ORIGINAL ARTICLE

Aortoiliac Morphology in a Thai Cohort: Implications for Endovascular Aneurysm Repair

Supong Worathanmanon, MD[1], Wittawat Tantarattanapong, MD[1], Boonprasit Kritpracha, MD[1], Pong Jantarapatin, MD[1], Dhanakom Premprapha, MD[1], Sorracha Rookkapan, MD[2]

[1] Department of Surgery, Faculty of Medicine, Prince of Songkla University, Songkhla, Thailand; [2] Department of Radiology, Faculty of Medicine, Prince of Songkla University, Songkhla, Thailand

Objective: To comprehensively characterize the aortoiliac segment in Thai patients with abdominal aortic aneurysms (AAAs) and to assess the suitability of employing endovascular aneurysm repair (EVAR) across different stent-graft devices.

Materials and Methods: Electronic medical records of AAA patients eligible for treatment between January 2014 and August 2020, drawn from the Songklanakarin Hospital database, were systematically analyzed. Preoperative assessments of whole aorta CT angiograms were conducted using 'Endosize' software, scrutinizing various anatomical parameters. The suitability of eight FDA-approved stent devices for EVAR was determined based on stringent criteria.

Results: Distinct variations in aortoiliac morphology were identified in the Thai population, deviating from characteristics observed in Western populations. Notably, these variances included smaller dimensions overall, juxtaposed with a marginally larger maximum aneurysm diameter. Key measurements encompassed suprarenal and infrarenal angles of 28 and 45.6 degrees, neck diameter and length of 21.1 and 25.3 mm, maximum aneurysm diameter of 62.8 mm, and aortic bifurcation at 29.7 mm. Common iliac artery dimensions featured diameters of 12.7 and 13 mm, coupled with lengths of 52.8 and 54.4 mm. Femoral artery diameters were recorded at 7.1 and 7.2 mm. Stent-graft compatibility exhibited variability, ranging from 24.9% to 67%, with Ovation® demonstrating the highest compatibility and AFX® the lowest. Common iliac length demonstrated greater compatibility, in contrast to diminished compatibility associated with larger neck and common iliac diameter requirements.

Conclusion: The present investigation uncovered distinctive morphological features within the aortoiliac segment of the Thai population, thereby contributing to the observed variations in EVAR compatibility across different stent-graft manufacturers. The results underscore the pivotal role of ethnicity as a crucial determinant in vessel morphology, with implications that hold particular relevance for the ongoing design and development of stent-grafts. The unique insights derived from the present study enhance understanding of population-specific anatomical considerations, thereby enriching the field of vascular surgery.

Keywords: Abdominal aortic aneurysm; Aortic anatomy; Endovascular aneurysm repair; Aortoiliac morphology

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Endovascular aneurysm repair (EVAR), first introduced by Parodi et al. in 1991, represents a contemporary and preferred intervention for abdominal aortic aneurysms (AAA) due to its reported low incidence of morbidity and mortality, particularly rendering it advantageous for frail AAA patients[(1)]. The anatomical intricacies of the aorta play a pivotal role in determining the suitability of a patient for EVAR, making not all cases amenable to this procedure[(2)]. Studies conducted in Western populations, which served as the basis for the design of currently available devices, reported a high EVAR suitability of up to 78%, while a study by Park et al. in Korea reported a notably lower rate of 46.6%[(3,4)]. The diminished suitability observed in Asian populations, attributed to their smaller aortic size, underscores the need for more comprehensive data on the specific aortic characteristics of this demographic[(5-8)].

Given the significant impact of ethnicity on aortic anatomies and EVAR suitability, inventors globally are actively developing diverse stent-graft designs to address the challenging anatomical features observed in different populations. Consequently, a nuanced understanding of specific aortic anatomies becomes imperative in overcoming these limitations[(9)].

The primary objective of the present study was to meticulously characterize the aortoiliac segment

Correspondence to:

Worathanmanon S.

Department of Surgery, Faculty of Medicine, Prince of Songkla University, Songkhla 90110, Thailand.

