Original Article

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Midterm results of endovascular aortic repair in patients with hostile neck

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ABSTRACT

Objectives: This study aims to investigate the feasibility of endovascular aortic aneurysm repair (EVAR) in patients with a hostile aortic neck anatomy.

Patients and methods: Between July 2010 and September 2019, a total of 54 patients (18 males, 36 females; mean age 77.0±6.2 years; range 63 to 89 years) with a hostile neck anatomy (proximal aortic neck angulation >60°; proximal aortic diameter >28 mm; proximal aortic length <15 mm; conical aortic neck) were retrospectively analyzed. Stent graft was inserted via infrarenal fixation in 24 patients, while it was inserted via suprarenal fixation in 30 patients. Chimney technique was used in three patients with a conical aortic neck.

Results: The mean aneurysm diameter was 73.1±6.8 mm, while the mean proximal aortic neck angulation was 86.2±13.8°. The mean proximal aortic length was 13.0±3.6 mm, while the mean aortic neck diameter was 28.5±2.3 mm. Technical success rate was 100% for stent graft insertion. The mean operation duration was significantly longer in female patients than males ($p<0.05$). Type 1 endoleak was developed in 13 patients, while a second intervention was required in two patients. No mortality or graft migration was observed.

Conclusion: Together with the advances in graft technologies, novel techniques, and increased experience of surgeons, EVAR has become a safe technique which can be employed in patients with a hostile aortic neck anatomy.

Keywords: Aneurysm, endovascular, hostile neck.

Since its first introduction in 1991, endovascular aortic aneurysm repair (EVAR) technique, which is used in the treatment of abdominal aortic aneurysms (AAAs), has become commonly preferred treatment modality owing to its lower perioperative and postoperative risks.[1] However, proximal aortic anatomy is the major factor limiting treatment in this technique, since EVAR success depends on sufficient proximal fixation of endograft to aortic wall to prevent type 1 endoleak and stent migration.[1] Accordingly, most stent manufacturers indicate anatomical criteria for EVAR use in their manufacturer's manual.

In 2003, Dillavou[2] first introduced the term hostile neck to define aortic neck characteristics not meeting aforementioned criteria in the manufacturer's manual. Today, proximal aortic neck angulation >60°, proximal aortic diameter >28 mm, proximal aortic length <15 mm, thrombi or calcification >50% at proximal aortic neck, and the presence of conical aortic neck are still accepted as hostile neck. Based on these criteria, 40 to 60% of patients with AAA are considered ineligible for standard EVAR due to anatomical limitation involving the proximal neck.[3,4] Although open repair seems to be still valid in these patients, surgical treatment of aneurysms, particularly in those with short and conical neck, is associated with increased mortality.[5] Although hostile neck morphology is linked to higher type 1A endoleak, repeated intervention, and aneurysm-related mortality rates, there are several studies demonstrating that EVAR is feasible in unfavorable proximal neck anatomy and that is as successful as standard endograft in morphologies other than defined in the manufacturer's instructions.[6,7]

The EVAR has been started to accept as suitable in patients with shorter, more angulated, and wider

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aneurysm neck by technological advances, use of Chimney and Snorkel techniques that can be applied to patients with short and conical aorta, and increased experience of surgeons regarding EVAR.[8]

In this study, we present our midterm results for EVAR therapy in patients with a neck diameter of >28 mm, a neck angulation of >60°, a neck length of <15 mm, and a conical neck.

PATIENTS AND METHODS

Between July 2010 and September 2019, we retrospectively reviewed a total of 54 patients (18 males, 36 females; mean age 77.0±6.2 years; range, 63 to 89 years) with an abdominal aneurysm and who were at high-risk for open surgery meeting at least one of the diagnostic criteria of a hostile neck (Table 1). Patients were selected among 440 patients who underwent EVAR and those who met the criteria for hostile neck. All radiological imaging studies and pre-, peri-, and postoperative data were recorded for all patients. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Twenty-two of 54 patients (40.74%) were asymptomatic and aneurysms were detected incidentally during imaging studies for other reasons. A total of 32 patients (59.25%) were symptomatic as common symptom being abdominal pain radiating to back. In all patients, there was at least one comorbid disease or risk factor accompanying to the aortic pathology (Table 2). All patients underwent computed tomography angiography (CTA) to plan the stent graft to be used and method to be applied. All interventions were performed at the angiography unit under spinal anesthesia in an elective manner.

