Duplex ultrasound scanning versus computed tomographic angiography for postoperative evaluation of endovascular abdominal aortic aneurysm repair

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Objective: The purpose of this study was to compare duplex ultrasound scanning and computed tomographic (CT) angiography for postoperative imaging and surveillance after endovascular repair of abdominal aortic aneurysm (AAA).

Methods: One hundred consecutive patients with AAA underwent endovascular (Medtronic AneuRx, stent graft) aneurysm repair and were imaged with both CT angiography and duplex ultrasound scanning at regular intervals after the procedure. Each imaging modality was evaluated for technical adequacy and for documentation of aneurysm size, endoleak, and graft patency. In concurrent scan pairs, accuracy of duplex scanning was compared with CT.

Results: A total of 268 CT scans and 214 duplex scans were obtained at intervals of 1 to 30 months after endovascular aneurysm repair (mean follow-up interval, 9 ± 7 months). All CT scans were technically adequate, and 198 (93%) of 214 duplex scans were technically adequate for the determination of aneurysm size, presence of endoleak, and graft patency. Concurrent (within 7 days of each other) scan pairs were obtained in 166 instances in 76 patients (1-6 per patient). The maximal transverse aneurysm sac diameter measured with both methods correlated closely (r = 0.93; P < .001) without a significant difference on paired analysis. In 92% of scans, measurements were within 5 mm of each other. Diagnosis of endoleak on both examinations correlated closely (P < .001), and compared with CT, duplex scanning had a sensitivity of 81%, a specificity of 95%, a positive predictive value of 94%, and a negative predictive value of 90%. Discordant results occurred in 8% of examinations, and in none of these was the endoleak close to the attachment sites or associated with aneurysm expansion. An endoleak was demonstrated on both tests in all eight patients who had an endoleak judged severe enough to warrant arteriography. Graft patency was documented in each instance, without discrepancy, with both modalities.

Conclusions: High-quality duplex ultrasound scanning is comparable to CT angiography for the assessment of aneurysm size, endoleak, and graft patency after endovascular exclusion of AAA. (J Vasc Surg 2000;32:1142-8.)

The long-term effectiveness of endovascular aneurysm repair in the prevention of aneurysm rupture is unknown. Persistent flow within the aneurysm sac (endoleak) may expose the patient to the risk of rupture. Therefore, patients require periodic follow-up imaging after endovascular repair of abdominal aortic aneurysms (AAAs) to evaluate aneurysm size and to ascertain that the endograft has properly excluded the aneurysm sac from the circulation. Computed tomographic (CT) angiography is currently the most com-
monly used imaging modality for this purpose. It can provide excellent resolution and detail of the aneurysm sac and the endograft and can demonstrate contrast within the aneurysm sac in cases of endoleak. However, the expense, risks of radiation exposure, and potential contrast-related nephrotoxicity warrant consideration of alternative imaging methods, particularly for routine periodic surveillance examinations.

Ultrasound scanning has been widely used for routine surveillance of AAA. It offers the advantages of wide availability, lower cost, and lack of radiation exposure or nephrotoxicity. Although the reliability of duplex ultrasound scanning for routine surveillance of AAA is well accepted, its accuracy and reliability in evaluating aneurysms after endovascular repair has not been well defined. Heilberger et al studied the reliability of duplex ultrasound scanning for follow-up imaging in 113 patients with aortic endografts; most were tube grafts. They found that duplex ultrasound scanning was almost as good as CT for diagnosis of endoleak, but that it was inferior to CT for assessment of graft integrity. Sato et al reported on a multicenter trial comparing duplex ultrasound scanning with CT angiography for the assessment of endoleaks. They reviewed 100 videotaped duplex scans from 18 centers and concluded that in only 19% of the duplex scans there was a complete assessment for an endoleak and that compared with CT, the sensitivity of ultrasound scanning was 97% with a specificity of 74%. The same group subsequently reevaluated a larger sample and reported similar results despite a high rate of technically inadequate duplex scans (28.1%) compared with CT (2.4%). To determine the usefulness of duplex scanning when we followed up patients who had endovascular grafts, we prospectively compared duplex scanning with CT for determination of aneurysm size, endoleak, and graft patency.

**PATIENTS AND METHODS**

One hundred patients underwent endovascular repair of AAA with the AneurRx (Medtronic) bifurcated endograft at Stanford University Hospital from October 1996 to May 1999. Follow-up protocol included CT angiography before discharge, duplex scan at 1 month, and CT angiography at 6 months, 1 year, and yearly thereafter. To compare CT and duplex scans, we obtained both studies, whenever possible, within a period of 7 days from each other.