Phone: +66-85-0811449

Email: st_master1@hotmail.com

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within the Thai population, shedding light on specific aneurysm features. Additionally, the study aimed to elucidate EVAR suitability concerning various stent devices. The authors anticipated that these insights would not only contribute information but will also play a pivotal role in enhancing the design of stent-graft systems to better cater to the unique anatomical considerations within this demographic.

Materials and Methods

The present study was a descriptive study leveraged data derived from the Songklanakarin Hospital database, focusing on electronic medical records of patients diagnosed with fusiform infrarenal and juxtarenal AAA meeting treatment indications, which is size greater than 5 cm, aneurysm growth greater than 1 cm per year, or symptomatic, between January 2014 and August 2020. Exclusion criteria encompassed patients without retrievable computed tomography (CT) scans from the hospital Picture Archiving and Communication System (PACS). Demographic details, including age, gender, body mass index (BMI), comorbidities, cardiovascular disorders, tobacco use, American Society of Anesthesiologists (ASA) class, and aneurysm status, were meticulously documented.

Preoperative assessments involved the reconstruction and analysis of whole aorta CT angiograms utilizing "Endosize" software version 3.1.40 for a comprehensive evaluation of aortic anatomy. Variables scrutinized encompassed aneurysm shape, aortic neck diameter, neck length, infra-renal neck angle, supra-renal neck angle, maximum aneurysm diameter, aortic bifurcation diameter, common iliac artery diameter, common iliac artery length, and common femoral artery diameter. To ensure accuracy, these measurements were conducted by two proficient vascular surgeons.

The criteria for evaluating the suitability of EVAR adhered to the instructions for use (IFU) of eight Food and Drug Administration (FDA)-approved stent devices, including Endurant II®, Zenith®, AFX®, Ovation®, Aorfix™, JOTEC® E-tegra, Gore® Excluder®, and TREO®. Subjective criteria prone to interpretation, such as wall calcification, luminal thrombus, and iliac artery tortuosity, were deliberately excluded from consideration during the determination of EVAR suitability.

Anatomic parameter variables were statistically presented as mean values with standard deviations. Visualization of the distribution of each parameter was achieved through graphical representation.

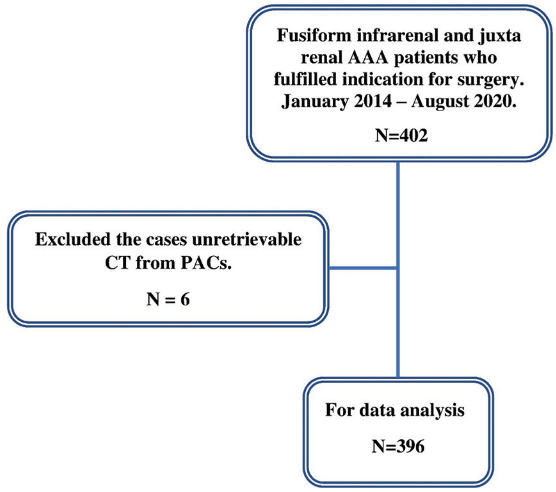

Figure 1. The study flow chart and exclusion cases in the study.

Finally, the percentile representation of EVAR suitability for each stent device was elucidated. These meticulous examinations were executed utilizing Rstudio, Version 1.1.456. This retrospective, descriptive study poses no safety risks to participants and was conducted in accordance with ethical guidelines. The study protocol (REC 58-140-10-1) received approval from the Human Research Ethics Committee (HREC) of the Faculty of Medicine, Prince of Songkla University (AF/17-03/01.1).

Results

The present study's procedural flow and instances of exclusion are succinctly encapsulated within Figure 1. A noteworthy aspect of the demographic profile of AAA patients subjected to the present study was the pronounced male predilection, constituting an overwhelming 83.3% of the cohort. The average age of the participants was 75 years, with a mean BMI of 22.2 kg/m². Impressively, 91.9% of patients presented with non-ruptured AAA during their initial hospital visit. Sixty-nine-point-nine percent had a history of smoking, while only 16.9% were identified as current smokers. The triad of prevailing underlying diseases comprised hypertension, dyslipidemia, and chronic kidney disease, sequentially. The ASA classification 3 emerged as the predominant classification type within this cohort, as detailed in Table 1.

