Duplex Ultrasound versus Computed Tomography for the Postoperative Follow-Up of Endovascular Abdominal Aortic Aneurysm Repair. Where Do We Stand Now?

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Abstract

In the last decade, endovascular aneurysm repair (EVAR) has rapidly developed to be the preferred method for infrarenal abdominal aortic aneurysm repair in patients with suitable anatomy. EVAR offers the advantage of lower perioperative mortality and morbidity but carries the cost of device-related complications such as endoleak, graft migration, graft thrombosis, and structural graft failure. These complications mandate a lifelong surveillance of EVAR patients and their endografts. The purpose of this study is to review and evaluate the safety of color-duplex ultrasound (CDU) as compared with computed tomography (CT), based on the current literature, for post-EVAR surveillance. The post-EVAR follow-up modalities, CDU versus CT, are evaluated questioning three parameters: (1) accuracy of aneurysm size, (2) detection and classification of endoleaks, and (3) detection of stent-graft deformation. Studies comparing CDU with CT scan for investigation of post-EVAR complications have produced mixed results. Further and long-term research is needed to evaluate the efficacy of CDU versus CT, before CDU can be recommended as the primary imaging modality for EVAR surveillance, in place of CT for stable aneurysms.

Keywords

- EVAR surveillance
- post-EVAR follow-up
- CDU vs CT

During the last decade abdominal aortic endovascular aneurysm repair (EVAR) grows rapidly and tends to dominate over the open surgery.

EVAR in patients with suitable anatomy as a method of minimally invasive surgical technique has advantages over open restoration, such as minimizing the surgical trauma and tissue injuries, the need for transfusion and the postoperative pain as well as less perioperative mortality and morbidity

especially in patients with comorbidities such as respiratory failure and coronary artery disease.^{1–9}

Potential disadvantage is the need for long-term follow-up combined with imaging modalities due to high risk of endoleaks and late endograft failure. Contrast-enhanced computed tomography (CT) was until recently the preferred method for monitoring of endoleaks, patency of the graft, and measurement of the aneurysmal sac.¹⁰ Target

practice, recommended by all manufacturers of implants in the user instructions on the packaging, was conducting radiographs and CT with intravenous (IV) contrast agent after 1, 6, 12, 18 months, and annually.

The current guidelines of the Society for Vascular Surgery for monitoring after EVAR recommend contrast-enhanced CT initially after 1 month and 12 months. An additional CT scan if an abnormality is diagnosed in the first CT, and color-duplex ultrasound (CDU) annually thereafter if the aneurysm is stable.^{11,12}

The need for lifelong surveillance of patients who have undergone EVAR and the cost-effectiveness against open repair is a disadvantage of the EVAR.^{13–18} It has been estimated that over 65% of postoperative costs after EVAR are due to CT follow-up.¹⁹ Other disadvantages include increased cost itself, exposure to radiation,^{20–23} kidney failure, and allergic complications to the IV contrast.^{22,24} The incidence of renal disease due to the IV contrast agent in CT angiography (CTA) has been estimated to be ranging from 7 to 12%.^{4,22,24,25}

Many recent studies support that CDU is a safe and effective alternative for the follow-up of EVAR^{26–47} even though it has several disadvantages: it is operator-dependent and its results are influenced by the patient's obesity, presence of bowel gas or large hernias in the abdominal wall. The purpose of this study is to review current literature for the effectiveness and safety of the CDU as compared with CT for post-EVAR surveillance.

Imaging Testing Requirements

According to the guidelines^{48,49} of the International Society of Interventional Radiology, the imaging that can be used for the post-EVAR follow-up, should include at least three parameters: (1) measurement of the aortic aneurysm, (2) identification and classification of endoleaks, and (3) detection of stent-graft deformation.

