and endpoints. The follow-up period was 1 year. The patients were informed and consented to participate, and the local ethics committee approved the study protocol. The data were collected by the vascular surgery fellowship team.

Hostile Neck Anatomy (HNA)

The aortic neck was defined as the area between most caudal renal arteries to the beginning of the aneurysm. The criteria for a HNA are defined as any of the following features: a short neck (neck length <10mm), a neck bulge (a focal enlargement of the aneurysmal neck defined as neck diameter > 28mm), an angulated neck >60 degrees, a significant neck thrombus > 50%, and neck calcification > 50% [5].

Surgical techniques

Conventional EVAR is defined as a minimally invasive procedure that manages AAA by endoluminally placing a stent (endograft or stent-graft) below the most caudal renal artery through the common femoral artery (CFA) using fluoroscopic guidance [6]. Anatomical data were collected preoperatively and postoperatively using CTA analysis software. All measurements were made by a vascular training surgeon, including a neck diameter at 0, 5, 10, and 15 mm perpendicular to central lumen line from the lower renal arteries, neck length from the lowest renal arteries to the proximal aneurysmal wall, suprarenal angulation between the neck and longitudinal axis of AAA, infrarenal angulation between the neck and longitudinal axis of AAA, as well as the percentage of circumferential neck calcification and thrombus.

All EVARs were performed at a hybrid operating theater, with both CFA being used for endovascular access. In all cases, the conventional treatment protocol included ultrasound-guided percutaneous techniques for endovascular access, intraoperative aortography and neck measurement, internal placement of an endograft at the suitable position, and completion aortography to detect any type of endoleaks.

Endpoints

The primary endpoint was early T1aEL, which was determined by contrast extravasation between the prosthesis and proximal aneurysmal wall, either observed on a CT scan or detected intraoperative aortography, within 30 days postoperatively. Secondary endpoints included 1-year mortality, ventilator days, length of hospital stay (LOS), intensive care unit (ICU) stay, and postoperative complications.

Statistical analysis

Categorical data were described using frequency and percentage and were tested using Fisher's exact probability test. Normally distributed continuous data were described using mean and standard deviation and were tested using independent t-test. Non-normally distributed continuous data were described using the median and interquartile range. Statistical uncertainties were expressed as 95% two-sided confidence intervals in all analyses. A p-value of < 0.05 was considered statistically significant. No multivariable adjustment was used in the analyses. All statistical analyses were performed with STATA version 16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC).

Risk ratios (RR) and multivariable risk ratios (mRR) were calculated to assess if any factors in the neck anatomy were strong predictors for T1aEL. The potential risk factors included in the mRR regression analysis were female [7], age ≥ 75 years [8], neck length < 10 mm, suprarenal angulation > 60 degrees, infrarenal angulation > 60 degrees, neck diameter of > 28 mm, ≥50% circumferential proximal neck thrombus, and ≥50% circumferential proximal neck calcification, operative time ≥ 180 minutes, and estimated blood loss > 150 ml using median value for each factor.

RESULTS

The data were collected from January 2016 to December 2020 at the vascular unit. A total of 133 patients underwent conventional endovascular repair from infrarenal AAA. Two patients were excluded from the study due to an unknown T1aEL status. The patients were categorized into two groups: early T1aEL (n=25, 19.1%) and no T1aEL (n=106, 80.9%). The mean age of the patients was 72.6 years, with 75.6% of them were male. The average body mass index (BMI) was 21.6 kg/m^2. The underlying diseases, smoking history, cardiac function, clinical characteristics, and laboratory findings were not statistically different between the two groups, as shown in Table 1.

This study's most commonly used commercial endograft in this study was Endurant (Medtronic, 72.3%) followed by Zenith (CookMedical, 19.2%). The choice of endograft was not influenced by HNA, p-value 0.955. Regarding the operative characteristics, HNA was found in 29% of the patients with infrarenal AAA who underwent conventional EVAR, while early T1aEL occurred in 19.1% of these patients. The prognostic factors for early T1aEL included a statistically significant wider neck diameter, shorter neck length, greater angulation, less estimated blood loss, and longer operative time. The corresponding p-values for these factors can be found at table 2.