In Figure 2, the AAA shape was depicted, mirroring the average anatomic parameters observed in the patients. Noteworthy measurements included suprarenal and infrarenal angles of 28 and 45.6 degrees, neck diameter and length of 21.1 and 25.3 mm, maximum aneurysm diameter of 62.8 mm, and

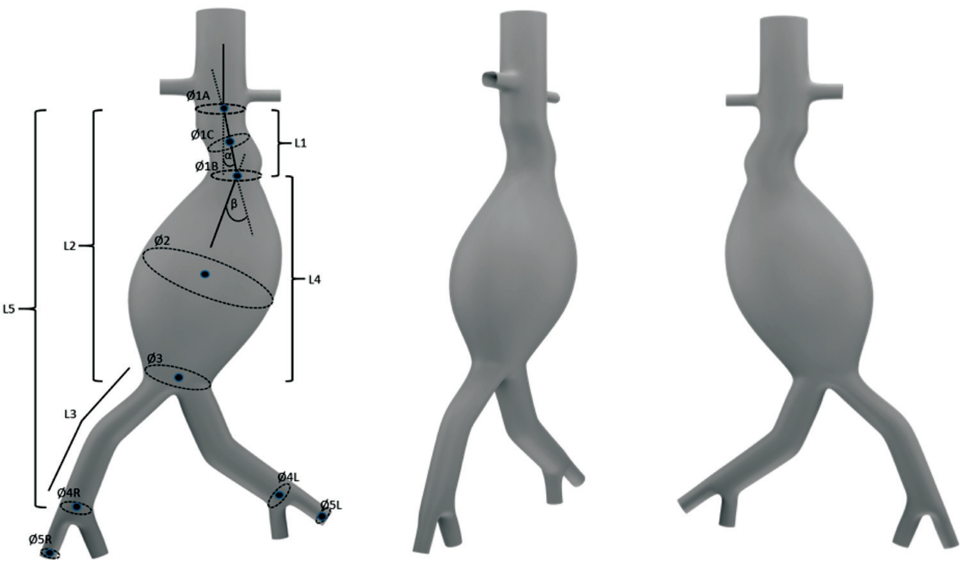

Figure 2. Characterizing Thai aortoiliac anatomy and key morphological parameters of abdominal aortic aneurysms.

Table 1. Patient characteristics

Characteristic	n=396
Male; n (%)	330 (83.3)
Age (year); mean [SD]	75.3 [7.99]
BMI (kg/m^2); mean [SD]	22.2 [3.7]
Non-ruptured; n (%)	364 (91.9)
Smoker; n (%)	277 (69.9)
Current smoker	67 (16.9)
Ex-smoker	210 (53.0)
Comorbidity; n (%)	
Hypertension	213 (53.8)
Dyslipidemia	114 (28.8)
Chronic kidney disease	83 (20.7)
Coronary arterial disease	54 (13.6)
COPD	49 (12.4)
Diabetes mellitus	39 (9.8)
Cerebrovascular disease	23 (5.8)
Peripheral arterial disease	2 (0.5)
ASA classification; n (%)	
2	56 (14.1)
3	299 (75.5)
4	25 (6.3)
5	3 (0.8)

BMI=body mass index; COPD=chronic obstructive pulmonary disease; ASA=American Society of Anesthesiologists; SD=standard deviation

aortic bifurcation at 29.7 mm. Both common iliac artery diameters were recorded at 12.7 and 13 mm, with corresponding lengths of 52.8 and 54.4 mm. Femoral artery diameters were measured at 7.1 and 7.2 mm. The average distance from the aneurysm to aortic bifurcation was 99.3 mm. The total length from the lowest renal artery to the distal sealing zone ranged from 177 to 179 mm, while the average length from the lowest renal artery to aortic bifurcation was 124 mm (see Table 2).

