Feeding Flow Velocity on Doppler Ultrasound Predicting the Outcome of Type II Endoleak following Endovascular Aneurysm Repair of Abdominal Aortic Aneurysm

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Abstract

Background: The objective is to study the relation between the velocity of the arterial feeder and the progression of the postendovascular aneurysm repair aneurysm to find out the cut point velocity, which causes a significant increase in size of the aneurysm sac. **Methods:** Retrospective study of patients with Type II endoleak followed up with the duplex ultrasound between January 2010 and June 2022. The sensitivity, specificity, and accuracy of the velocity, number of feeding artery, and flow pattern were studied. Receiver operating characteristic analysis was performed to evaluate a test performance and the most appropriate cutoff velocity of the arterial feeder. **Results:** The peak systolic velocity (PSV) of >75 cm/s, multiple feeding arteries, and the to-and-fro pattern show a significant distinguish the stable size from the significant increase in the size of the aneurysm with a sensitivity of 100.0%, a specificity of 100.0%, and an accuracy of 100.0% ($P = 0.002$). **Conclusion:** The patient with a PSV >75 cm/s, multiple feeding arteries, and the to-and-fro pattern are correlated with significant aneurysm expansion and need closer follow-up than the patient with low PSV, single feeding artery, and monophasic pattern.

Keywords: Abdominal aortic aneurysm, blood flow velocity, Doppler ultrasonography, Doppler ultrasound, endoleak, endovascular aneurysm repair, pulse wave velocity

Introduction

Nowadays, the standard treatment of abdominal aortic aneurysm (AAA) is an endovascular aneurysm repair (EVAR) because it can significantly reduce a 1-year mortality rate than the conventional open repair.[1-4]

After the EVAR, an endoleak occurs in 44% of cases. The rates of late complications requiring further interventions are 2.1%–2.8%. The endoleak can cause a recurring AAA, leading to aneurysm rupture. The most common type of endoleak is type II, reporting 6%–30%.[5-8] The type II endoleak needs to be detected early, and a proper follow-up with a computed tomographic angiography (CTA) or a duplex ultrasound because it can cause a significant progression of the post-EVAR aneurysm sac, which needs to be treated by embolization.

Every patient needed to follow-up with a CTA or a Doppler ultrasound according to the standard protocol of each institute, recommending study at 1–3 months and 6 months–1 year after EVAR.

The recent data show no significant difference between the duplex ultrasound and the CTA in detecting the endoleak after EVAR. Moreover, the duplex ultrasound is more radiation-safe and gives more information about the velocity of the feeding artery and the flow direction. However, the duplex ultrasound is an operator-dependent study requiring an experienced operator.[9-12]

Many factors from the duplex ultrasound affect the progression of the aneurysm, such as feeding flow velocity, flow direction, and number of feeding arteries.[13]

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The high flow velocity of the feeding artery, bidirectional flow (to-and-fro pattern), and multiple feeding arteries are the critical factors causing a significant increase size of the post-EVAR aneurysm sac, which needs further embolization.[14,15] However, there is no definite cut point of the high flow velocity of the feeding artery, which may predict the prognosis of Type II endoleak.

This retrospective study reviews the findings from the duplex ultrasound, such as the velocity of the feeding artery, flow direction, and the number of feeding arteries in the follow-up of Type II endoleak after EVAR and focuses on the relationship between the velocity of feeding arteries and the progression of the aneurysm.

We intend to find the most appropriate cut-point velocity of feeding arteries, which can cause a significant increase size of the post-EVAR aneurysm.

Materials and Methods

A study included consecutive patients who underwent EVAR and were diagnosed with Type II endoleak from the CTA between January 2010 and June 2022. All data were collected retrospectively from electronic medical records and in-picture archiving and communication systems from February to April 2023. The study conformed to the principles outlined in the Declaration of Helsinki and was approved by the institutional ethics committee (COA. MURA2023/62; Date of approval February 6, 2023), and informed consent was waived because of a retrospective study.

