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Which mode of color Doppler ultrasound is most suitable for detecting endoleaks in surveillance after endovascular aneurysm repair?

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ABSTRACT

Objectives: The aim of this study was to evaluate the best mode of Doppler ultrasound, blood flow imaging (BFI) versus color Doppler ultrasound (CDUS), in detecting endoleaks diagnosed using computed tomography angiography (CTA).

Patients and methods: A total of 70 consecutive patients (60 males, 10 females; mean age: 68.5±7.8 years; range, 48 to 82 years) undergoing standard EVAR procedure were retrospectively evaluated in the outpatient clinic following CTA between January 2018 and December 2019. Ten (13.9%) patients in which endoleaks were detected were also evaluated using CDUS which was performed by two radiologists specializing in Doppler ultrasound. The radiologists were blind to CTA reports. A reporting protocol was developed for endoleak detection using different modes of CDUS (BFI vs. CDUS).

Results: Of all cases, 10 (13.9%) endoleaks were detected using CTA. All five type I and III endoleaks requiring an intervention were detected by both modes of CDUS, while four of the five type II endoleaks were not. The single case of type II endoleak was suspected following the visualization of fresh thrombus formation. There was an inadequacy in detecting low flow endoleaks both using BFI and standard color Doppler mode. There was a strong correlation between the aneurysmal sac diameters measured using CTA and CDUS.

Conclusion: The CDU and BFI are capable of detecting type I and III endoleaks with similar sensitivity and specificity. These modes should be used in combination as confirmatory tests. For surveillance, CDUS promises accurate results without missing any potential complication requiring an intervention. Lack of detecting type II endoleaks may be negligible, as sac enlargement is the key for reintervention in this case.

Keywords: Aneurysm, computed tomography angiography, Doppler ultrasound, endovascular aneurysm repair.

With the introduction of the early results of randomized-controlled trials, endovascular procedures have spread out through the world, offering low early mortality with more rapid patient turnover and minimally invasive nature for infrarenal abdominal aortic aneurysms (iAAAs). Endovascular iAAA treatment carries an early mortality advantage with erosion in the mid-term and the same long-term results with open surgical repair, as reported in randomized-controlled trials.[1-5] As the endovascular procedures carry its potential complications and aneurysm-related events have not completely vanished, lifelong surveillance is mandatory. The main goal of follow-up protocols is to diagnose any complication earlier enough to treat in an elective manner. Endoleaks, migration, stenosis or occlusions, and structural integrity are the key points for success in endovascular follow-ups.

Computed tomographic angiography (CTA) has a potential cancer risk due to the cumulative ionizing radiation and risk of nephrotoxicity due to the use of contrast agent (7 to 12%).[6-10] However, it is still the gold standard as a diagnostic tool and preoperative measurements in aortic aneurysms for endovascular

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abdominal aortic aneurysm repair (EVAR). However, it is not a suitable follow-up modality due to the health economic concerns. Color Doppler ultrasound (CDUS) may be preferred as a follow-up modality after EVAR, as it is cost-effective and easy-to-apply with no harm to patients. There are many studies in the literature on CDUS as a surveillance modality after EVAR. Nevertheless, there are conflicting data that may result from the heterogeneity study designs, equipment, techniques or training.[6,7,11-15] The current guidelines suggest CTA and CDUS as follow-up modalities.[14,15]

In the literature, there is no study comparing the different modes of CDUS and their accuracy in detecting endoleaks. In the present study, we hypothesized that blood flow imaging (BFI) could be more advantageous than CDUS. We, therefore, aimed to evaluate the best mode of Doppler ultrasound, BFI versus CDUS, or combination in detecting endoleaks diagnosed by CTA.