In Figure 3, the authors observed a detailed portrayal of the distribution of aneurysm anatomic parameters. A discernible right-skewed pattern dominated the majority of distribution graphs, with particular emphasis on the common iliac diameter distribution graph. This skewness was unequivocally attributed to the prevalence of smaller diameter sizes, eclipsing their larger counterparts, thereby offering valuable insights into the nuanced anatomical intricacies within the present study patient cohort.

Shifting the focus to the intricate compatibility dynamics, Figure 4 illustrated the nuanced interplay between patient aneurysm anatomies and stent-grafts from various manufacturers. The observed range spanned from 24.9% to 67%. Ovation® emerges as the pinnacle of compatibility, standing in stark contrast to AFX®, which represents the least compatible option.

A meticulous criterion-by-criterion examination revealed common iliac length as the singular parameter wherein patient anatomies aligned with stent-grafts, highlighting a compatibility range from 86.3% to 99.2%. This observation remained consistent even when scrutinized against each manufacturer's distinct requirements.

Analyzing neck and common iliac artery diameter criteria across manufacturers, a discernable

Table 2. The morphology of the Thai aortoiliac segment

Anatomic parameters	Mean [SD]
Supra renal angle (α) (degree)	28.0 [18.1]
Infra renal angle (β) (degree)	45.6 [21.0]
Proximal non-aneurysmal aortic neck diameter (Ø 1A) (mm)	20.4 [2.91]
Distal non-aneurysmal aortic neck diameter (Ø 1B) (mm)	21.8 [2.80]
Neck diameter (Ø 1C) (mm)	21.1 [2.74]
Maximum diameter of aneurysm (Ø 2) (mm)	62.8 [13.1]
Distal diameter of aorta/aneurysm above aortic bifurcation (Ø 3) (mm)	29.7 [10.5]
Distal diameter of non-aneurysmal neck of right iliac artery (Ø 4R) (mm)	13.0 [4.14]
Distal diameter of non-aneurysmal neck of left iliac artery (Ø 4L) (mm)	12.7 [3.61]
Diameter of access vessels, right femoral artery (Ø 5R) (mm)	7.21 [1.39]
Diameter of access vessels, left femoral artery (Ø 5L) (mm)	7.10 [1.36]
Length of non-aneurysmal aortic neck (L1) (mm)	25.2 [14.2]
Length from lowest renal artery to aortic bifurcation (L2) (mm)	124 [20.6]
Length of portion of right iliac from aortic bifurcation to end of seal zone (L3R) (mm)	52.8 [19.6]
Length of portion of left iliac from aortic bifurcation to end of seal zone (L3L) (mm)	54.4 [20.3]
Length from proximal aneurysm to aortic bifurcation (L4) (mm)	99.3 [24.6]
Length from lowest renal artery to end of right seal zone (L5R) (mm)	177 [27.7]
Length from lowest renal artery to end of left seal zone (L5L) (mm)	179 [27.5]

SD=standard deviation

Table 3. EVAR compatibility for each device; in each IFU criteria

Compatibility criteria	Device							
	Zenith®		AFX®		Endurant II®		Ovation®	
	Criteria	%	Criteria	%	Criteria	%	Criteria	%
Neck angle (°)	≤60	76.6	≤60	76.6	60-75° (length >15)	87.8	≤60	76.6
Neck diameter (mm)	18-32	89.8	18-32	89.8	19-32	78.4	16-30	99.2
Neck length (mm)	≥15	75.6	≥15	75.6	≥10	89.6	≥10	97.2
Common iliac artery diameter (mm)	8-20	85.3	10-23	65.0	8-25	91.1	8-25	91.1
Common iliac artery length (mm)	≥10	99.2	≥15	98.2	≥15	98.2	≥10	99.2
Common femoral artery diameter (mm)	≥6	73.4	≥6.5	63.5				