A Gore Excluder® (Gore Excluder®, W.L. Gore, Inc., Flagstaff, AZ, USA) with infrarenal fixation was used in 24 patients, while Endurant® (Medtronic Vascular, Santa Rosa, CA, USA) with suprarenal fixation was used in 30 patients (Figure 1a, b). Three patients underwent the Chimney technique due to conical neck, and a Viabahn® stent (W.Z. Gore, Inc., Flagstaff, AZ, USA) was used in renal arteries. Intraoperative balloon dilatation or aortic extension was used in patients with postoperative type 1 endoleak. The follow-up visits were scheduled at 1, 3, 6, and 12 months and annually thereafter in patients with type 1 endoleak. The patients without endoleak as assessed by CTA were followed at 1 and 12 months and annually thereafter.

Table 1. Hostile neck criteria

Hostile neck criteria
Proximal aortic neck diameter >28 mm
Proximal aortic neck angulation >60 degrees
>50% calcification or thrombi at proximal aorta
Aortic neck length <15 mm
Conical aortic neck

Statistical analysis

Statistical analysis was performed using the PASW for Windows version 17.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max), or number and frequency. The Kolmogorov-Smirnov test was used to assess normal distribution in quantitative data. For quantitative variables, independent sample t-test was used to assess data with normal distribution, while the Mann-Whitney U test was used to assess skewed data. The Fisher's exact test and chi-square tests were used to assess nominal and ordinal data. Pearson correlation analysis was used to examine the relationship among variables. A p value of <0.05 was considered statistically significant at 95% confidence interval (CI).

RESULTS

The mean aneurysm diameter was 73.1±6.8 mm in 54 patients included in the study and had at least one criterion for hostile neck. It was 72.8±7.3 mm in female patients and 73.6±6.0 mm in male patients. Stent graft implantation was successful in all patients. Table 3 presents clinical variables. A significant difference was observed in duration of intervention between two genders ($p<0.05$). The Chimney technique was used in three patients with conical and wide neck, while a renal artery stent was inserted to bilateral renal arteries

Table 2. Risk factors

Risk factor	n	%
Hypertension	52	96.29
Chronic obstructive pulmonary disease	18	33.3
Cardiovascular disorders	14	25.9
Previous laparotomy	14	25.9
Smoking	27	50
Diabetes mellitus	17	31.4
Carotid artery disease	4	7.4
Malignancy	6	11.1
Peripheral artery disease	8	14.8

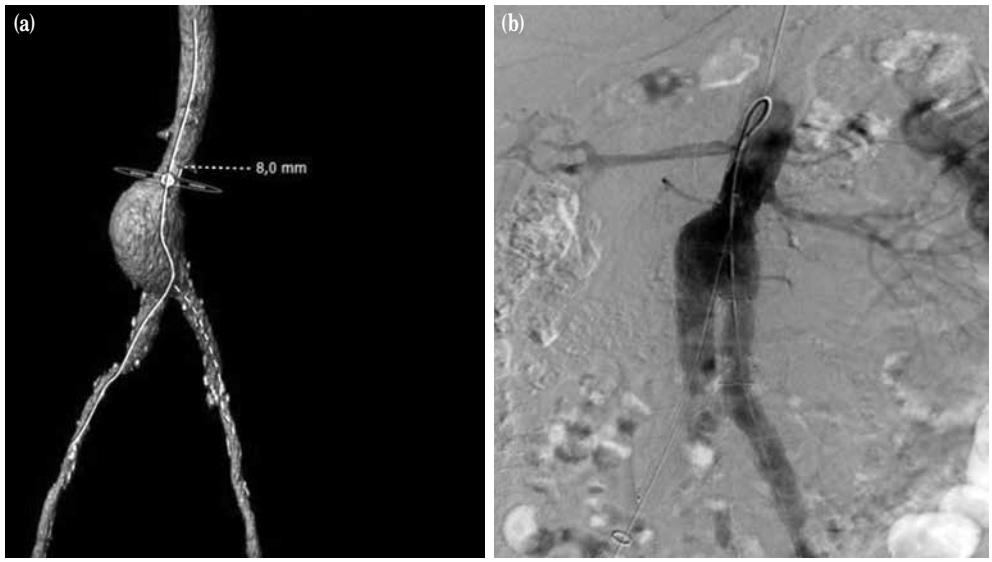

Figure 1. **(a)** A preoperative computed tomography angiography image of a patient with a neck length of <15 mm. **(b)** A postoperative computed tomography angiography image.

in one patient and to unilateral renal artery in two patients (Figure 2a-c).

