Duplex ultrasound in aneurysm surveillance following endovascular aneurysm repair: a comparison with computed tomography aortography

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Objectives: **Cumulative radiation dose, cost, and increased demand for computed tomography aortography (CTA) suggest that duplex ultrasonography (DU) may be an alternative to CTA-based surveillance. We compared CTA with DU during endovascular aneurysm repair (EVAR) follow-up.**

Methods: **Patients undergoing EVAR had clinical and radiological follow-up data entered in a prospectively maintained database. For the purpose of this study, the gold standard test for endoleak detection was CTA, and an endoleak detected on DU alone was assumed to be a false positive result. DU interpretation was performed independently of CTA and vice versa.**

Results: **One hundred thirty-two patients underwent EVAR, of whom 117 attended for follow-up ranging from six months to nine years (mean, 32 months). Adequate aneurysm sac visualisation on DU was not possible in 1.7% of patients, predominantly due to obesity. Twenty-eight endoleaks were detected in 28 patients during follow-up. Of these, 24 were initially identified on DU (four false negative DU examinations), and eight had at least one negative CTA with a positive DU prior to diagnosis. Twenty-three endoleaks were type II in nature and three of these patients had increased sac size. There was one type I and four type III endoleaks. Two of these (both type III) had an increased sac size. Of 12 patients with increased aneurysm size of 5 mm or more at follow-up, five had an endoleak visible on DU, yet negative CTA and a further five had endoleak visualisation on both DU and CTA. Of six endoleaks which underwent re-intervention, all were initially picked up on DU. One of these endoleaks was never demonstrated on CTA and a further two had at least one negative CTA prior to endoleak confirmation. Positive predictive value for DU was 45% and negative predictive value 94%. Specificity of DU for endoleak detection was 67% when compared with CTA, because of the large number of false positive DU results. Sensitivity for DU was 86%, with all clinically significant endoleaks demonstrated on CTA also detected on DU.**

Conclusion: **Despite its low positive predictive value, we found DU to be a sensitive test for the detection of clinically significant endoleaks. Given concerns about cumulative radiation exposure and cost, and the surprisingly low sensitivity of CTA for endoleak detection in this series, selective CTA based on DU surveillance may be a more appropriate long-term strategy. (J Vasc Surg 2009;49:60-5.)**

Endovascular aneurysm repair (EVAR) has been widely adopted as a first line approach for the treatment of aortic aneurysmal disease, particularly of the infrarenal aorta. Uncertainty about the long term durability of endovascular grafts as well as the known association between persistent pressurisation of the aneurysm sac and aneurysm enlargement and subsequent rupture has made long term surveillance of the aneurysm sac and the aortic stent a requirement for all patients following EVAR.[1] There has been much debate about the ideal surveillance program, the frequency of imaging required, and the optimal imaging strategy. Most centres use a combination of computed tomography aortography (CTA), duplex ultrasound (DU) scanning, and plain abdominal radiography at six-month or yearly intervals. However, concerns about the cumulative effects of radiation from repeat CTA, and the resources involved have led some to question whether duplex ultrasound could replace CTA scanning.[2,3] In the current study, we aimed to compare the results of DU surveillance of endovascular grafts with those of CTA surveillance of the same patients, in order to determine whether patient follow-up could be safely based on DU surveillance alone, with CTA reserved only for those patients with positive, equivocal, or inconclusive DU.