No statistically significant postoperative complications were observed, and the secondary endpoints (ventilator days, ICU stay, and length of hospital stay) are also shown in Table 3. The overall 1-year survival rate for patients who underwent conventional EVAR was 73.3%. Interestingly, the patients without early T1aEL had a significantly higher survival rate compared to those with early T1aEL (77.4% and 56.0% respectively; p-value 0.043). The univariable analysis (Table 4) revealed several prognostic factors associated with early T1aEL.

These factors included being female (RR 2.43, 95%CI 1.23 – 4.82, p-value = 0.011), age≥75 years (RR 2.14, 95%CI 1.04 – 4.41, p-value = 0.039), neck length < 10 mm (RR 4.36, 95%CI 2.35 – 8.07, p-value < 0.001), suprarenal angulation > 60 degree (RR 2.58, 95%CI 1.13 – 5.93, p-value = 0.025), infrarenal angulation > 60 degree (RR 2.97, 95%CI 1.50 – 5.90, p-value =

0.002), neck diameter > 28 mm (RR 2.83, 95%CI 1.44 – 5.54, p-value = 0.002), operative time 180 minutes or greater (RR 2.46, 95%CI 1.17 – 5.16, p-value = 0.018), and estimated blood loss > 150 ml (RR 2.94, 95%CI 1.07 – 8.08, p-value = 0.037). The multivariable analysis using risk ratio regression indicated that the significant prognostic factors of early T1aEL were neck length < 10 mm (mRR 2.68, 95%CI 1.05 – 6.88, p-value = 0.039), and infrarenal angulation > 60 degrees (mRR 1.98, 95%CI 1.08 – 3.63, p-value = 0.027).

DISCUSSION

The challenge with infrarenal AAA treatment is to find a management approach the minimize complications. The less invasive endovascular repair, which involves placing and endograft via the CFA to internally exclude the AAA, has become an attractive option for patients with suitable anatomy. This is in contrast to conventional open surgical repair, which requires laparotomy and aortic cross-clamping [9, 10]. Although perioperative and two-year mortality rates are lower with EVAR [11], its long-term effectiveness remains a matter of debate [12]. Long-term outcomes of EVAR are still not as favorable as open repair regarding all-cause mortality, the need for reinterventions, and the rates of secondary rupture. Continuous surveillance is also necessary in patients who have undergone EVAR [13].

One major concern following EVAR is endoleak, which is characterized by persistent blood flow within the residual aneurysmal sac despite the placement of an endograft [14]. Some types of endoleaks can be managed conservatively or monitored expectantly. T1aEL, which involves leakage at the proximal aortic neck after EVAR, is a complication that often requires further intervention. Post-repair, the diameter of the proximal neck has been observed to increase [15], casting doubt on the definitiveness of EVAR as solution for AAA treatment. Conservative treatment and coil embolization were preserved for selected patients [16].

Anatomical risk factors for T1aEL include an HNA. Patients with AAA presenting HNA are typically advised against undergoing conventional EVAR [17]. There have been attempts to reduce T1aEL in AAA patients with HNA using chimney [18] and fenestrated graft techniques [19]. However, the effectiveness of these outcomes remains questionable [20]. The technical challenges associated with these techniques have limited their widespread adoption, and the issue of managing the proximal neck persists when determining if conventional EVAR is a viable option for infrarenal AAA patients with HNA [21]. This study aimed to identify the anatomical risk factors of T1aEL in our institute, where the majority of the patients are Asian.