Type 1 endoleak was observed in 13 patients on control imaging study following stent graft implantation. Of these, seven underwent stent implantation with infrarenal fixation, while six with suprarenal fixation. The endoleak was controlled by balloon dilatation in eight and aortic extension graft in three of 13 patients. In two patients, balloon dilatation failed to control endoleak, and these patients were followed without a further intervention, as endoleak was considered mild. A second intervention was performed at three months in these patients due to the persistent endoleak, and aortic extension graft was inserted which successfully controlled endoleak.

Based on the variables in patients with endoleak, it was observed that these patients had a higher neck angulation angle, shorter neck length, and wider aortic diameter (Table 4). According to the difference analysis, there were significant differences in the neck angulation, neck length, aneurysm diameter, length of stay, amount of contrast material used, and duration

Table 3. Demographic and clinical variables according to gender and difference analysis

	Female (n=36)			Male (n=18)			Total (n=54)			
Parameter	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			77.1±6.3			76.8±6.3			77.0±6.2	0.854*
Aortic neck diameter (mm)			28.4±2.4			28.6±2.2			28.5±2.3	0.772*
Neck angulation (degree)			86.3±14.9			85.8±11.6			86.2±13.8	0.907*
Neck length (mm)			12.8±3.9			13.4±3.0			13.0±3.6	0.609*
Length of stay (day)			2.9±0.8			2.9±0.7			2.9±0.8	0.976†
Amount of contrast material (mL)			127.9±13.0			123.1±7.1			126.3±11.5	0.184†
Follow-up time (month)			29.9±17.7			35.6±23.2			31.8±19.6	0.318*
Right iliac diameter (mm)			24.8±5.3			23.9±4.3			24.5±4.9	0.563*
Left iliac diameter (mm)			23.4±5.2			24.3±5.8			23.7±5.3	0.568*
Aneurysm diameter (mm)			72.8±7.3			73.6±6.0			73.1±6.8	0.686*
Operation duration (min)			**84.8±19.4**			73.3±17.7			81.0±19.5	**0.040***
Endoleak type 1 (n)	8	22.2		5	27.8		13	24.1		0.448‡

SD: Standard deviation; * Independent Sample t-test; † Mann Whitney-U test; ‡ Fisher's Exact test; p<0.05.

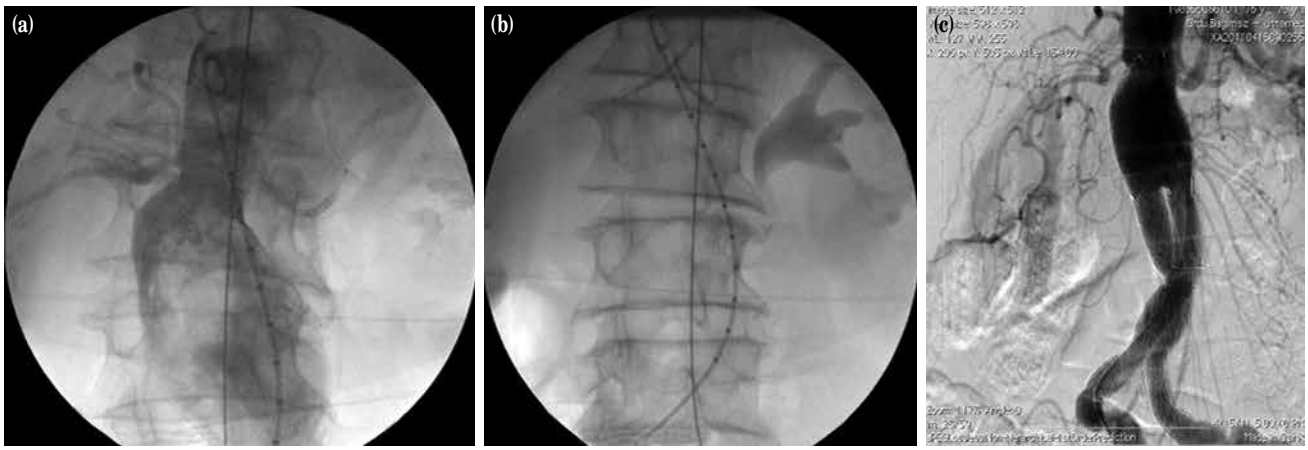

Figure 2. (a) A preoperative computed tomography angiography image of a patient with short-conical neck undergoing Chimney procedure. **(b)** Renal artery cannulation. **(c)** A postoperative computed tomography angiography image at six months of follow-up.

of intervention between the patients with and without endoleak (p<0.05).