METHODS

All patients undergoing endovascular aneurysm repair between 1996 and 2007 were entered into our surveillance program and all clinical and radiological follow-up data as well as treatment details were entered in our prospectively maintained vascular database. Our surveillance program

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consists of CTA performed six to eight weeks post-operatively, at one year, and yearly thereafter, along with a plain abdominal radiography, anteroposterior (AP), and lateral views. Surveillance CT scans were biphasic, with initial non-contrast, followed by arterial phase scans. As follow up progressed in the absence of endoleak or increase in sac size, the initial non-contrast component was omitted and arterial phase only performed, using the previous non-contrast scan as a reference. Where endoleak was suspected but not confirmed, or an increase in sac size noted, the patient was recalled for a triphasic CTA using non-contrast, arterial phase, and delayed phase CTA. Digital subtraction aortography was performed selectively in patients with endoleak or increase in sac size demonstrated on DU, CTA, or both. DU was performed post-operatively and at six-month intervals for the duration of follow-up, along with physical examination. DU was performed by one of three experienced vascular technicians using an ATL HDI 5000 or IU22 ultrasound systems (Philips Medical Systems, Bothell, Wash) with a 3.5 MHz transducer probe. Briefly, patients were examined in the supine position with the head slightly elevated at 10°. B-mode imaging was initially used to identify the aorta, and maximum diameter of the aneurysm sac was measured in the transverse plane. Patency of the renal arteries was confirmed using spectral Doppler. The aorta was scanned from the superior attachment of the endograft to the inferior point in both transverse and saggital planes in B mode. Using color and spectral Doppler, the stent was assessed for perigraft flow, graft stenosis, thrombosis, or kinking. We do not use intravenous contrast material during DU, nor do we request that our patients fast overnight.

For the purpose of comparison for this study, CTA was used as the gold standard test with which DU was compared. The principal end point taken in this study was detection of endoleak. If a patient had endoleak detected on CTA, which was also demonstrated on DU, this was regarded as a true positive result. An endoleak on DU not found on CTA was a false positive, and an endoleak found on CTA but not picked up on DU was a false negative. We defined reintervention in this study as any planned therapeutic intervention which occurred during the course of follow-up (ie, during the surveillance period, and not in the immediate post-operative period). We have excluded diagnostic aortograms performed without intention to treat. Data regarding aneurysm sac size on CTA and on DU was also recorded and change in sac size of 5 mm or more in the course of follow-up was reported as a significant increase or decrease for the purposes of this comparison. In all cases, the ultrasonographer was blind to the result of the CTA and vice versa, with both CTA and the corresponding DU performed on the same day in nearly all cases. After the initial six-month period, twice as many DU examinations as CT examinations were performed as per our protocol. However, if DU was positive for the presence of endoleak within six months of a previously negative CTA, a further CTA was also performed at that time and the results compared.

RESULTS

Of 132 patients who underwent EVAR between April 1996 and May 2007, 117 had at least six months of recorded follow-up based on a protocol including CTA, DU, and plain radiography. The mean age of these patients was 74 ± 8 years (mean ± SD; range, 51 to 88 years) with a male to female ratio of 5.2:1. The mean duration of follow up was 32 ± 24 months (range, 6 to 108 months). Overall 462 CTA scans were performed (406 predicted from protocol) and 809 DU scans (857 predicted). The additional studies were usually performed if endoleak was suspected or an initial scan was inconclusive. Four hundred and six paired examinations were performed, with DU and CTA performed on the same day in almost every case. Remaining DU scans were either perioperative scans, or six-monthly scans between the annual CT, so in almost all cases DU was done within six months of the CT scan, if not on the same day as the scan. In 1.7 % of cases DU was inconclusive, in all cases due to obesity.

In all, endoleaks were detected in 28 patients during the course of follow-up, one type I, 23 type II, and four type III, (one of these being from late fabric porosity [Table I]). In 24 of 117 cases, endoleak was detected on both DU and CTA, regarded as true positives for DU. Of these 24 patients, eight patients had a least one normal CTA scan following a positive DU before the endoleak was demonstrable on CTA. In 54 of 117 patients both CTA and DU reported no evidence of endoleak (true negatives). There were 33 patients with false positive DU scans, endoleaks reported that were not confirmed by CT. Of these false positives, four were positive for endoleak at the time of the perioperative DU only and so, with no CT comparison immediately postoperatively, these were not included as false positives in further analysis. Two more cases were positive at the six week scan with negative CT and subsequent DU scans negative. In four cases called false positives, the positive DU was associated with an increase in aneurysm sac size, despite a negative CT scan. In one of these cases, a type III endoleak (due to increased fabric porosity) was eventually diagnosed at aortography and further intervention was undertaken.