The EVAR's goal is the prevention of the rupture of the abdominal aortic aneurysm (AAA). The gradual reduction in size of the aneurysmal sac is believed to be a strong indication for reducing the risk of the rupture.⁵⁰ In contrast, the increase in diameter of the aneurysm after EVAR is associated with an increased risk of rupture.⁵¹

Therefore, the accuracy of measurement of the exact diameter is crucial. Monitoring of the aneurysmal volume is considered by some authors as a more objective and precise parameter compared with the measurement of the diameter of the AAA.^{52,53} Even though changes in aneurysmal volume comports with changes in the maximal diameter, they are not more strongly associated with the presence of an endoleak. Their predictive value with regards to the risk of rupture remains to be evaluated. Nevertheless, there is a controversy about the practical use of volume measurement for post-EVAR follow-up.⁵⁴ The imaging modality should indicate with accuracy the starting point of the endoleak as well as the direction, and the size of the sac. However, in both the techniques, CDU and CT there are cases where an endoleak cannot be detected.⁵²

Aortic remodeling after endovascular repair may lead to structural changes in the introduced stent-grafts as deformation of the metal frame, angulation, displacement, damage or even decay, which can cause serious complications, including rupture.^{52,55–59} For these reasons, the above complications should be identified by the appropriate imaging test and treated appropriately.

Methods

A multiple electronic health database search was performed using PubMed, Medline, Ovid, Embase, and the Cochrane Database, on all accessible published articles between 1995 and 2013 referring to post-EVAR surveillance. The search was limited to articles in English, using terms such as: "abdominal aortic aneurysm repair," "EVAR surveillance," "post EVAR follow up," "ultrasound," "contrast enhanced ultrasound," "computed tomography," "computed angiography," "endoleak detection," "endovascular repair," "graft migration," "graft transposition," in combination with the Boolean operators AND or OR. Studies including suprarenal aortic endografts, thoracic aneurysms or aortic dissection or small number of patients (under 20 years), were excluded. The references of all obtained articles were examined for further relevant citations. The full texts of the articles were retrieved.

Results

The electronic literature search yielded 35 articles comparing ultrasound (CDU and/or enhanced-CDU [ECDU]) with CT for the post-EVAR follow-up. The number of patients, kind of CT scans performed, CDU and/or ECDU evaluation in detecting endoleaks (sensitivity/specificity) are demonstrated in ► **Table 1**.^{26–47,60–71} CT was taken as the standard imaging modality for the estimation of sensitivity and specificity.

There was a substantial heterogeneity among the studies due to the following reasons:

1. The wide range of the number of patients enrolled in each study (20–561).
2. Variation in CT protocol (CT or CTA, arterial phase, biphasic or triple phase).
3. The interobserver reliability for the ultrasound imaging, which was not defined with the exception of two studies: (a) Zannetti et al in 2000, evaluated the interobserver agreement in endoleak detection (κ analysis value = 1) and in a type of endoleak (κ = 0.7) in 50 random duplex examinations. (b) Lezzi et al in 2009, estimated that the interobserver agreement in all reading sessions of ECDU for endoleak detection was high (κ analysis value $\geq$ 0.89).

In six studies all the ultrasound examinations were conducted by one single vascular sonographer. CDU or ECDU were performed by experienced vascular technologists in 18 trials. There is no information reported about the CDU/ECDU operators for the rest 11 studies. Moreover, differences in ultrasound equipment quality, particularly in the earlier studies with less advanced ultrasound instruments, have not been evaluated.

Table 1 Studies comparing CDU or ECDU versus CT for detection of endoleak after EVAR