Furthermore, the amount of contrast material had significant, positive correlations with duration of intervention (r=0.405; p<0.01), neck angulation (r=0.507; p<0.01), neck length (r=0.423; p<0.01) and aneurysm diameter (r=0.453; p<0.01). In addition, the operation duration had significant positive correlations with the neck angulation (r=0.743; p<0.01), aortic neck diameter (r=0.300; p<0.01) and aneurysm diameter (r=0.438; p<0.01) (Table 5). The amount of contrast material used and operation duration were higher in patients with endoleak (Figure 3). Also, endoleak incidence was increased by increasing neck angulation and aortic neck diameter (Figures 4 and 5).

Table 4. Demographic and clinical variables according to endoleak type and difference analysis

	No-endoleak (n=41)	Endoleak tip 1 (n=13)	
Parameters	Mean±SD	Mean±SD	*p*
Age (year)	76.3±5.7	**79.3±7.4**	0.124*
Aortic neck diameter (mm)	28.2±2.3	**29.5±1.9**	0.056*
Neck angulation (degree)	81.4±10.7	**101.0±11.9**	0.000*
Neck length (mm)	12.4±3.3	**14.9±3.9**	0.029*
Length of stay (day)	2.7±0.7	**3.6±0.7**	0.000†
Amount of contrast material (mL)	123.3±8.0	**135.8±15.8**	0.002†
Follow-up time (month)	29.0±16.4	**40.6±26.3**	0.154*
Right iliac diameter (mm)	24.1±4.9	**25.9±4.8**	0.235*
Left iliac diameter (mm)	24.1±5.6	22.5±4.2	0.347*
Aneurysm diameter (mm)	71.5±5.9	**78.1±7.3**	0.002*
Operation duration (min)	75.4±17.49	**98.5±14.7**	0.000*

SD: Standard deviation; * Independent Sample t-test; † Mann Whitney-U test; p<0.05.

No mortality or graft migration was observed within the first 30 days and the mean follow-up was 31.8±19.6 (range, 10 to 84) months. During follow-up, a second intervention was required in only two patients. No significant difference in the rate of endoleak development was observed between the patients who underwent infrarenal and suprarenal fixation (Figure 6).

DISCUSSION

Although EVAR has been emerged as a safe and effective treatment for abdominal aortic aneurysms in patients with eligible anatomy, it is still controversial in the treatment of patients with ineligible anatomy defined as hostile neck. Patients at high risk for open surgery often have a complex aortic anatomy which is inappropriate for conventional EVAR.[9] In the literature, it has been reported that 55 to 73.3% of patients with a hostile neck anatomy are ineligible for open repair or general anesthesia.[10,11] Thus, EVAR has been increasingly used as an alternative to open surgery in patients with hostile proximal neck anatomy. Schanzer et al.[12] reported that majority of clinicians performed EVAR in settings which were not encompassed by stent graft instructions.

Although there is no consensus regarding the safety of EVAR in patients with a hostile neck anatomy, the number of studies on this issue has been increasing in the literature. In a study by Stather et al.[13] using hostile neck criteria as in our study, it was found that there was two-fold increase in the risk for

Table 5. The relations between amount of contrast material, operation duration, neck angulation, neck length, aortic neck diameter and aneurysm

	Amount of contrast material	Operation duration	Neck angulation	Neck length	Aortic neck diameter
Operation duration	0.405**				
Neck angulation	0.507**	0.743**			
Neck length	0.423**	0.353**	0.454**		
Aortic neck diameter	0.179	0.300*	0.400**	0.178	
Aneurysm diameter	0.453**	0.438**	0.509**	0.360**	0.246

* Significant correlation at level of p<0.05; ** Significant correlation at level of p<0.01.

type 1 endoleak. Although some studies have linked EVAR therapy with a higher rate of repeated type 1A endoleak intervention in hostile neck morphology, advances in graft technology and advanced techniques employed by surgeons have rapidly decreased the complication rates.[14,15] In a meta-analysis on EVAR outcomes in patients with a normal and hostile neck anatomy, Antoniou et al.[15] showed comparable results regarding the technique success, 30-days mortality, and secondary intervention rates at year one.