Of the 28 endoleaks detected and confirmed, 23 of these were type II, and 13 of these occurred and were detected perioperatively, within six weeks of EVAR. A further five were detected within the first year, with five more being detected subsequent to this and the latest at 53 months post-EVAR. One Type I endoleak was detected on the first post-operative DU, as was one type III, with the remaining three type III endoleaks detected at 42, 44, and 78 months post-treatment. In all but two cases, where endoleaks were detected on DU, endoleak was also reported on a least one subsequent scan, and in the two cases where the follow-up scan was negative, follow-up CT also confirmed resolution of the endoleaks. Of 23 type II endoleaks detected, eight had resolved at the time of last follow-up.

Table I. Endoleaks detected during follow-up

Patient	*Endoleak type*	*Time from EVAR (months)*	*Duplex positive*	*CTA positive*	*Sac size*	*Re-intervention*
1	II	60	Yes	Yes	↓	No
2	II	14	Yes	No*	↓	No
3	II	30	Yes	No*	↓	No
4	III	66	Yes	No*	↑	Yes
5	III	44	Yes	No*	↑	Yes
6	II	42	Yes	Yes	↓	No
7	II	12	Yes	Yes	↓	No
8	II	3	Yes	No*	↑	Yes†
9	III	24	Yes	Yes	↓	Yes
10	II	42	Yes	Yes	↓	No
11	II	3	No*	Yes	↓	No
12	II	2	Yes	Yes	↓	No
13	II	12	Yes	Yes	↔	No
14	II	2	Yes	No*	↔	No
15	II	2	No*	Yes	↑	No
16	II	6	No*	Yes	↓	No
17	II	6	Yes	Yes	↔	No
18	II	2	Yes	Yes	↓	No
19	II	2	Yes	Yes	↓	No
20	I	2	Yes	Yes	↓	Yes
21	III	72	Yes	No	↑	Yes
22	II	36	Yes	No*	↑	No
23	II	2	Yes	Yes	↔	No
24	II	2	Yes	Yes	↔	No
25	II	2	Yes	Yes	↓	No
26	II	2	Yes	Yes	↔	No
27	II	2	Yes	Yes	↔	No
28	II	2	No*	Yes	↔	No

CTA, computed tomography aortography; *DU,* duplex ultrasonography; *EVAR,* endovascular aneurysm repair.
*Endoleak initially negative on CTA, but positive on DU was subsequently identified on CTA also or vice versa.
†An intervention where digital subtraction angiography only was performed.

In four cases DU did not show an endoleak while CTA did. In all four cases, DU subsequently demonstrated the endoleak, and in all cases the endoleak was type II (see Fig 1). In only one case was there an association with increase in aneurysm sac size, and this was noted on DU. None of these patients have undergone further intervention to date. There were eight cases in which CTA may potentially have given falsely negative results. Five cases have shown increase in aneurysm sac size during the course of the follow-up, and DU has been positive for demonstration of endoleak. However CTA (triphasic) has not demonstrated endoleak. In a further three cases, CTA was reported as negative yet aneurysm sac size had increased and endoleak was subsequently diagnosed in a follow-up CT in two cases and at aortography in the third. Endotension in this study was defined as the presence of aneurysm sac enlargement in the absence of detectable endoleak, on triphasic CTA or DU, and two patients were in this category, both of whom had negative triphasic CTA as well as DU, and one of whom also had digital subtraction angiography, which failed to detect an endoleak.

Of those patients diagnosed with an endoleak, six have undergone re-intervention. In all six cases, DU was first positive for endoleak. In one case, endoleak was never detected on CTA (a late type III endoleak due to increased fabric porosity), and in two further cases, at least one negative CTA was performed following a positive DU prior to confirmation of the endoleak. Six endoleaks were associated with an increase in aneurysm sac size, three type III, and three type II.