Author	Year	No. of patients	Specific type of CT	CDU	ECDU	US operators (number/ κ score)
				(Sensitivity/ specificity)		
Heilberger et al ²⁶	1997	102	CT	95/95	97/NR	
Sato et al ²⁷	1998	79	CTA	97/74		
Thompson et al ²⁸	1998	20	CT	100/100		
Zanneti et al ²⁹	2000	103	Axial, spiral CT	92/98		2 ($\kappa = 1$)
Wolf et al ³⁰	2000	76	Helical CT	81/95		r
Fletcher et al ³¹	2000	36	CT	100/100		
d'Audiffret et al ³²	2001	89	Helical CT	96/94		
Pages et al ³³	2001	40	Spiral CT	48/93		3
Parent et al ³⁴	2002	83	Helical CT-triple phase	100/NR		r
McLafferty et al ³⁵	2002	79	Helical CT	100/99		
McWilliams et al ⁶⁰	2002	51	CT-biphasic	12/94	50/74	1
Giannoni et al ³⁶	2003	26	CTA	63/93	100/65	
Bendick et al ³⁷	2003	20	CTA-triple phase	NR	100/100	r
Raman et al ⁶¹	2003	281	Helical CT	43/96		
Elkouri et al ⁶²	2004	107	Helical CT	25/89		r
Napoli et al ⁶³	2004	30	CTA-biphasic	↓ NR	100/NR	1
AbuRahma et al ⁶⁴	2005	178	CT	68/99		
Dill-Macky et al ⁶⁵	2007	20	CTA-biphasic		75/88	1
Sandford et al ⁶⁶	2006	310	Spiral CT	67/91		r
Henao et al ³⁸	2006	20	CTA-biphasic		100/100	
Collins et al ³⁹	2007	160	Helical CT	100/100		r
Tomlinson et al ⁴⁰	2007	93	CT	↑ NR		
Chaer et al ⁴¹	2009	184	Helical CT	↑ NR		r
Beeman et al ²⁵	2009	199	Spiral CT-triple phase	71/99		3
Iezzi et al ⁴²	2009	84	Multislice CTA-triple phase		98/82	1($\kappa \geq 0.89$)
Schmieder et al ⁶⁷	2009	236	CT	64/84		r
Manning et al ⁶⁸	2009	117	CTA-biphasic	86/67		3
Bargellini et al ⁶⁹	2009	196	CTA-triple phase	63/98		1
Ten Bosch et al ⁴³	2010	83	CTA-triple phase		↑NR	3
Nagre et al ⁷⁰	2011	561	CTA	35/95		r
Cantisani et al ⁴⁴	2011	108	CTA-triple phase	58/93	96/100	2
Harrison et al ⁷¹	2011	194	CTA-arterial phase	NR		r
Perini et al ⁴⁵	2011	395	CTA-triple phase		100/100	3
Gürtler et al ⁴⁶	2013	132	Multislice CT		97/73	1
Millen et al ⁴⁷	2013	33	CTA-arterial phase		100/100	r

Abbreviations: ↑, high; ↓, low; CDU, color duplex ultrasonography; CT, computed tomography; CTA, computed tomography angiography; ECDU, enhanced duplex ultrasonography; EVAR, endovascular aneurysm repair; NR, not recorded; r, registered vascular operators reported; US, ultrasound.

Discussion

Facts Regarding Computed Tomography

CT with or without angiography was until recently the most widely used imaging test to detect endoleaks, patency of the graft, and measurement of the aneurysm sac in several

protocols.¹⁰ It is considered to be the preferred imaging method to measure the diameter of the aneurysm with a sensitivity and specificity around 100%, even in cases with the marked convolution of the aorta using a reconstruction of multiple CT slices. The values of specificity and sensitivity of

CT (92 and 90%, respectively) in the identification of endoleaks has been estimated to be higher than those of classical digital angiography (DSA) (63 and 77%).^{72,73} However, it is stated that:

1. If an endoleak is very small, it could not be detected on CT.⁷³
2. Determining the direction of flow endoleaks and the artery responsible for this with only the CT imaging is very difficult.
3. In addition, CT is not the ideal test for the classification of endoleaks as a 14% error is estimated as compared with the selective DSA.⁷⁴
4. Identifying endoleaks depends largely on the protocol of the CT conduction.⁷⁵ This can be: (a) single phase with only arterial phase, (b) biphasic (without contrast and arterial phase or arterial phase and delayed shots), or (c) three-phase (without contrast, arterial phase and delayed shots). The views on the necessity and the phase of CT without contrast and poor shots are conflicting.^{72,75–78}

The diagnostic value of CT performed in the arterial phase for detecting endoleaks itself is lower than that achieved by the two-phase CT protocol.⁷⁷ The CT sections in arterial phase help to identify the exact point of the endoleak. The combination of the arterial phase and late shots aim at the identification of the low flow endoleak that can escape if we only use the arterial phase alone. Other possible complications after EVAR can be diagnosed on CT such as infection, thrombosis, obstruction, angulation, or migration of the graft.