The surveillance ultrasound protocol was applied to every patient with Type II endoleak. Within 1 month after CTA, the duplex ultrasound was done for baseline information, including the size of the aneurysm, location and number of feeder arteries, flow velocity of feeder artery, and flow pattern or character of the spectral waveform. After that, a follow-up ultrasound was done every 6 months to evaluate the progression or resolution of endoleak Type II.

Inclusion criteria

1. All patients diagnosed with Type II endoleak from CTA
2. Complete information of the baseline duplex ultrasound within 1 month after CTA
3. Complete information of the follow-up duplex ultrasound 6 months after the baseline ultrasound.

Exclusion criteria

1. No official report of the duplex ultrasound
2. Lack of follow-up.

Five consultant radiologists with a minimum of 5 years of postqualification experience performed the same protocol for the first ultrasound scanning after diagnosis of endoleak type II from the CTA and the follow-up study.

All patients underwent ultrasound examination on a Philip iU22 (Philips Health care, Andover, Mass) with a C5-1 curved linear array transducer and an Aplio™ 500 (Canon Medical Systems Corporation, Japan) with a 3.5 MHz convex transducer PVT-7375BT. The ultrasound protocol begins with a cross-sectional grayscale image for measurement of the maximum anteroposterior (AP) and transverse diameter of the aneurysm.

The endoleak Type II was diagnosed by a retrograde flow in a branch into the aneurysm sac during the color flow image study, confirmed by the arterial spectral waveform. The flow velocity measurement was performed at the entrance of feeding vessels with an angle of <60°. The peak systolic velocity (PSV) was recorded in cm/s. The highest velocity was used in patients with more than one vessel diagnosed as Type II endoleak. The to and flow waveform was noted when the arterial blood went into the aneurysm in a systolic cycle and exited the aneurysm in a diastolic cycle [Figure 1].

We defined stable size as an increase of AP and transverse diameters <5 mm in 6 months and progression as an increase of AP and transverse diameter of more than 5 mm in 6 months, and the aneurysm needed to be embolized.

This study pays attention to three factors from duplex ultrasound: the PSV of feeding arteries, flow pattern (presence of to-and-fro pattern or not), and the number of feeding arteries (single or multiple feeders) affecting Type II endoleak.

Using Statistical Package for the Social Science for Mac version 25, the PSV of feeding arteries, flow pattern, the number of feeding arteries, the progression of the aneurysm size, and other descriptive information were recorded statistically.

Receiver operating characteristic (ROC) analysis was performed to evaluate a test performance and the most appropriate cut-off velocity of feeding arteries to distinguish low-flow and high-flow feeding arteries, significantly leading to the progression of an aneurysm sac from Type II endoleak.

Chi-square tests were also done to obtain sensitivity, specificity, and accuracy of high-flow feeding arteries, flow pattern, and the number of feeding arteries and combined all three factors in identifying significant Type II endoleak.

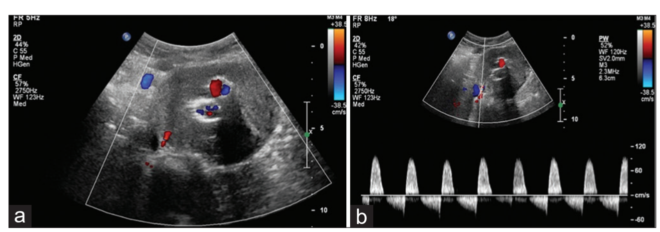

Figure 1: The Type II endoleak through right lumbar artery was diagnosed by a retrograde flow (red color) in a right lumbar artery into the aneurysm sac in color flow image (a) and the to and flow waveform on spectral PW Doppler ultrasound (b)

Results

From the total of 34 patients, two patients showed a significant increase in the aneurysm size (>5 mm in both AP and transverse diameter) and continued embolization. One patient refers to embolization after the first follow-up ultrasound, and another one undergoes embolization after the 2nd time of follow-up ultrasound due to the persistence of Type II endoleak and the increased size of the aneurysm. Spontaneous complete resolution of Type II endoleak was observed in the rest of the 32 patients at the first follow-up ultrasound.