The positive-predictive value for DU when compared with CTA (excluding DU results positive for early endoleak only) was 45%, with a negative predictive value of 94%. Sensitivity was calculated as 86% and specificity as 67%.

During the follow-up period, 32 patients were either lost to follow-up or died. There were no conversions to open repair in this series. There were two case of rupture. The first was a patient in whom aneurysm sac size gradually increased during the course of follow-up. DU always reported the presence of an endoleak, which was not identified by triphasic CT or by aortography. The patient died 39 months post-operatively, at which time a decision had already been taken that he was not fit for any further intervention due to end stage respiratory disease. Rupture was confirmed on CTA prior to the patient's demise. The second rupture occurred in a patient who presented acutely to another institution and underwent open repair. Prior to this, at his last follow-up 36 months postoperatively, aneurysm size had been unchanged since surgery and no endoleak was noted on CTA or on DU.

Overall, in terms of sac size, 38% of aneurysms remained unchanged (sac size within 5 mm of the pre-treatment value), 52% had decreased in size, and 10% showed an increase in size during the course of follow-up, confirmed

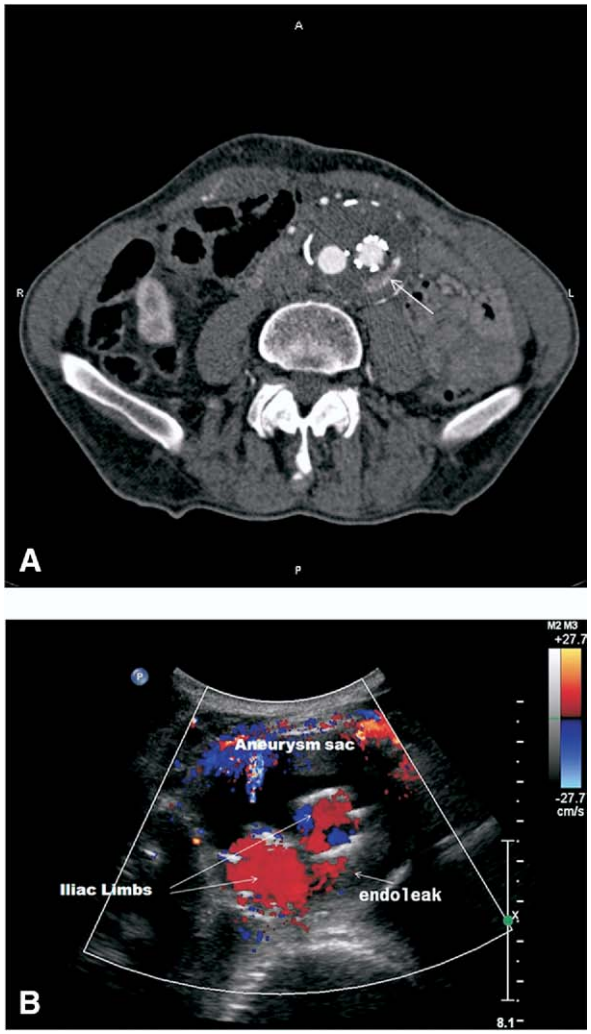

Fig 1. (A) An example of a type II endoleak as demonstrated on CTA. This was shown to originate from the inferior mesenteric artery, and was not associated with an increase in aneurysm sac size, and so was managed conservatively. **(B)** The same endoleak demonstrated on duplex ultrasonography. The iliac limbs of the bifurcated endovascular device are shown, with abnormal color flow visible in the aneurysm sac.

by both DU and CTA. As expected, those with endoleak confirmed were significantly more likely to have an increase in sac size during the course of follow-up ($P < .01$, Chi squared test). There were three cases of graft migration, detected on both CTA and plain radiographs, and all associated with the development of endoleaks (two type III and one type II), which required re-intervention. In all cases, endoleak was detected on DU.