Major difficulties in monitoring patients who have undergone EVAR, using CT are as follows:

1. Exposure to ionizing radiation,^{20,21,79–81} which has been linked to carcinogenesis.
2. Use of IV contrast agent that can cause kidney disease or allergy (the incidence of renal disease due to IV contrast agent in CTA has been estimated to be 7 to 12%).^{4,22,24,25}
3. The increased costs^{13–17}: it has been estimated that over 65% of postoperative costs after EVAR are due to CT (►Table 2).¹⁶

Facts Regarding Color Duplex Ultrasound

The use of ultrasound in screening of patients with AAA,⁸² is widely accepted, but there are conflicting opinions on the effectiveness of the CDU in post-EVAR surveillance. CDU is noninvasive, easily accessible (potentially portable ultrasound system if necessary), and reproducible with low cost and neither radiation nor nephrotoxicity (no IV contrast media).⁴¹

The accuracy in measuring the diameter of the aneurysm by ultrasound is comparable to that of CT and less affected by whorls and aortic angulations especially over 25 degrees.⁸³ Often, the diameter is underestimated to a small extent by ultrasound as compared with the measurement by CT. Identifying endoleaks by ultrasound requires the use of CDU. Although, the reported specificity of endoleak identification by CDU is high (89–97%), there are conflicting opinions on the CDU sensitivity and diagnostic values as compared with the corresponding indexes of CTA. In some studies, it is reported

Table 2 Advantages and disadvantages of CT/CTA

Advantages
Highly reproducible
Not dependent on patients body weigh
Faster picture analysis
Disadvantages
Contrast agent nephrotoxicity
High cost
Radiation
False negative or endotension

Abbreviations: CT, computed tomography; CTA, computed tomography angiography.

that the predictive value of CDU is higher^{26–32,35,37,39} while others estimated that the sensitivity of CDU is less than that of CT.^{60,62,64,66,84} CDU has a great advantage over CTA for the identification of endoleaks' flow direction because this parameter is difficult to be assessed by CTA. Disadvantage of the CDU is that its results are influenced by the examiner, bowel gas, possible patient's obesity, and presence of a large hernia in the abdominal wall (►Table 3). Moreover, it requires the patient to observe fast for at least 6 hours before the examination. The development of the technological systems and ultrasound imaging techniques reduced the influences of these limitations and increased the diagnostic value of the CDU. The use of contrast agents is an application that is noninvasive, reproducible, relatively rapid, well tolerated by the patient, and increases the sensitivity of the test.^{26,37,38,63,85} Cases of low flow endoleaks or endotension that CTA could not identify, have been detected by ECDU.^{38,85}

Comparison of Computed Tomography and Color Duplex Ultrasound

Studies that compare CT with CDU in the diagnosis of endoleaks have exported conflicting results (►Table 1). Certain studies suggested that the predictive value of CDU is higher,^{26–28,30–32,35,37,39} while others estimated that the sensitivity of CDU is less than that of CT^{60–62,64,66,84} particularly with regard to the identification of type II endoleak.^{60,64,84} Sato et al²⁷ and d'Audiffret et al³² argue that CDU is an excellent test for identifying endoleaks with sensitivity 97 and 96%, respectively. Schmieder et al estimated that CDU in detecting endoleaks that require restoration, has a sensitivity of 90%, specificity 81%, negative predictive value 99%, and positive predictive value of 16% as compared with 58, 87, 98, and 15% of the corresponding indices of CT.⁶⁷ Beeman et al support that the endoleak identification by CDU is as (or even more than) accurate as by CT. As it was estimated that the negative predictive value was 2.5% versus 5.5% that of CT.²⁵ The same authors in 2010 announced the results of their study in 278 patients who underwent EVAR, between 1998 and 2009, and follow-up with CDU. Parameters measured by CDU, as the diphasic range of wave Doppler (spectral Doppler waveform) and the persistent endoleaks