Multivariable risk ratio regression analysis revealed that a short neck length and a wide infrarenal angulation were the factors that significantly affected the incidence of T1aEL, which is consistent with findings from other studies [22]. In contrast, a wide neck diameter, neck thrombus, and calcification did not contribute to T1aEL. In our practice, we commonly employed the main body oversizing technique, employing 20-30% oversizing in patients with a broad aortic neck, believing it would enhance seal at the proximal zone and prevent device migration [23]. While some studies supported our approach [24], most discourage the use of large endografts [25].

The impact of oversizing endografts in patients with a broad neck anatomy warrants further investigation to determine if it improves or worsens outcomes. Neck thrombus or calcification, which were not commonly observed in our patients, showed consistency with another study from our region [26]. We also discovered that factors such as age, gender, operative time, and estimated blood loss might impact our primary outcome, according to univariable risk ratio regression analysis. These should be further investigated in a study with a larger sample size. The principles of degenerative change may explain why older individuals, particularly those aged 75 or older, were at higher risk for T1aEL [27].

The outcomes related to gender were not consistent with previous studies, which suggested differences in aortic wall dispensability between females and males [28]. This discrepancy could be due to the effect of sample size. Prolonged operative times and increased blood loss could lead to more complications and morbidity [29], and it was observed that 1-year survival rate was significantly shorter in patients with T1aEL, although these results were not specified in this study due to its nature. In the future, it may be necessary to better define the acceptable rates of T1aEL by balancing the risks and benefits of complex EVAR or open surgical repair. It will support the choice of conventional EVAR as the preferred treatment for AAA with HNA. These aspects warrant further investigation. This study has several limitations. First, it was a retrospective analysis, which is subjected to recall bias and may contain missing data. Second, due to the small sample size, we were unable to employ imputation methods to address the missing data adequately. Lastly, future studies should focus on the benefits of conventional EVAR comparison to complex techniques, such as chimney or fenestrated EVAR. Such research could help to define the true indications for complex EVAR, which are time-consuming and costly procedures.

CONCLUSION

The current analysis showed that patients treated with conventional EVAR who developed T1aEL had statistically significant shorter 1-year survival rate compared to those without T1aEL. Factors contributing to the occurrence of T1aEL include neck length and neck angulation. These findings are in agreement with previous studies, though further explanation is required to understand these associations fully.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

Ethic approval

Local ethic committee: HE631670.

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Table 1: baseline characteristics

Baseline characteristics	Missing data, n (%)	Total, n=131 (100)	T1aEL, n=25 (19.1%)	No T1aEL, n=106 (80.9%)	p-value
Sex					
Male	0 (0)	99 (75.6)	14 (56.0)	85 (80.2)	0.018
Female		32 (24.4)	11 (44.0)	21 (19.8)	
Age (year)	0 (0)	72.69 ±8.94	75.76 ±9.87	71.96 ±8.60	0.056
Weight (kg)	0 (0)	56.15 ±11.30	54.04 ±12.59	56.65 ±10.99	0.300
Height (cm)	0 (0)	161.04 ±8.37	158.48 ±8.94	161.64 ±8.16	0.090
BMI (kg/m^2)	0 (0)	21.57 ±3.58	21.35 ±3.73	21.62 ±3.56	0.735
Hypertension	0 (0)				
No		37 (28.2)	5 (20.0)	32 (30.2)	0.459
Yes		94 (71.8)	20 (80.0)	74 (69.8)	
Diabetes mellitus	0 (0)				
No		114 (87.0)	21 (84.0)	93 (87.7)	0.740
Yes		17 (13.0)	4 (16.0)	13 (12.3)	
Chronic obstructive pulmonary disease	0 (0)				
No		115 (87.8)	23 (92.0)	92 (86.8)	0.736
Yes		16 (12.2)	2 (8.0)	14 (13.2)	
Ischemic heart disease	0 (0)				
No		121 (92.4)	23 (92.0)	98 (92.5)	1.000
Yes		10 (7.6)	2 (8.0)	8 (7.5)	
Renal failure	0 (0)				
No		117 (89.3)	21 (84.0)	96 (90.6)	0.469
Yes		14 (10.7)	4 (16.0)	10 (9.4)	