Compatibility criteria (continued)	Device							
	Aorfix™		JOTEC® E-tegra		Gore® Excluder®		TREO®	
	Criteria	%	Criteria	%	Criteria	%	Criteria	%
Neck angle (°)	≤90	96.7	≤75	91.1	≤60	76.6	Suprarenal <45 Infrarenal <60	86.0 76.6
Neck diameter (mm)	19-29	77.9	19-32	78.4	19-32	78.4	17-32	96.2
Neck length (mm)	≥15	75.6	≥15	75.6	≥15	75.6	>15	72.3
Common iliac artery diameter (mm)	10-20	60.7	8-25	91.1	8-25	91.1	8-13 (length >10) 13-20 (length >15)	86.3
Common iliac artery length (mm)	≥15	98.2	≥15	98.2	≥10	99.2		
Common femoral artery diameter (mm)								

decrement in stent compatibility was observed as the requirement size increases. For instance, the initially robust 99.2% compatibility of neck diameter criteria for Ovation® attenuated to 78.4% when subjected to the more stringent requirements of Endurant II®. Similarly, the compatibility of common iliac artery diameter criteria for Zenith®, starting at 85.3%, diminished to 60.7% when aligned with the requirements of Aorfix™ (see Table 3).

Delving into neck angulation criteria, approximately three-fourths of the patients meet the requirement even under the strictest criteria, which is less than 60 degrees, as imposed by Zenith®, AFX®, Ovation®, Gore® Excluder®, or TREO®.