Table 3 Advantages and disadvantages of CDU

Advantages
Low cost
Portable
Static and Dynamic information
Disadvantages
Examiner dependent
Longer time of examination
Dependent on patient body
Dependent on patient body habitus
Dependent on the quality of the equipment

Abbreviation: CDU, color duplex ultrasound.

type II, were the strongest predictors of increasing AAA diameter and therefore of a secondary intervention to avoid rupture.⁸⁶ Instead, McWilliams et al⁶⁰ evaluated the CDU sensitivity in identifying endoleaks at the low value of 12%, Elkouri et al⁶² 25%, and Nagre et al 35%.⁷⁰

Other studies in the recent years support that color ultrasound is safe and effective examination not only in measuring the size of the aneurysmal sac, but also in diagnosing possible complications after EVAR,^{37,39,40} if intravenously administered soluble contrast medium is used (ECDU). The use of ECDU was first announced in 1997 by Heilberger et al, in a study of 113 patients after EVAR, where the efficacy between the ECDU and CT for the post-EVAR follow-up was compared.²⁶ In their study, only one endoleak was not detected by ECDU (because of bowel gas) and the test sensitivity was estimated at 97%. Moreover, three type II endoleaks were diagnosed by ECDU that were not detected in CT. This result indicates that the ECDU may be more sensitive in identifying endoleak type II than CT. Bendick et al in 2003 estimated that ECDU is highly sensitive in identifying and classifying endoleaks type I and type II.³⁷ In addition, it is reported that the contrast medium that is used for EDCU is less nephrotoxic than the contrast substances that are administered for CT and rarely causes side effects. However, the criteria for exclusion in the ECDU protocol they used, included patients with known cardiac communications from right to left, lung disease, liver disease, hypersensitivity or allergy to albumin and its derivatives, and premenopausal women.

Cantisani et al estimate that while CDU is not suitable and adequate for the post-EVAR follow-up (sensitivity and specificity: 58 and 93%), ECDU (sensitivity and specificity: 96 and 100%) has little more accuracy in identifying and classifying endoleaks than CTA (sensitivity and specificity: 83 and 100%).⁴⁴ In the meta-analysis conducted by Mirza et al it was estimated that CDU is less sensitive than ECDU concerning the endoleak identification.⁸⁷ They conclude that although the ECDU imaging is highly sensitive, further research is needed to determine whether this may be the proposed examination for the follow-up after EVAR.

Tomlinson et al in 2007 reported the results of their retrospective study in 415 patients who had undergone EVAR within the last 8 years and had a mean follow-up of 18 months.⁴⁰ Of these, 93 patients (76%), 1 year after the surgery, were observing the following criteria: (1) stable or shrinking aneurysmal sac and (2) no endoleak was present at 1 year follow-up. Only 2 of the 93 patients required secondary surgery to confront a complication that was diagnosed by CDU without the need for CT. In that study, it was concluded that the available data may support the hypothesis that patients who meet the above criteria are unlikely to present a complication, which cannot be diagnosed by CDU. Therefore, a year after the EVAR, these patients do not require monitoring with CT.

Based on the previous reports and their own studies, some researchers (such as Sternbergh et al and Go et al in 2008) recommend that post-EVAR follow-up with only imaging the CDU is suitable for patients with no endoleak or increased aneurysmal sac in the 1st year CT.^{12,88,89} In cases, where an increased size of the aneurysmal sack or endoleaks are detected by CDU, a CT should be performed. In addition, they support that the 6 months CT, can be avoided if endoleak is not detected in the 1st month CT after EVAR.