All duplex scans were obtained after the patients fasted for 6 hours and were performed by a registered vascular technologist proficient in both vascular and abdominal imaging; a Sequoia 512 ultrasound scanning system (Acuson, Mountain View, Calif) and a sector V4 transducer were used. An internally standardized duplex scanning protocol was used for assessing the abdominal aorta. The protocol included transverse and sagittal imaging and peak systolic diameter measurements at the largest region of the proximal, mid, and distal segments of the abdominal aorta. Visible segments of the iliac arteries were also measured. Close attention was given to the stent device in gray scale and in color Doppler scanning to rule out endoleak and graft compression. All duplex ultrasound scans were reviewed by a vascular surgeon. During the examination and the reading of the duplex scan, the vascular technologist was not aware of the CT scan results.
Fig 2. CT (A) and duplex scan (B) demonstrating an endoleak curving along the posterior wall of the aneurysm. Selective arteriography (C) demonstrates the lumbar artery feeding this endoleak.
Helical CT was performed with either a CTi single detector–row or a Lightspeed QXi multi detector–row CT scanner (both General Electric Medical Systems, Milwaukee, Wis). Precontrast studies were obtained routinely. After preliminary timing of 15 mL of iodinated contrast bolus, 80 to 150 mL of nonionic iodinated contrast medium was injected at 4 mL/s. Single detector–row CT scans were acquired at a pitch 2.0 with a 3.0-mm nominal section thickness from the celiac origin to the infrarenal aorta, followed by a 5.0-mm nominal section thickness to the femoral bifurcation. Multi detector–row CT scans were acquired at pitch 6.0 with a 2.5-mm nominal section thickness throughout the entire scan. All images were reconstructed at intervals equal to 50% of nominal section thickness and viewed interactively on a workstation. Delayed scans were obtained routinely since September 1998. These were obtained 90 seconds after initiation of contrast injection in 5-mm thick sections, through the aneurysm and the stent graft. In addition to a formal reading by a radiologist who was unaware of the duplex scan result, CT angiograms were reviewed by a panel of radiologists and vascular surgeons to confirm the presence or absence of an endoleak.

CT and duplex scans were compared for the determination of aneurysm size, for diagnosis of endoleak, and for assessment of graft patency. Statistical analysis included calculation of the Pearson correlation coefficient, the $\chi^2$ test, and the Student $t$ test. Results are expressed as mean ± SD, and a $P$ value less than .05 was considered significant.

RESULTS

A total of 268 postoperative CT scans (2.7 ± 1.7 scans per patient) and 214 postoperative duplex scans (2.1 ± 1.9 scans per patient) were obtained over 1 to 30 months of follow-up (mean interval, 9 ± 7 months). All CT scans were technically satisfactory. Delayed scans, which were obtained routinely after September 1998, were performed in 57% of CT scans. Sixteen (7%) duplex scans in 10 patients were technically inadequate for determination of aneurysm size and presence of endoleak. Four of these patients were markedly obese. CT and duplex scans were obtained concurrently (within 7 days of each other) in 166 instances in 76 patients (1-6 scan pairs per patient). These concurrent scan pairs form the basis for the comparison between the tests.

Aneurysm size. The maximal transverse diameter as measured with both methods (58.8 ± 8.5 mm on CT and 60.0 ± 9.8 mm on duplex scan) correlated closely ($r = 0.93; P < .001$; Fig 1). On paired analysis no significant difference (mean difference, 0.17 mm; duplex scan was larger) was found between the measurements of both studies (Student $t$ test). In 92% of the scans, diameter measurements were within 5 mm of each other. In eight patients duplex scan–measured values were larger by 6 to 12 mm, and in five patients, CT was larger by 6 to 8 mm. Changes in aneurysm size throughout follow-up were $-2.6 \pm 5.8$ mm on duplex ultrasound scan and $-2.4 \pm 4.7$ mm on CT without a significant difference on paired $t$ test.

Endoleak. The presence or absence of endoleak was diagnosed by means of both methods with excellent correlation ($P < .001$; Table, Fig 2). In comparison with CT, diagnosis of endoleak with duplex scanning was associated with a sensitivity of 81%, a specificity of 95%, a positive predictive value of 94%, and a negative predictive value of 90%. All endoleaks identified with CT and missed on duplex scanning were small and posterior and appeared to be associated primarily with lumbar artery flow. Three endoleaks were identified with duplex scanning and missed on CT. Of these, two CT scans included delayed images, whereas one did not. For purposes of the analysis with CT as the gold standard, they were considered false positives. Nonetheless, they probably represented true findings and were associated with to-and-fro flow in the inferior mesenteric artery. During follow-up, aortography was performed in 10 patients, 6 weeks to 20 months after aneurysm exclusion, for identifying and treating the source of an endoleak. The indication for aortography was suspicion of a leak originating at the fixation sites or persistence of an endoleak without a decrease in aneurysm size (Fig 3). Eight patients underwent both CT and duplex scans, and in all of them, the endoleak was clearly evident on both tests. Compared with the results of aortography, duplex scanning was as good as CT at localizing the source of the endoleak.