PATIENTS AND METHODS

A total of 70 consecutive patients (60 males, 10 females; mean age: 68.5±7.8 years; range, 48 to 82 years) undergoing standard EVAR procedure were retrospectively evaluated at Department of Cardiovascular Surgery Ankara State Hospital outpatient clinic following CTA between January 2018 and December 2019. Those who underwent hybrid operations, complex EVAR procedures (chimney, snorkel), and emergency cases were excluded from the study. All patients included in the study were evaluated using CTA which included aneurysmal sac measurements. Those in which endoleaks were detected were also evaluated using the CDUS including CDU and BFI. Ten patients diagnosed with endoleak prospectively on CTA were evaluated by two radiologists who were blind to the CTA results, using the CDUS modes. Caliper placements for measurement of aortic diameter were put into a consensus as an outer-to-outer manner. The primary outcome measure of the study is endoleak detection and sac measurement. A written informed consent was obtained from each patient. The study protocol was approved by the Ankara State Hospital Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

CDUS mode

All CDUS examinations were performed using the GE LOGIQ™ S7 Expert R3 (General Electric Company, WI, USA) equipped with a C1-6 Mhz curvilinear broadband transducer probe. The aorta was scanned starting from the diaphragm to the iliac vessels in transverse and longitudinal planes. The aortic diameter was always measured in an outer-to-outer manner. All patients were scanned in the supine position in a dark outpatient clinic room per protocol. The contrast agent was not used in any of the patients.

BFI mode

This technique (B-flow) uses digitally encoded sonography techniques to boost blood echoes and to preferentially suppress non-moving tissue signals. The remainder of the data processing is essentially the same as with the conventional B-mode. The BFI provides real-time visualization of blood flow by directly showing blood reflectors and presenting this information in a gray-scale form. The BFI has a higher spatial and temporal resolution than the Doppler ultrasound, owing to the clearer definition of the vessel lumen.

The CTA GE Revolution™ (General Electric Company, WI, USA) (512-slice) equipped with an Ulrich automatic injector (Ulrich Medical, Ulm, Germany) with a total amount of 90 mL contrast agent. The arterial and late venous phases were performed in all patients.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 15.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed in mean ± standard deviation or median (min-max), while categorical variables were expressed in number and percentage. The sensitivity and specificity values were analyzed using the contingency table. A p value of <0.05 was considered statistically significant.

RESULTS

Of all patients, endoleak was detected in 10 (13.9%) using CTA. Of 10 endoleaks, six (8.3%) were also diagnosed using CDUS, which included type I and III endoleaks. However, CDUS failed to detect four (5.5%) of the type II endoleaks diagnosed on CTA. There was one type Ia, two type Ib, two type III, and five type II endoleaks detected using CTA (Table 1). Figure 1 and 2 show the type III endoleaks detected with BFI and CDU. The BFI seems to be better at demonstrating endoleaks than CDUS.

Table 1. Types of endoleaks detected by the modalities

	Type I endoleak	Type II endoleak	Type III endoleak
Computed tomographic angiography	3	5	2
CDUS	3	1	2
Blood flow imaging	3	1	2
Combination CDUS + CTA	3	1	2

CDUS: Color Doppler ultrasound; CTA: Computed tomographic angiography.

There is an insufficiency in detecting low flow in BFI and standard CDUS. Both modes were capable of detecting type I and III endoleaks; however, they were inferior to CTA in detecting type II endoleaks. Aside from this, there was a strong correlation between the aneurysmal sac diameters measured using CTA and CDUS. There was one-to-one correspondence on the sac diameter measurements in these 10 patients. There were no leaks missed on Doppler ultrasound requiring an intervention. All endoleaks detected with CDUS were the same with both modes (BFI and CDUS), showing no superiority to each other.

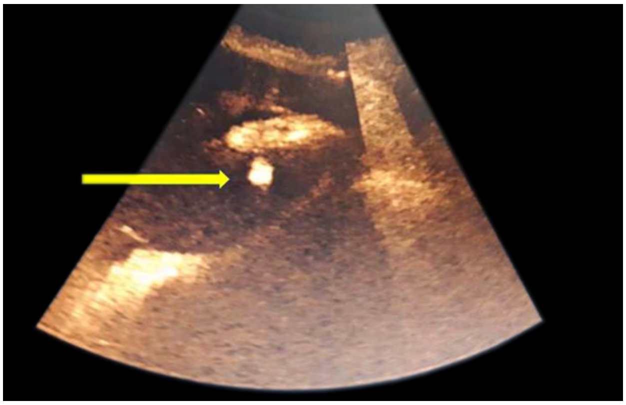

Figure 1. Type III endoleak in blood flow imaging caused by a defect in graft due to a tear in fabric of graft or due to disconnection of overlap.