DISCUSSION

When DU is compared with CTA as the gold standard, reported sensitivities have varied considerably, from 12 to 100%, with specificity ranging from 74-99% (see Table II).[4-9] In the present study, we report sensitivity of 86% and a negative predictive value of 94% for DU. Ramon et al reported their experience in the only other larger series with an equivalent follow-up time. Sensitivity for DU in this report was only 42.9%, and the authors concluded that DU could not replace CT scan in surveillance post EVAR. In that series, of 35 cases of endoleak detected on CTA, 28 of these were not picked up on DU.[9] This contrasts with our experience of 28 endoleaks, of which only four were not initially detected on DU. Such differences highlight the operator-dependent nature of ultrasound-based investigations and the need for individual institutions to validate their own results rather than quoting the experience of others. For such reasons, a comparison of DU with CTA in endoleak detection may not lend itself well to meta-analysis where pooled sensitivities are calculated. A recent such study included authors who report 25% sensitivity[8] with those who report 97% for the same test,[4] and excluded larger series,[7] not surprisingly concluding that DU should not displace CT for aortic endograft surveillance.[10]

We have used biphasic CT scanning with non-contrast and arterial phase contrast scans as our standard protocol, reserving triphasic scan for cases where endoleak is suspected but not confirmed or cases of sac enlargement in the absence of endoleaks on a biphasic scan. Although non-contrast scans are employed in all patients in the initial follow-up (at six weeks), subsequently these scans are used for reference in order to differentiate contrast from calcification within the aneurysm sac. This has meant that arterial phase only studies are performed after the first year of follow-up, in order to reduce radiation dose. Plain abdominal radiography remains an essential part of our surveillance protocol, and has been previously reported as comparable to non-contrast CT for the detection of graft migration and structural failure.[11,12]

The safety of routine triphasic CT scanning for all patients undergoing follow-up post EVAR must be questioned. Although we accept that late type II endoleaks are more likely to be picked up in the delayed post-contrast phase, there is little evidence to suggest that this translates to a clinically significant advantage, in a group of patients in whom most aneurysms remain stable or shrink following treatment. In fact, Iezzi et al, in the only prospective study to address this issue, reported no significant difference in sensitivity for endoleak detection between analysis of arterial phase images alone, unenhanced and arterial phase images, and arterial and delayed phase images, after the initial follow-up at 1 month.[13] In the current series as in other similar studies,[4,9,14] we did not routinely use triphasic CT scans in the absence of aneurysm sac growth or positive duplex findings. This may partly account for the apparently superior sensitivity of DU scans over CTA. However, in the eight patients in whom an increase sac size was noted, without demonstrable endoleak on biphasic CT, in only one case was an endoleak (type II) diagnosed when the patients were recalled for triphasic scans.

Can our results justify modification of our surveillance program to rely primarily on DU (in addition to plain film radiography and clinical assessment) for surveillance, re-

Table II. Comparison of selected larger series comparing duplex ultrasonography with computed tomography angiograpy in post-endovascular aneurysm repair surveillance

Author	*Year*	*n*	*Follow-up (months)*	*Sensitivity %*	*Specificity %*	*PPV %*	*NPV %*
Sato[6]	1998	79	n/a	97	74	66	98
Zannetti[4]	2000	103	8	91.7	98.4	78.6	99.4
Wolf[5]	2000	100	9	81	95	94	90
D'Audiffret[9]	2001	89	18	96	94	89	98
McWilliams[8]	2002	53	11	12*	94	33	81
Raman[7]	2003	281	34.6	42.9	96	53.9	93.9

NPV, negative predictive value; *PPV,* positive predictive value.
Follow-up was mean number of months.
n/a, data not available.
*12% was for non-contrast enhanced DU, in this series, sensitivity was 50% using Levovist-enhanced power Doppler.