In another study including patients with a hostile neck anatomy by Broos et al.,[16] type 1 endoleak was observed in only 13 patients and two patients underwent a second intervention. In addition, the authors reported longer duration of intervention and higher amount of contrast material used. In our series, type 1 endoleak was observed in 13 patients and a second intervention was required in only two patients at three months. In addition, the endoleak rate, duration of intervention, and amount of contrast material increased by increasing severity of the hostile neck criteria (increasing neck angulation and diameter, shortening neck length). In the hostile neck anatomy, suprarenal fixation serves as a good alternative for treatment in complex proximal neck anatomy and improves graft stability by increasing the fixation

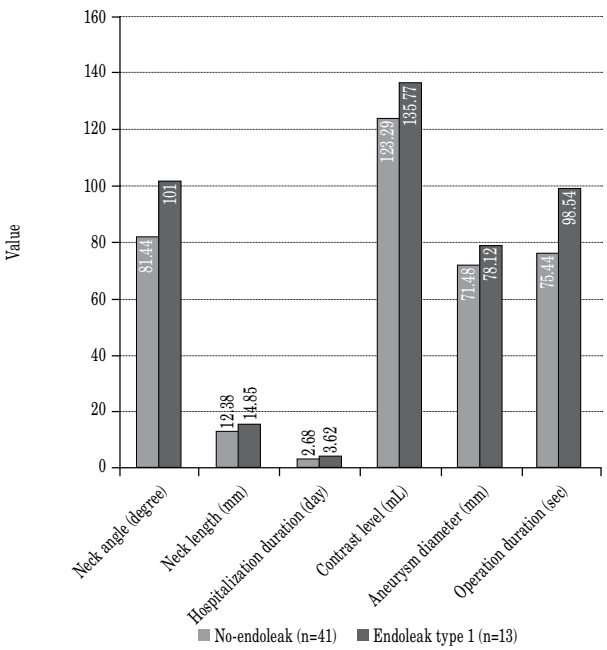

Figure 3. Relationship between parameters in patients with endoleak.

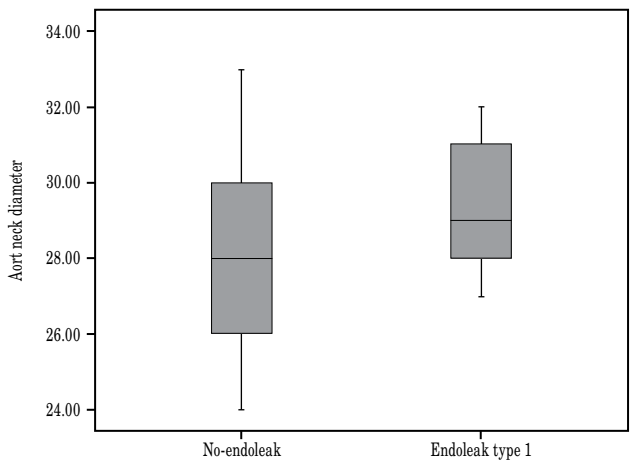

Figure 4. Relationship between aortic neck diameter and endoleak.

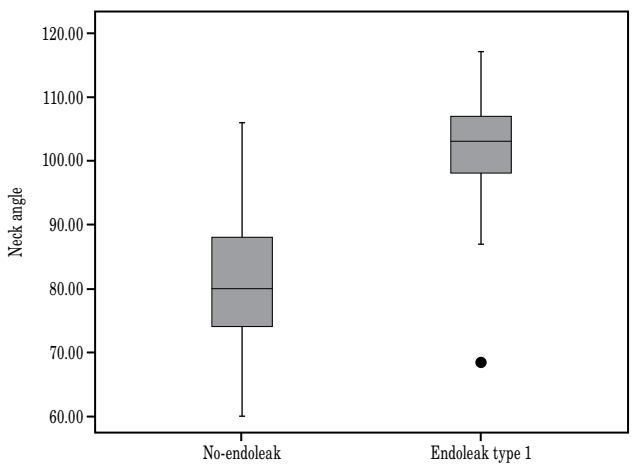

Figure 5. Relationship between aortic neck diameter and endoleak.