Lezzi et al in 2009, compared ECDU imaging with CT and obtained a sensitivity of 98% and specificity of 82%. They supported that ECDU imaging is reliable and a valid alternative to multislice CTA for endoleak detection, certainly superior to CDU.⁴²

In 2009, Chaer et al suggested that the post-EVAR follow-up of selected patients (initially included patients with aneurysmal sac less than 4 cm and extended to those who have a stable size 2 years after EVAR, with or without stable endoleak type II) may be safely done only by CDU, early postoperatively.⁴¹ However, they reported that their initial experience with the older CDU equipment in the endoleak identification was disappointing.

In the same year, the guidelines of the Society for Vascular Surgery¹² were published and recommended which included:

1. CT with IV contrast agent 1 and 12 months after EVAR (level of recommendation: strong and quality of evidence: high).
2. If in the 1st month CT an alarming endoleak or other abnormal medical imaging is detected, an additional CT at 6 months should be conducted to assess the exclusion or nonexclusion of the aneurysm (level of recommendation: strong and quality of evidence: high).
3. If endoleak or increase of the aneurysm are not diagnosed during the 1st year of the EVAR, thereafter CDU is an important alternative follow-up examination, proved that CDU is performed by reliable operators in adopted ultrasound laboratories (level of recommendation: weak and quality of evidence: low).
4. It is recommended from the start, post-EVAR follow-up with CDU or CT without a contrast agent to patients with renal failure (level of recommendation: strong and quality of evidence: high).

5. If an endoleak type II is diagnosed, initially a follow-up with CT is recommended for assessing increase or regression of the aneurysmal sac. If it remains stable or is shrinking, then the surveillance can be continued by CDU (level of recommendation: weak and quality of evidence: low).
6. The detection of a new endoleak, whereas previous tests suggested complete exclusion of the aneurysm, needs assessment for type I or III endoleak (level of recommendation: strong and quality of evidence: high).
7. Given the risk of developing para-anastomotic aneurysms or thoracic aneurysm CT without contrast every 5 years after open or endovascular AAA repair is recommended (level of recommendation: strong and quality of evidence: high).

Perini et al in 2011, based on their large case series of patients followed up with both ECDU and CTA, demonstrated a good agreement in aneurysmal sac diameter evaluation and the same efficacy in endoleak detection. They supported that even though ECDU cannot be proposed as the sole imaging modality for the post-EVAR surveillance it can replace most of the CTA. In their center, 6- and 24-months CT scans have been replaced (and yearly thereafter) by ECDU.⁴⁵

In 2013, Gürtler et al reported high sensitivity and specificity values (97 and 93%, respectively) of ECDU and suggested that a switch of the preferred examination from CT to ECDU imaging should be considered.⁴⁶ The same year, Millen et al reported the results of their cohort of 33 patients who had post-EVAR surveillance based on plain abdominal radiographs and ECDU with single arterial CTA reserved for abnormalities or nondiagnostic imaging.⁴⁷ They concluded that ECDU was able to resolve the clinical issue of endoleak detection and classification, resulting in secondary intervention in 10 patients (30%). In accordance with other studies (Parent et al³⁴ and Harrisson et al⁷¹) Millen et al agreed that duplex ultrasound scan (DUS) imaging is superior to CT scan in the detection of endoleaks because it provides hemodynamic information.

Further studies are needed to guarantee the effectiveness of modified protocols. It is mentioned, that while the risk of the endoleak detection decreases with the increasing of the negative post-EVAR imaging modalities, new endoleaks may occur much later in the follow-up period.¹² Moreover, the recommendations of global conferences suggest that the endoleaks type II, even when there is no increase in the size of the aneurysm sac should be monitored with CT every 6 months. Although, endoleaks type II regarding small or shrinking aneurysms are characterized, in most cases, by benign natural history and evolution. Therefore, further studies may possibly conclude that CDU every 6 or 12 months is a reasonable and reliable alternative imaging examination during the post-EVAR follow-up, particularly with regard to aneurysms with a diameter not larger than 6.5 cm.¹²

The study "acute pressure measurement to confirm aneurysm exclusion trial," confirmed that the pressure and pressure changes within the aneurysmal sac can be reliably measured, noninvasively, using pressure sensors.⁹⁰ For the

evaluation and assessment, alternative to CT and color ultrasound, post-EVAR follow-up methods, that are being developed, such as algorithms designed to identify significant endoleaks, through changes in pressure within the aneurysmal sac, measured by the pressure sensors.