Arrhythmia No	0 (0)	124 (94.7)	23 (92.0)	101 (95.3)	0.618
Yes		7 (5.3)	2 (8.0)	5 (4.7)	
Dyslipidemia	0 (0)				
No		95 (72.5)	16 (64.0)	79 (74.5)	0.323
Yes		36 (27.5)	9 (36.0)	27 (25.5)	
Peripheral arterial disease	0 (0)				
No		127 (96.9)	24 (96.0)	103 (97.2)	0.576
Yes		4 (3.1)	1 (4.0)	3 (2.8)	
Valvular heart disease	0 (0)				
No		130 (99.2)	24 (96.0)	106 (100.0)	0.191
Yes		1 (0.8)	1 (4.0)	0 (0.0)	
Clinical presentation Incidental finding	0 (0)	32 (24.4)	7 (28.0)	25 (23.6)	0.321
Rupture Condition		13 (9.9)	3 (12.0)	10 (9.4)	
Abdominal pain		67 (51.1)	10 (40.0)	57 (53.8)	
Back pain		0 (0.0)	0 (0.0)	0 (0.0)	
Acute limb ischemia		5 (3.8)	2 (8.0)	3 (2.8)	
Blue toe syndrome		1 (0.8)	0 (0.0)	1 (0.9)	
GI Bleeding		1 (0.8)	1 (4.0)	0 (0.0)	
Pulsatile mass		12 (9.2)	2 (8.0)	10 (9.4)	
LVEF	84 (63.16)	65.10 ±9.43	70.10 ±9.13	63.82 ±9.18	0.059
METS	0 (0)				
> 4		103 (78.6)	21 (84.0)	82 (77.4)	0.593
< 4		28 (21.4)	4 (16.0)	24 (22.6)	
ASA classification	0 (0)				
0		1 (0.8)	0 (0.0)	1 (0.9)	0.586
1		0 (0.0)	0 (0.0)	0 (0.0)	
2		35 (26.7)	6 (24.0)	29 (27.4)	
3		72 (55.0)	13 (52.0)	59 (55.7)	
4		19 (14.5)	6 (24.0)	13 (12.3)	
5		4 (3.1)	0 (0.0)	4 (3.8)	
Smoking status	0 (0)				
Never		91 (69.5)	18 (72.0)	73 (68.9)	0.637
Current		28 (21.4)	4 (16.0)	24 (22.6)	
Ex-smoker		12 (9.2)	3 (12.0)	9 (8.5)	
Morphology of aneurysm	0 (0)				
Fusiform		111 (84.7)	24 (96.0)	87 (82.1)	0.121
Saccular		20 (15.3)	1 (4.0)	19 (17.9)	
Unstable hemodynamic status No	0 (0)	123 (93.9)	24 (96.0)	99 (93.4)	1.000
Yes		8 (6.1)	1 (4.0)	7 (6.6)	
Cardiac arrest	125 (93.98)				
No		7 (87.5)	1 (100.0)	6 (85.7)	1.000
Yes		1 (12.5)	0 (0.0)	1 (14.3)	
Hemoglobin (g/dL) (Mean±SD)	0 (0)	11.25 ±2.10	11.68 ±2.09	11.15 ±2.10	0.260
Hematocrit (%), (Mean±SD)	0 (0)	34.35 ±6.49	35.41 ±6.65	34.10 ±6.46	0.366
White blood cell count (cell/mm^3), (Mean±SD)	0 (0)	9123.51 ±4924.67	8987.60 ±4832.47	9155.57 ±4968.25	0.879
Neutrophil (%), Median [Q_1, Q_3]	0 (0)	67 [57, 77]	67 [55, 75]	68 [58, 77]	0.680
Platelet count (10^9/L), Median [Q_1, Q_3]	0 (0)	212 [162, 282]	187 [158, 241]	214 [167, 286]	0.229
BUN (mg/dL), Median [Q_1, Q_3]	0 (0)	14 [11, 21]	16 [12, 25]	14 [11, 20]	0.192
eGFR (mg/dL), (Mean±SD)	13 (9.77)	60.82 ±27.27	53.94 ±25.42	62.49 ±27.56	0.179
Plasma glucose (mg/dL) , (Mean±SD)	109 (81.95)	105.83 ±36.62	92.50 ±19.30	110.28 ±40.26	0.314
Glycated hemoglobin (%), (Mean±SD)	82 (61.65)	5.70 ±0.73	6.07 ±1.14	5.64 ±0.63	0.150
Serum triglyceride (mg/dL), (Mean±SD)	87 (65.41)	118.67 ±51.15	131.18 ±65.03	114.74 ±46.40	0.358
Serum total cholesterol (mg/dL), (Mean±SD)	17 (12.78)	164.34 ±47.28	167.95 ±44.11	163.48 ±48.20	0.692
Serum LDL (mg/dL), Median [Q_1, Q_3]	87 (65.41)	110 [85, 142]	98 [86, 114]	120 [85, 147]	0.193
Serum albumin (mg/dL), Median [Q_1, Q_3]	5 (3.76)	4 [3, 4]	4 [3, 4]	4 [3, 4]	0.537
ESR (mm/hr), Median [Q_1, Q_3]	54 (40.60)	37 [17, 74]	25 [10, 60]	37 [18, 74]	0.331
CRP (mg/dL), Median [Q_1, Q_3]	60 (45.11)	12 [2, 58]	12 [4, 28]	11 [2, 58]	0.949