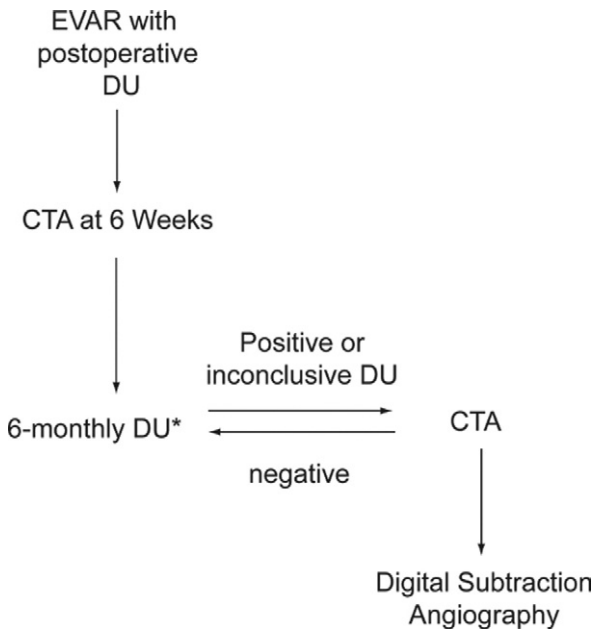

Fig 2. Our current algorithm for post-endovascular aneurysm repair (*EVAR*) surveillance. Annual computed tomography angiography (*CTA*) has been omitted and CTA is now performed only in the presence of a positive or inconclusive duplex ultrasonography (*DU*), or an increase in aneurysm sac size. *Clinical assessment is carried out on each visit and our protocol also includes yearly plain abdominal radiographs.

serving CTA for those patients who have a DU positive for endoleak, or who have an increase in aneurysm sac size? The present series has led to a significant change in our follow-up algorithm (Fig 2). The safety of such an approach can be estimated from examining those patients in whom DU failed to detect an endoleak, which was picked up on CTA. In each of the four cases, endoleak was classified as type II, and although initially missed, all were noted on the subsequent DU. In only one case was there an increase in sac size, but this was noted on the DU, alerting us to the need for further evaluation. None of these patients required re-intervention.

Of the six patients in this series who required re-intervention, three of these had initially normal CTA scans, despite DU scans that reported the presence of an endoleak. Furthermore, in eight other cases, CTA may have given falsely negative results as reported above. This includes five cases where there was an increase in sac size. Perhaps the most striking evidence that the gold standard CTA is less than the ideal tool for endoleak detection comes from recent studies comparing it with magnetic resonance angiography (MRA) in post-EVAR surveillance. Pitton et al report sensitivity for endoleak detection of 92.9% for magnetic resonance imaging (MRI) versus 44% for biphasic CT in their follow-up study of 52 patients.[15] Van der Lean et al found that MRI detected endoleaks in 23 of 35 of the patients who they studied, compared with only 11 of the same group in whom endoleaks were detected by CTA.[16] Both authors conclude that MRI is significantly more sensitive than CTA for the detection of endoleaks. In light of such reports, it is likely that the specificity and positive predictive value of DU reported in this and previous studies, which have relied upon CTA as the gold standard, are significantly underestimated, and false positive DU scans may in fact be falsely negative CTA scans. We might conservatively estimate the specificity of DU in the present series as 76% rather than 67% reported above.

In conclusion, we have shown DU to be a safe and effective tool in post-EVAR surveillance. Varying reports in the literature demonstrate the need for careful audit of DU in individual units, by comparison with CTA or perhaps ideally MRI. Where DU is validated as sensitive and with high negative predictive value, it may safely replace CTA for post-EVAR surveillance, with CTA being reserved for cases of positive or inconclusive DU.

AUTHOR CONTRIBUTIONS

Conception and design: BM, SN, DM
Analysis and interpretation: BM, SO, MC
Data collection: BM, SH, PM
Writing the article: BM
Critical revision of the article: SO, MC, PM, DM
Final approval of the article: MC, PM, DM
Statistical analysis: BM, MC

Obtained funding: N/A
Overall responsibility: DM

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