Feeding arteries' PSV ranges from 9.6 to 104 cm/s (mean 40.87 ± 23.03). The to-and-fro pattern was found in eight patients. Four patients have more than one feeding artery [Table 1].

In comparison between the stable and aneurysmal progression groups, the PSV of feeding arteries in the aneurysmal progression group (mean PSV = 89.9 cm/s) is higher than the stable group (mean PSV = 37.81 cm/s). Moreover, the to-and-fro pattern and multiple feeding arteries are seen in all patients needing embolization [Table 1].

The ROCs curve was constructed to determine the PSV that maximizes the summation of sensitivity and specificity for the progression of the aneurysm. The ROC area of the PSV of the feeding artery was 0.953 [Figure 2 and Table 2].

The PSV of more than 75 cm/s can significantly distinguish the stable size of the AAA from the significant increase in the size of the aneurysm with a sensitivity of 100.0%, a specificity of 90.6%, and an accuracy of 91.2% ($P = 0.018$).

The to-and-fro pattern can significantly distinguish the stable size from the significant increase in the size of the aneurysm with a sensitivity of 100.0%, a specificity of 81.3%, and an accuracy of 82.4% ($P = 0.050$).

Multiple feeding arteries can also significantly distinguish the stable size of the AAA from the significant increase in the size of the aneurysm with a sensitivity

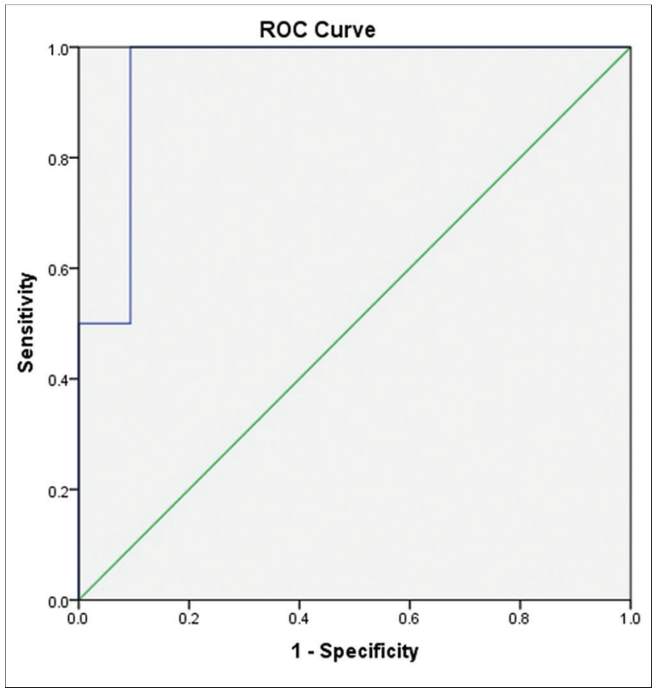

Figure 2: ROC curve analysis of the peak systolic velocity. ROC: Receiver operating characteristic

Table 1: Characteristics of patients and ultrasound findings

Characteristics	All patients (%)	Stable size of the aneurysm	Increase in size of aneurysm*
Gender			
Male	27 (79.41)	26	1
Female	7 (20.59)	6	1
Total	34 (100)	32	2
Age (years)			
Mean (±SD)	77.71 (±7.09)	77.91 (±7.24)	74.5 (±3.54)
Minimum	58	58	72
Maximum	90	90	77
Concerning factors affecting significant type II endoleak			
Peak systolic velocity of feeding arteries (PSV, cm/s)			
Mean (±SD)	40.87 (±23.03)	37.81 (±19.66)	89.9 (±19.87)
Minimum	9.6	9.6	75.9
Maximum	104	81.7	104
The flow patterns of feeding arteries (number of patients)			
To-and-fro pattern	8 (23.53)	6	2
Monophasic pattern	26 (76.47)	26	0
Number of feeding arteries (number of patients)			
Multiple (≥2)	4 (11.76)	2	2
Single	30 (88.24)	30	0