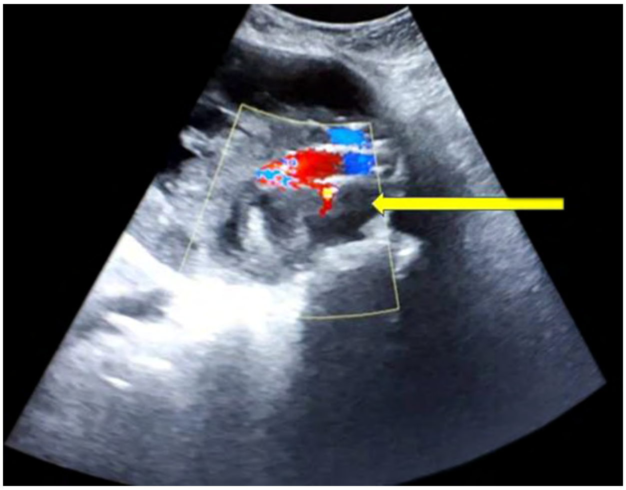

Figure 2. Type III endoleak in color Doppler ultrasound mode. Image clarity is compromised due to low blood flow.

Missing type II endoleaks were not considered to be clinically significant. They are still under follow-up for sac enlargement. The type II endoleak was reported as a suspected endoleak, due a mobile thrombus seen inside the aneurysmal sac.

DISCUSSION

The frequent use of computed tomography (CT) scanning during EVAR follow-up has raised concerns related to the added cost, as well as cumulative radiation exposure and the use of nephrotoxic agents.[16,17] The Society for Vascular Surgery practice guidelines currently recommend contrast-enhanced CT scanning at one and 12 months during the first year after EVAR and that, if neither endoleak nor aneurysm expansion is detected, subsequent Duplex follow-up may be a reasonable alternative.[14] Although the risk of endoleak declines over the years, new endoleaks have been identified as late as seven years following EVAR,[17] underscoring the importance of lifelong surveillance.

All the guidelines suggest that type I and III endoleaks should be treated immediately with a strong recommendation.[14,15] For type II endoleaks, aneurysm expansion should be surveilled. Expansion of a sac diameter of ≥1 cm detected during follow-up after EVAR using the same modality and measurement method may be considered a reasonable threshold for a significant growth.[14,15]

The CDUS carries the lack of associated radiation exposure and nephrotoxicity, as well as the obvious advantage of being readily available and non-invasive manner. These specifications make it a more desirable imaging modality for long-term surveillance. However, it is largely operator-dependent

Table 2. Sensitivity and specificity of CDUS for detecting endoleaks compared to CTA

	Sensitivity (%)	Specificity (%)
Arko et al.[18]	81	95
Gray et al.[7]	100	85
Sanford et al.[19]	67	91
Manning et al.[20]	67	86
Cantisani et al.[13]	58	93

CDUS: Color Doppler ultrasound; CTA: Computed tomographic angiography.

and the quality of the images may be adversely affected by obesity or excess bowel gas that may almost always be achieved by the position of the transducer. Concerns were raised in the past regarding its variable sensitivity in detecting endoleaks, almost always due to type II endoleaks.[6,7,10-14] Based on the recent reports, some authors have proposed that follow-up with Duplex ultrasound as the sole imaging modality is appropriate.[7,10,12]

Our study results showed one-to-one correspondence in 10 patients among CDUS and CTA in measuring the sac diameter. These results are consistent with Gray et al.[7] and Arko et al.[17] to the degree of correlation. In the literature, there are many diverse reports about sensitivity and specificity concerning the endoleak detection of CDUS. These conflicts may be due to heterogeneity of study designs, equipment, techniques or training. Some of these reports are given in Table 2.