T1aEL = type 1a endoleak; SD = standard deviation; kg = kilograms; cm = centimeters; METs = metabolic equivalents; ASA = American society of anesthesiologists; GI = gastrointestinal; WBC = white blood cell count; BUN = blood urea nitrogen; eGFR = estimated glomerular filtration rate; HbA1C = hemoglobin A1C; LDL = low-density lipoprotein; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein, T1aEL = type 1a endoleak; mm = millimeters; IQR = interquartile range; mL = milliliters.

Table 2: operative characteristics

Operative characteristics	Missing data, n (%)	Total, n=131	T1aEL, n=25 (19.1%)	No T1aEL, n=106 (80.9%)	p-value
widest aortic neck diameter, mm (mean±SD)	0 (0)	24.50±4.51	26.79±4.61	23.96±4.33	0.004
neck length (mm), median [Q_1, Q_3]	2 (1.50)	24 [15.20, 32.00]	17.30 [11.20, 25.00]	25.05 [16.15, 35.00]	0.006
neck calcification , % circumferential, median [Q_1, Q_3]	0 (0)	0 [0, 0]	0 [0, 0]	0 [0, 0]	0.993
neck thrombus, % circumferential, median [Q_1, Q_3]	0 (0)	0 [0, 0]	0 [0, 0]	0 [0, 0]	0.149
angulation, degree					
Suprarenal, median [Q_1, Q_3]	0 (0)	24 [14, 37]	38 [14, 53]	23.5 [13, 33]	0.006
Infrarenal, median [Q_1, Q_3]	0 (0)	47 [25, 64]	62 [35, 92]	45 [24, 60]	0.009
estimated blood loss (mL), median [Q_1, Q_3]	0 (0)	250 [100, 400]	400 [250, 700]	200 [100, 400]	0.001
operative time (minutes), (mean±SD)	0 (0)	165.27±75.45	211.60±84.19	154.34±69.26	0.001

T1aEL = type 1a endoleak; SD = standard deviation; mm = millimeters; mL = milliliters