Conclusion

Early detection of complications during the post-EVAR surveillance remains the major challenge for the follow-up of these patients. CT of the upper and lower abdomen with IV contrast agent was until recently the preferred imaging for monitoring endoleaks and patency of the graft and measurement of the aneurysmal sack after EVAR in various protocols. Recent studies support that the color ultrasound is safe and effective test for measuring the size of the aneurysmal sac and diagnosing possible complications after EVAR. Future studies may conclude that CDU every 6 or 12 months is a reasonable and reliable alternative imaging examination during the post-EVAR follow-up, particularly with regard to aneurysms with a diameter not larger than 6.5 cm.

Further long-term research studies are needed to evaluate the efficacy of CDU versus CT, before CDU can be recommended as the primary imaging modality for the post-EVAR surveillance, in place of CT for stable aneurysms.

Summary

The early detection of complications during the post-EVAR surveillance that are likely to lead to aneurysm rupture, if not remedied, remains the major challenge for the follow-up of these patients. CT of the upper and lower abdomen with IV contrast agent was until recently the preferred (gold standard) imaging for monitoring endoleaks and patency of the graft and measurement of the aneurysmal sac after EVAR in various protocols.

Recent studies monitoring patients, after EVAR and as international experience is growing, used protocols that require CT with contrast agent at intervals less frequently. The need for continuous surveillance for life of patients who have undergone EVAR, because of possible complications, questioned the value of cost-effectiveness of endovascular surgery itself against open surgical AAA treatment.

Due to the disadvantages of CT for post-EVAR monitoring alternative imaging methods have been suggested such as the color ultrasound (CDU or triplex). Studies in recent years report that color ultrasound is safe and effective test for measuring the size of the aneurysmal sac and diagnosing possible complications after EVAR. CDU examination is non-invasive, easily accessible (and with the possibility of portable ultrasound system), and reproducible with low cost and no radiation and nephrotoxicity. Although, the reported specificity of CDU in the identification of endoleaks is high (89–97%), sensitivity and diagnostic value compared with the corresponding indices of axial angiography is a matter of conflicting views. Some studies suggest that the predictive value of CDU is higher, while others estimated that the sensitivity of CDU is less than that of CT.

The identification of the flow direction of the endoleak by DUS has great advantage over CTA, because by the latter this parameter is difficult to be assessed.

A disadvantage of CDU is that its results are depending on the examiner, the gas bowel, the patient's body weight, and the presence of a large hernia in the abdominal wall. Moreover, CDU requires preoperative fasting of the patient. The development of technological systems and ultrasound imaging techniques have helped in the reduction of the influence of these limitations and increased the diagnostic value of the CDU. The use of contrast agents in the CDU (ECDU) is an application that is noninvasive, reproducible, relatively rapid, and well tolerated by the patient (if they have no nephropathy or allergy to the contrast agent), which increases the sensitivity of the test. Cases of low flow endoleak or endotension that cannot be diagnosed by CTA can be detected by ECDU.

It is mentioned, that while the risk of the endoleak detection decreases with the increasing of the negative post-EVAR imaging modalities, new endoleaks may occur much later in the follow-up period. Moreover, the recommendations of global conferences suggest that the endoleaks type II, even when there is no increase in the size of the aneurysm sac should be monitored with CT every 6 months. Although, endoleaks type II regarding small or shrinking aneurysms are characterized, in most cases, by benign natural history and evolution. Therefore, supplementary studies may possibly conclude that CDU every 6 or 12 months is a reasonable and reliable alternative imaging examination during the post-EVAR follow-up, particularly with regard to aneurysms with a diameter not larger than 6.5 cm.

Further studies are needed to guarantee the effectiveness and safety of the modified protocols which require the performance of CT with IV contrast agent at intervals less frequently, for the post-EVAR follow-up.

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