*>5 mm in 6 months and needed to be embolization. SD: Standard deviation, PSV: Peak systolic velocity

Table 2: Area under the receiver operating characteristic curve of peak systolic velocity

Area	SE[a]	Asymptotic significant[b]	Asymptotic 95% CI	
			Lower bound	Upper bound
0.953	0.046	0.034	0.863	1.000

[a]Under the nonparametric assumption, [b]Null hypothesis: True area=0.5.
CI: Confidence interval, SE: Standard error

of 100.0%, a specificity of 93.8%, and an accuracy of 94.1% ($P = 0.011$).

Finally, when combined, all three mentioned factors. The test shows a significant difference in the stable size from the significant increase in the size of the aneurysm with a sensitivity of 100.0%, a specificity of 100.0%, and an accuracy of 100.0% ($P = 0.002$). The sensitivity and specificity of each factor are shown in Table 3.

Discussion

Currently, the optimal management of Type II endoleak remains controversial, with no definite consensus. Due to the low risk of aneurysm rupture, approximately 1% of ruptured aneurysm associated with Type II endoleak was reported.[16] And the type II endoleak, detected 1 year after EVAR, can be resolved spontaneously in 75% of cases.[17] Therefore, many clinicians support the conservative observation of the Type II endoleak with surveillance follow-up ultrasound. However, the treatment was a concern when the post-EVAR aneurysm showed a significant increase in size. The most recent guideline from the Society of Vascular Surgery[18] recommends the treatment when the aneurysm expansion is more than 5 mm. Other criteria include endoleak persistence longer than 6 months.

It is a reason for this study aims to determine the parameter for predicting the progression of aneurysm size not only for selecting patients for the treatment but also for the appropriate interval of the follow-up duplex ultrasound. The patient with a risk for an aneurysm progression and endoleak persistence should be examined more frequently than the patient without.

From this study, the PSV >75 cm/s and the multiple numbers of feeding arteries can distinguish the stable size of the AAA from the significant increase in the size of the aneurysm with statistically significant ($P < 0.05$). Our result supports the previous publication from Maximus *et al*.[14] about the velocity of Type II endoleak might be able to predict spontaneous resolution of Type II endoleak or progression of aneurysm size and report that every patient with growing aneurysm size had a PSV >100 cm/s. Correspond with the publication from Arko *et al*.,[15] which analyzed the velocity and resolution of Type II endoleak. They found that patient with spontaneous resolution of Type II endoleak has an average velocity of 75.5 cm/s.

It can be concluded that the velocity of Type II endoleak affects the aneurysm size. The aneurysm expansion will depend on the retrograde blood volume into the aneurysm. A large amount of blood volume will affect the aneurysm expansion more than a small blood volume because the blood volume is the summation of the blood flow velocity and cross-sectional area of the feeding artery. The high PSV and multiple feeder arteries significantly correlate with aneurysm expansion.

Furthermore, the to-and-fro pattern, which causes blood flow inward to the aneurysm in the systolic phase and outward in the diastolic phase, also correlates with a significant increase in the size of the aneurysm with statistically significant ($P < 0.05$). To explain this finding, the to-and-fro pattern represents a pseudoaneurysm-like phenomenon. The blood flow moves into and out of the un-clotted, sac-like area in the partially thrombosed aneurysm through the same channel. Together with the high velocity, these are the resist factors for the spontaneous closure of the feeding artery. Interestingly, our study shows that the to-and-fro pattern is always founded with a high PSV. Moreover, two patients with aneurysm expansion show higher blood flow velocity during the diastolic phase than the mean of PSV in the patient with the monophasic pattern. All patients with PSV lower than 75 cm/s, single artery feeder, and monophasic pattern show spontaneous regression or absence of Type II endoleak at the 6 months' follow-up ultrasound.