Graft patency. The patency rate was 99% as measured with both CT and duplex scan. One late graft occlusion occurred in the entire series in a patient with a small distal aorta where the proximal portion of the left limb of the endograft was compressed. This was demonstrated by means of both CT and duplex scan 2 months before thrombosis but was not treated prophylactically. In all others, graft patency was regularly documented with both modalities.

DISCUSSION

After endovascular repair of AAA, long-term and perhaps lifelong imaging surveillance may be
Fig 3. An endoleak originating at the proximal attachment site within a narrow space posterior to the proximal portion of the endograft is difficult to discern on CT (A). The space is nicely demonstrated on gray scale ultrasound scan (B), and endoleak flow is seen on color flow duplex scan (C). Aortography (D) demonstrates contrast alongside and to right of the proximal portion of the graft.
required. The most appropriate imaging modality for performing this follow-up has not been defined, and a combination of plain abdominal radiography for definition of stent integrity and contour and cross-sectional imaging for evaluation of the aneurysm sac may be appropriate. The cost and potential complications related to such routine follow-up studies are expected to acquire even greater importance as the number of patients after endovascular aneurysm repair increases.

In this study, duplex ultrasound scanning was compared with CT angiography for follow-up of cross-sectional aneurysm diameter and assessment of endoleak and graft patency. A problem with this type of comparative study is the lack of an ultimate gold standard. Although CT is considered less operator dependent than duplex scanning, technical factors such as timing of the contrast bolus and the distance between sections represented on film, as well as the reader’s experience, may affect interpretation. In this study, routine delayed images on CT were obtained since September 1998 and were performed in 57% of the examinations. Earlier initiation of this protocol may have increased the CT diagnosis of endoleaks.

CT is very accurate for the measurement of aortic diameter. Even so, interobserver variability in measuring the diameter of AAA from the CT film images can be significant and has been reported to differ by 5 mm or more in 17% of cases. The difference between ultrasound scanning and CT has been reported to be even greater, with 33% of cases different by more than 5 mm and ultrasound scan measurements being, on average, smaller than CT. In our study, the correlation between tests was better. There was no statistically significant difference in the measurements, and in only 8% was the difference between the studies more than 5 mm. Although discrepancy between duplex scanning and CT does occur, differences among duplex scans from different laboratories may be even greater, and it is important to compare duplex scans from the same laboratory. CT and duplex ultrasound scans may be interchangeable for routine uneventful surveillance, but in cases of significant change in size, a clinical change or uncertainty, confirmation with the alternative study seems prudent.

The number of endoleaks identified on CT and missed on duplex scans exceeded the number of those identified on duplex scans and missed on CT. However, none of the endoleaks for which a discrepancy in the diagnosis existed was judged severe enough to warrant arteriography and reintervention. Although the eventual outcome of various types of endoleaks has not been conclusively defined, our policy has evolved to investigate and treat those that originate at the attachment sites or in the graft and those that are associated with increasing size of the aneurysm sac. Patients with endoleaks that appear to be related to branch vessels without aneurysm expansion are observed. The desirable sensitivity of a useful follow-up study for identifying endoleaks is ultimately related to their natural history. If branch-related endoleaks are inconsequential unless associated with aneurysm sac expansion, missing these endoleaks is irrelevant, and a test that visualizes endoleak every minute may be unnecessary. In all patients with endoleaks that were thought to involve the attachment sites and to warrant arteriography and reintervention, duplex scans demonstrated the endoleak whenever it was performed. Thus, reliance on duplex scan alone would not have resulted in different clinical management.

On the basis of our findings, a well-performed duplex ultrasound scan delivers results very similar to high-quality CT angiography. The 7% rate of inadequate duplex scans in this study is much lower than the 28% rate reported by Meier et al. This difference is likely related in part to differences in study design. This study was performed at a single center with close cooperation between vascular laboratory personnel and vascular surgeons, whereas the cited report was carried out as a multicenter investigation. Because duplex ultrasound scanning of deep intracavitary structures such as the aorta is highly operator dependent, close cooperation between laboratory staff and physicians and internal validation with other imaging modalities, particularly CT, are vital to achieve good results.

Although CT and duplex scans are not completely equivalent, their results are sufficiently similar to make financial considerations pertinent. A formal cost identification analysis of duplex ultrasound scanning relative to CT angiography has not been performed, but the cost of duplex ultrasound scanning is likely to be substantially less. In our opinion, follow-up with duplex ultrasound scanning or a protocol consisting of alternating the use of both modalities may result in reduced cost, radiation exposure, and potential nephrotoxicity associated with the use of contrast materials, without compromising patient care.

In conclusion, high-quality duplex ultrasound scanning is comparable to CT angiography for measuring aneurysm size and for identifying endoleaks after endovascular exclusion of AAA. It may be used for surveillance and routine follow-up.
REFERENCES


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