Table 3: Postoperative outcomes and complications

Postoperative outcomes and complications	Missing data, n (%)	Total, n = 131 (100%)	T1aEL, n=25 (19.1%)	No T1aEL, n=106 (80.9%)	p-value
Urinary tract infection, n (%)	0 (0)	10 (7.63)	3 (12.00)	7 (6.60)	0.402
Pneumonia, n (%)	0 (0)	9 (6.87)	2 (8.00)	7 (6.60)	0.681
Ventilator > 48 h, n (%)	0 (0)	17 (12.98)	5 (20.00)	12 (11.32)	0.318
Spinal cord ischemia, n (%)	1 (0.75)	0 (0.00)	0 (0.00)	0 (0.00)	1.000
Postoperative myocardial infarction, n (%)	0 (0)	0 (0.00)	0 (0.00)	0 (0.00)	1.000
Postoperative arrhythmia, n (%)	0 (0)	8 (6.11)	2 (8.00)	6 (5.66)	0.648
Postoperative limb ischemia, n (%)	0 (0)	4 (3.05)	1 (4.00)	3 (2.83)	0.576
Postoperative intraabdominal bleeding, n (%)	0 (0)	0 (0.00)	0 (0.00)	0 (0.00)	1.000
Bowel ischemia, n (%)	0 (0)	6 (4.58)	0 (0.00)	6 (5.66)	0.595
Stroke, n (%)	0 (0)	2 (1.53)	0 (0.00)	2 (1.89)	1.000
Deep venous thrombosis, n (%)	0 (0)	2 (1.53)	0 (0.00)	2 (1.89)	1.000
ventilator (days), median [Q_1, Q_3]	0 (0)	0 [0,1]	1 [0, 2]	0 [0, 1]	0.088
ICU stay (days), median [Q_1, Q_3]	0 (0)	2 [1, 3]	2 [1, 4]	2 [1, 3]	0.302
length of hospital stay (days), median [Q_1, Q_3]	0 (0)	9 [7, 14]	11 [7, 15]	9 [7, 14]	0.305
1-month survival, n (%)	0 (0)	121 (92.37)	23 (92.00)	98 (92.45)	1.000
1-year survival, n (%)	0 (0)	96 (73.28)	14 (56.00)	82 (77.36)	0.043

T1aEL = type 1a endoleak; SD = standard deviation; ICU = intensive care unit

Table 4: Univariable and multivariable analysis

Potential risk factors	T1aEL, n=25 (19.1%)	No T1aEL, n=106 (80.9%)	RR	upper 95%CI	lower 95%CI	p-value	mRR	upper 95%CI	lower 95%CI	p-value
female	11 (44.00)	21 (19.81)	2.43	1.226	4.819	0.011	1.62	0.804	3.258	0.177
Age≥75 years	15 (60.00)	39 (36.79)	2.14	1.038	4.409	0.039	1.42	0.641	3.160	0.385
Neck length of < 10 mm	5 (20.00)	2 (1.92)	4.36	2.346	8.091	0.000	2.69	1.053	6.879	0.039
suprarenal angulation > 60 degree	4 (16.00)	5 (4.72)	2.58	1.125	5.926	0.025	1.74	0.728	4.162	0.213
infrarenal angulation > 60 degree	13 (52.00)	22 (20.75)	2.97	1.498	5.896	0.002	1.98	1.080	3.632	0.027
diameter of >28 mm	10 (40.00)	15 (14.50)	2.83	1.441	5.544	0.003	1.60	0.735	3.463	0.237
≥50% circumferential proximal neck thrombus	2 (8.00)	13 (12.26)	0.67	0.175	2.584	0.563	0.52	0.175	1.519	0.230
Operative time ≥ 180 minutes	16 (64.00)	39 (36.79)	2.46	1.170	5.160	0.018	2.04	0.853	4.866	0.109
Estimated blood loss > 150 ml	21 (84.00)	63 (59.43)	2.94	1.068	8.079	0.037	1.70	0.639	4.496	0.289

T1aEL = type 1a endoleak; RR = risk ratio; mRR = multivariable risk ratio; CI = confidence interval; mm = millimeters; ml = milliliters