Our clinical approach for surveillance after EVAR begins with baseline CTA for all patients as a reference point. It should be performed in the first three months after the procedure, according to the patient's renal status, aneurysm anatomy, and risk of graft-related complications. Component overlap, sealing zones, positioning, and endoleaks are evaluated, and the images are recorded for future reference. Subsequently, in the absence of an endoleak or aneurysmal sac enlargement, the patient is followed every six months using CDUS as the imaging technique of choice. When a type II endoleak is detected on CTA, again CDUS is performed every six months to monitor the sac enlargement.

As it has been well documented that CTA has always a risk for cancer due to repeated exposure to ionizing radiation and contrast agent-related nephrotoxicity,[6-10] follow-up of the patient with the best possible risk/benefit balance is challenging. There is strong evidence at the doses relevant to CT scanning that the risks of radiation carcinogenesis are true, although small, but unlikely to be zero for any individual.[18,19] There are some concerns, when CT is used without a proven clinical indication, when alternative modalities can be used with an equal efficacy.

On the other hand, CDUS is a cost-effective modality for surveillance which poses no risk to the patient and is as effective as CTA, when used to monitor the sac enlargement. The use of CTA should be reserved, when CDUS is considered insufficient in detecting the presence of endoleak, anechoic lesions or fresh thrombi, and sac enlargement. Small endoleaks cannot be detectable using CT. In the study of Henao et al.,[20] type II endoleaks which were overlooked by CT were successfully detected using contrast-enhanced US (CEUS). Therefore, identifying small endoleaks depends largely on the protocol of the CT conduction phases. The contrast-enhanced CDUS-based protocols for EVAR seem to be superior to CDUS. On the other hand, CEUS is not as cost-effective as CDUS.[21] In addition, allergic reactions or potential cardiac complications occur more commonly following CEUS and, thus, early discharge is not possible.[10,21]

The BFI mode does not require different equipment and can be implemented using the same Doppler equipment alongside additional software. Both examinations can be performed with the same single equipment that is a new-generation CDUS machine. This tool is advantageous in terms of time and cost. The combined use of these two non-invasive methods provides a crosscheck of the diagnosis. In addition, BFI is much clearer, since this mode eliminates all blooming artifacts and the need for an experienced CDUS operator.

The BFI should be used in combination with CDU as a confirmatory test, due to its high specificity and good interobserver variability. Tola et al.[22] also found that the combined use of CDU and BFI provided a better diagnostic accuracy than either method alone. Thus, CDUS can be a more confidential surveillance modality after EVAR. Invasive diagnostic tools should only be required in case of inadequacy of non-invasive tests or detection of endoleaks or sac enlargement. In this way, the cost-effectivity of the EVAR procedure can be improved.

Limitations for CDUS include its high rate of operator dependency and some patient characteristics such as obesity, abdominal gaseous distension, ascites, severe calcification which can negatively influence or serves for the technical difficulty in obtaining a clear sonographic window. However, changing the angle and position of the probe almost always provides solutions to overcome this limitation. Besides this, both of the radiologists performing the CDUS in our study were highly specialized in Doppler ultrasound. Another limitation is the detection of structural abnormalities within the endograft. Some mandate the inclusion of an abdominal X-ray as part of any protocol. Nevertheless, this is not compulsory, as such structural changes do not cause any clinical deterioration.

In the present study, we hypothesized that BFI could be more advantageous than CDUS. However, the outcomes revealed no superior mode. The CDUS seems to be operator-dependent, which may be a limitation of this study. Nevertheless, all the ultrasound examinations were performed by two highly specialized radiologists which may be the reason why the two modes displayed no significant difference. However, type I and type III endoleaks can be easily detected by Doppler USG. Furthermore, the aneurysm diameter and sac measurements can be done using Doppler USG with high sensitivity. Furthermore, the small sample size included in this study, compared to previous studies, may be another limitation.

In conclusion, CDU and BFI revealed no superiority to each other in the detection of endoleaks. They should be used in combination as a confirmatory test. Blood flow images may be more demonstrable; however, their accuracy is the same. The findings of the study suggest that CDUS can be used effectively in monitoring type I and type III endoleaks and in detecting cases requiring an intervention. Inadequacy in detecting type II endoleaks may be negligible, as sac enlargement is the key for reintervention in this case, and CDUS has a very high correlation with CTA in the sac diameter measurement.

Declaration of conflicting interests

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