Even if we found the three parameters from the duplex ultrasound included the PSV >75 cm/s, multiple numbers of feeding arteries, and to-and-fro pattern correlate with a significant increase in aneurysm size. However, the indication for the treatment of Type II endoleak also depends on many factors. The essential benefit of our results is knowing about the natural history of Type II endoleak detected on the follow-up duplex ultrasound and setting up the appropriate follow-up ultrasound protocol.

The patient with PSV >75 cm/s, multiple feeding arteries, and to-and-fro pattern need closer follow-up than those with low PSV, single arterial feeder, and monophasic pattern.

There are some limitations due to the small population, low prevalence of aneurysm expansion in the single-center study and the size measurement by the ultrasound alone. However, we achieve our objective, which might affect the current treatment but has validity for the follow-up study.

Conclusion

Patients with PSV >75 cm/s, multiple feeding arteries, and to-and-fro pattern correlate with significant aneurysm expansion and need closer follow-up than those with low PSV, single arterial feeder, and monophasic pattern.

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Table 3: Sensitivity and specificity

Factors	Significant increased size of aneurysm (S)		Total (a+b)	*P*
	Yes, *n* (%)	No, *n* (%)		
PSV of feeding arteries				
PSV (A)				
≥75 cm/s				
Number of patients	2	3	5	0.018
Percentage in A	40.0	60.0	100.0	
Percentage in S	100.0	9.4	14.7	
<75 cm/s				
Number of patients	0	29	29	
Percentage in A	0.0	100.0	100.0	
Percentage in S	0.0	90.6	85.3	
Total				
Number of patients	2	32	34	
Percentage in A	5.9	94.1	100.0	
Percentage in S	100.0	100.0	100.0	
The flow pattern of feeding arteries				
To-and-fro (B)				
Yes				
Number of patients	2	6	8	0.050
Percentage in B	25.0	75.0	100.0	
Percentage in S	100.0	18.8	23.5	
No				
Number of patents	0	26	26	
Percentage in B	0.0	100.0	100.0	
Percentage in S	0.0	81.3	76.5	
Total				
Number of patients	2	32	34	
Percentage in B	5.9	94.1	100.0	
Percentage in S	100.0	100.0	100.0	
The number of feeding arteries				
Number (C)				
Multiple				
Number of patients	2	2	4	0.011
Percentage in C	50.0	50.0	100.0	
Percentage in S	100.0	6.3	11.8	
Single				
Number of patients	0	30	30	
Percentage in C	0.0	100.0	100.0	
Percentage in S	0.0	93.8	88.2	
Total				
Number of patients	2	32	34	
Percentage in C	5.9	94.1	100.0	
Percentage in S	100.0	100.0	100.0	
Combined three factors				
3 factors (D)				
Yes				
Number of patients	2	0	2	0.002
Percentage in D	100.0	0.0	100.0	
Percentage in S	100.0	0.0	5.9	
No				
Number of patients	0	32	32	
Percentage in D	0.0	100.0	100.0	

Contd...

Table 3: Contd...

Factors	Significant increased size of aneurysm (S)		Total (a+b)	*P*
	Yes, *n* (%)	No, *n* (%)		
Combined three factors				
Percentage in S	0.0	100.0	94.1	
Total				
Number of patients	2	32	34	
Percentage in D	5.9	94.1	100.0	
Percentage in S	100.0	100.0	100.0	

*Chi-square tests (Fisher's exact test), **3 factors=high PSV (≥75 cm/s), to-and-fro flow pattern and multiple numbers of feeding arteries. PSV: Peak systolic velocity

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Conflicts of interest

There are no conflicts of interest.

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