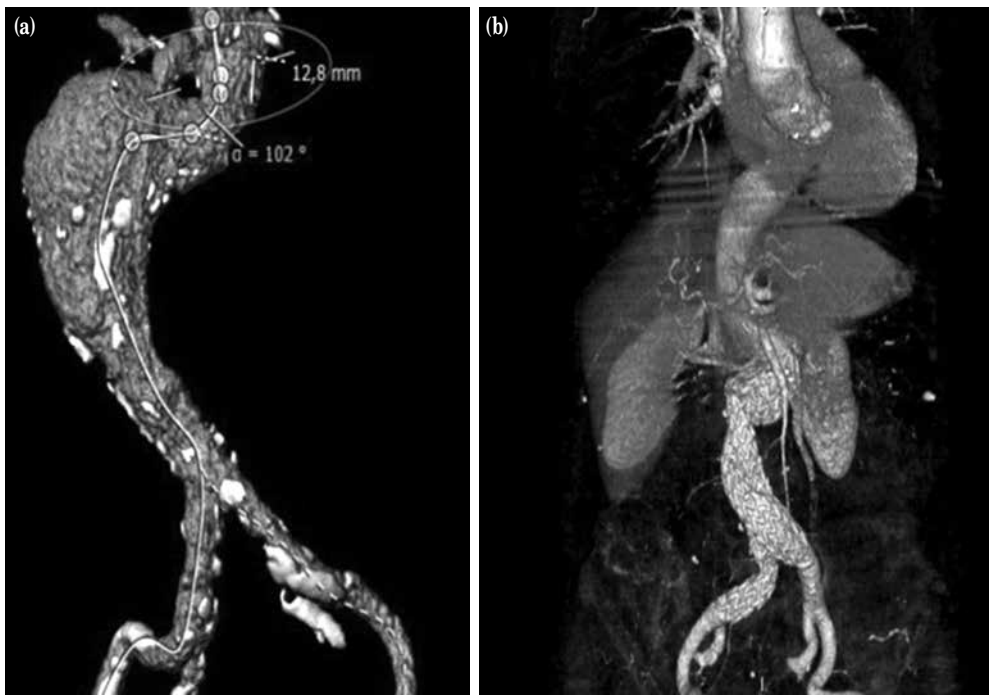

Figure 6. **(a)** A preoperative CTA image of a patient with a neck angulation of >60 degrees and neck length of <15 mm. **(b)** A postoperative CTA image at five years of follow-up.
CTA: Computed tomography angiography.

length. In a study, it was reported that suprarenal fixation reduced proximal type endoleak.[17] In a study on short neck, no significant difference was observed in 30-day and one-year type 1 endoleak incidence between the patients who underwent EVAR with suprarenal or infrarenal fixation.[18] In our study, no significant difference was observed in the endoleak incidence between the patients undergoing infrarenal and suprarenal fixation.

The desire of surgeons to treat patients with hostile neck by EVAR has driven stent graft manufacturers to design new-generation grafts and surgeons to use different techniques over the years. The alternative methods for treatment of challenging neck anatomy include fenestrated EVAR (FEVAR) and Chimney techniques. Although some authors advocate that treatment can be achieved by fenestrated stent grafts in patient with a short neck, the complication rate was reported to be higher in patients underwent FEVAR in a study comparing FEVAR and infrarenal fixation.[19] In a meta-analysis published on Chimney technique which we also used in three of our patients with a conical neck, the authors concluded that the technique could be employed as an adjunctive technique in high-risk patients.[20] Of note, the Chimney technique is used to allow EVAR treatment in patients with a severely short and conical aortic neck by experienced clinicians.

The majority of stent grafts are not recommended in patients with a neck angulation of >60°. In two studies using the Endurant® stent graft system in patients with severe neck angulation (mean: 80.8°), outcome was found to be satisfactory as in patients with a normal aortic neck.[11,21] Again, in a study using Gore® stent graft system in a similar patient population, no mortality or type 1 endoleak was reported.[22]

The neck angulation was 86.15° in our study, consistent with the literature. Some intraoperative maneuvers can be helpful to fix the stent graft effectively and to prevent endoleak in patients with a hostile neck anatomy. These include dilatation to the proximal aorta by high-pressure balloon, insertion of aortic extension graft and insertion of main trunk of stent by slow and controlled opening. In particular, the pressure exerted on proximal part of graft by balloon dilatation aids better fixation of graft on aortic wall and prevents majority of type 1 endoleak. In a recent study, it was shown that the patients with a short neck had worse prognosis, followed by those with a conical neck and angulated neck; however, EVAR was found to be safe and feasible in these patients.[23]

The main limitations are relatively small sample size and short follow-up.

In conclusion, although hostile neck anatomy is a barrier for EVAR therapy, the feasibility of the technique in such patients has been shown with aging population and increased number of comorbid factors and high-risk patients. In our series, we show that EVAR can be performed with low endoleak and mortality rates, despite an increased amount of contrast materials and prolonged duration of intervention in aneurysm patients with a hostile neck anatomy. We believe that the term hostile neck would be abandoned with the advances in graft technology and increased experience of surgeons in the future.

Declaration of conflicting interests

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