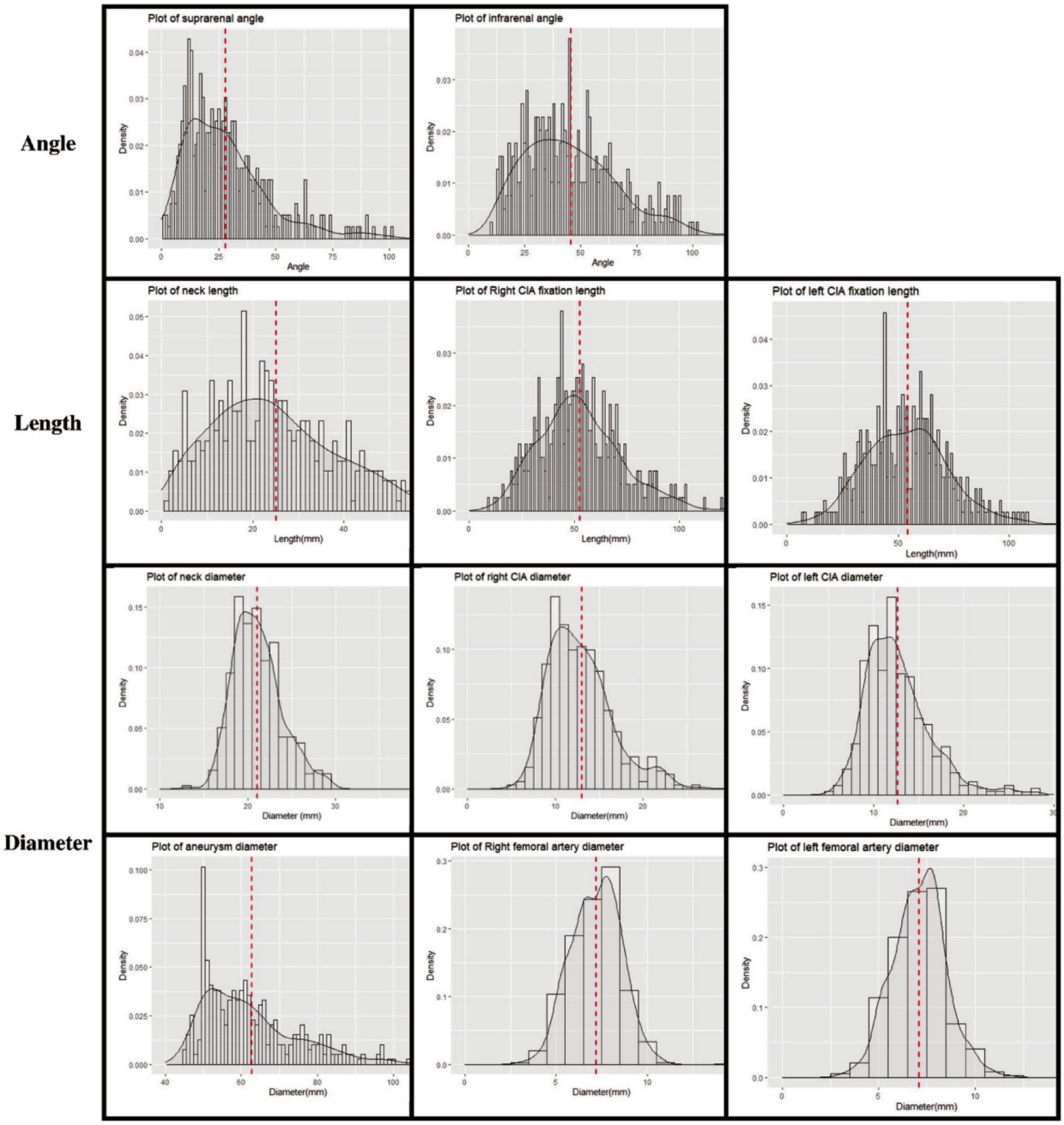

Figure 3. Distribution of Thai aortoiliac morphology.

Intriguingly, nearly 100% stent compatibility of neck angulation criteria was achieved when the requirement was judiciously relaxed to “less than 75 degrees” and “less than 90 degrees”, exemplified by Aorfix™ and JOTEC® E-tegra, respectively (see Table 3). This meticulous analysis underscored the intricate interplay between anatomical considerations and manufacturer specifications, providing nuanced insights crucial for informed clinical decision-making and optimal device selection in the context of endovascular interventions.

Discussion

The present study meticulously dissects distinctive features in Thai aortoiliac morphology when juxtaposed with their Western counterparts, elucidating a predilection for smaller dimensions coupled with a marginally increased maximum aneurysm diameter. The spectrum of EVAR compatibility, spanning from 24.9% to 67%, is contingent upon the specific stent-graft employed, with common iliac length emerging as the most attainable criterion, while neck angle and length

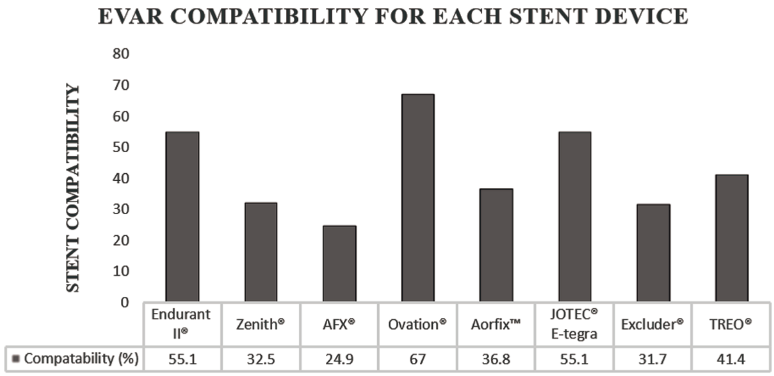

Figure 4. Percentage of EVAR compatibility for each stent device.

render approximately one-fourth of the cohort unsuitable for EVAR.

The observed diminution in aortoiliac size and the subtle augmentation in maximum aneurysm diameter corroborate earlier findings, notably expounded upon by Banzic et al. This alignment underscores inherent structural disparities between Asian and Western populations, elucidating a smaller anatomical profile among Asians and implying a proportional diminution in vessel size within this demographic[5,6]. The present study's cohort, with an average age of 75.3 years, slightly surpassing that of the Banzic et al. study, at 69.1 years, suggested that the augmented maximum aneurysm diameter observed may be attributed to advanced age and delayed clinical presentation[6].

Despite indicating a discernible trend of lower EVAR compatibility in the present study compared to Western populations at 67% versus 78% in the Wolf et al. study, direct comparisons prove challenging due to the inherent divergence in stent-graft types[3]. Notably, the impact of smaller vessel diameter on EVAR feasibility, particularly evident in the stringent criteria of certain devices mandating larger diameters, underscores the need for nuanced considerations. This declining trend in EVAR compatibility may be influenced by the fact that the IFU for most devices are rooted in Western population anatomy, inadequately addressing the nuances of Asian aneurysm anatomy.

Remarkably, the study unveils an interesting facet regarding Thai common iliac artery length, which notably surpasses most criteria, highlighting a compliance with IFU criteria. This contradicts the results of the Banzic et al. study, adding a layer of complexity to the understanding of Asian and Caucasian anatomy[6]. Furthermore, it contrasts with Stephen WK series, a study in Chinese populations, emphasizing the unique character of a short common iliac artery in Chinese aneurysm anatomy that affects the suitability of EVAR[5]. This advantage in Thai patients ensures an adequate distal sealing zone without necessitating additional procedures, such as internal iliac embolization.

As expected, neck configuration remains a common and challenging parameter, rendering around one-fourth of patients unsuitable for EVAR[8]. Diameter parameters also pose challenges, affecting EVAR suitability rates due to the tendency of patients in the present study to have smaller vessel diameters. While the relaxation of parameters in devices appears to almost cover EVAR compatibility completely, the study acknowledges that this phenomenon is secondary to the critical consideration of treatment outcomes.

The present study advocates for the pursuit of further research into novel, specifically designed stent-grafts tailored to the unique anatomical attributes of Thai patients. The overarching goal is to achieve universal applicability of EVAR in the Thai population while ensuring optimal outcomes. The present study's findings resonate with prior reports on Asian aortoiliac morphology, highlighting differences compared with Western populations[9]. However, the study introduces contradictory aspects, such as common iliac artery length and the range of EVAR compatibility, underscoring the crucial role of ethnicity in anatomical variations. In the realm of precision medicine, specific data and information become indispensable tools to surmount the challenges posed by diverse anatomies, laying the foundation for more effective and tailored interventions.

Conclusion

The present study has elucidated unique

morphological features within the aortoiliac segments of the Thai population. The discerned characteristics of anatomy contribute significantly to variations in EVAR compatibility observed across different stent-graft manufacturers. These findings unequivocally affirm the pivotal role of ethnicity as a determinant factor influencing the morphological nuances of vessels. The specific information and data gleaned from the present study hold substantial promise for informing and guiding the future design and refinement of stent-grafts, facilitating a more tailored and effective approach to endovascular interventions in diverse demographic populations.

What is already known on this topic?

Currently, the data supporting EVAR are derived from studies on Western populations anatomy, which have informed the design of the stent-graft systems available today. However, a comprehensive evaluation of anatomical data specific to Asian populations, particularly Thai individuals, holds the potential to play a crucial role in refining stent-graft designs. Such efforts would enable the development of devices that are better tailored to the distinct anatomical characteristics of this demographic.

What does this study add?

This study provides a detailed analysis of the unique characteristics of Thai aortoiliac morphology in comparison to Western counterparts, highlighting a tendency towards smaller overall dimensions coupled with a slightly larger maximum aneurysm diameter. The compatibility of EVAR, ranging from 24.9% to 67%, is dependent on the specific stent-graft system employed. Among the anatomical criteria, common iliac length is the most frequently met, whereas neck angle and length pose significant challenges, rendering approximately one-fourth of the cohort unsuitable for EVAR. The configuration of the aortic neck remains a particularly problematic factor, contributing to the exclusion of a similar proportion of patients from EVAR eligibility.

The present study underscores the necessity of further research aimed at developing novel stent-grafts specifically tailored to the distinct anatomical characteristics of Thai patients. The ultimate objective is to expand the applicability of EVAR within the Thai population while ensuring optimal clinical outcomes. In the context of precision medicine, the generation and application of specific anatomical data are essential to overcoming the challenges posed by diverse anatomical variations, thereby facilitating more effective and individualized treatment strategies.

Conflicts of interest

The authors declare no conflict of interest.

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