Duplex Scanning After Endovascular Aneurysm Repair: An Alternative to Computed Tomography

By Frank R. Arko, Konstantinos A. Filis, Maarit A. Heikkinen, Bonnie L. Johnson, and Christopher K. Zarins

Late complications following endovascular aneurysm repair indicate the need for long-term surveillance. Clinical trials involving endoluminal stent grafts have typically used computed tomography angiography as the main imaging modality for surveillance. However, computed tomography angiography exposes the patient to higher levels of ionizing radiation, nephrotoxic agents, and increased cost compared to duplex ultrasound. Duplex ultrasound scanning has been widely used for surveillance of abdominal aortic aneurysms for many years. It is well established and the procedure of choice for noninvasive imaging of the aorta. It offers the advantages of easy access, decreased cost, no radiation exposure, and no nephrotoxicity. There is little controversy about duplex scanning for preoperative patient evaluation or surveillance of patients with small aneurysms. However, the use and reliability of duplex scanning in the evaluation and surveillance of patients following endovascular repair is controversial. This article will discuss the benefits, techniques, and limitation of duplex ultrasound in the long-term surveillance of endografts following endovascular abdominal aortic aneurysm repair.

© 2004 Elsevier Inc. All rights reserved.

ENDOVASCULAR ABDOMINAL AORTIC aneurysm repair (EVAR) compared to open surgical repair has demonstrated benefits including decreased mortality, shorter hospital length of stay, and improved quality of life postprocedure. Late complications following endovascular abdominal aortic aneurysm repair, including endoleaks, migration, limb thrombosis, and ruptures, indicate the need for long-term surveillance. Clinical trials involving endoluminal stent grafts have typically used computed tomography angiography (CTA) or magnetic resonance angiography (MRA) as the main imaging modality for surveillance. However, CTA exposes the patient to higher levels of ionizing radiation, nephrotoxic agents, and increased cost compared to duplex ultrasound (DUS) and plain abdominal films.

DUS scanning has been widely used for surveillance of abdominal aortic aneurysm (AAA) for many years. It is well established and the procedure of choice for noninvasive imaging of the aorta. It offers the advantages of wide availability, lower cost, no radiation exposure, noninvasiveness, and no nephrotoxicity compared to CTA, MRA, and arteriography. The ease and reliability of DUS allows it to be used to determine whether the aneurysm is enlarging, in order to select patients for treatment. There is little controversy about duplex scanning for preoperative patient evaluation or surveillance of patients with small aneurysms. However, the use and reliability of duplex scanning in the evaluation and surveillance of patients following endovascular repair is controversial. This controversy arises from the perception that duplex scanning lacks reliability, is technologist-dependent, and reproducible results cannot be obtained.

However, DUS can be reliable and reproducible if the protocol is standardized and current ultrasound equipment with sufficient Doppler penetration and sensitivity is used.

TECHNIQUE DUS

DUS assessment of AAA after endovascular repair is more detailed compared to the standard protocol for gray-scale ultrasonography of the abdominal aorta. Knowledge of the abdominal aorta and its branches with regard to aneurysmal disease is crucial. Additionally, a general understanding of the different types of endovascular grafts is essential.

Examination of the endovascular AAA repair begins with a history and physical exam. Physical assessment includes palpation of the abdomen to check for aortic pulsations and tenderness. Furthermore, ankle brachial indices and auscultation of the
femoral arteries are performed to document outflow status of the endograft.

All duplex scans are obtained after the patient has been fasting for 6 hours to minimize bowel gas. A registered vascular technologist proficient in vascular and abdominal imaging performs all duplex scans. A Sequoia 512 ultrasonography scanning system (Siemens/Acuson, Mountain View, CA) and 3.0 to 4.0 MHz sector V4 transducer are used.

The exam begins in the midline with the patient supine. In obese patients the lateral decubitus position can be used to image the aorta in a coronal plane to improve visualization. The abdominal aorta is imaged in gray scale from the diaphragm to the aortic bifurcation to determine transverse and anterior-posterior diameters and to note any wall defects. The iliac arteries are imaged to the inguinal ligament when possible. Diameter measurements are obtained in the transverse and antero-posterior planes using the outer wall of the aorta. Measurements are obtained from the largest segment of the suprarenal aorta, infrarenal aorta, and common iliac arteries. Additional measurements are obtained if hypogastric or external iliac artery aneurysms are present. Circumference measurements using software tools are also obtained and can be used for serial comparisons, as aneurysm morphology changes with time (Fig 1).

Attention is given to the endograft in gray scale to determine the presence of graft compression, luminal defect, and separation of modular junctions (Fig 2). Color Doppler is used to evaluate for potential extrastent flow. Imaging the aneurysmal sac requires sensitive color Doppler scale settings to determine low-velocity leaks. Unfortunately, very sensitive scale settings also produce excessive color Doppler artifacts such as “bleed-over” of color beyond the stent wall and posterior reverberation artifacts behind the stent device. These artifacts produce indiscriminate flashes of color Doppler noise in the area of interest but diminish during diastole. However, flow associated with an endoleak is relatively uniform, reproducible, and color typically persists into diastole. The source of the extrastent flow can often be determined by color flow imaging. Spectral Doppler is used when imaging any suspected extrastent flow. When assessing for endoleak the graft is closely inspected at the proximal and distal fixation points to determine the presence of Type I endoleaks (Fig 3). The presence of “to and fro flow” during systole and diastole involving the inferior mesenteric arteries and/or the lumbar arteries within the aneurysm sac is used to define the presence of Type II endoleaks (Fig 4). The direction of the systolic peak is important in determining the origin of inflow. The junction of the main body and contralateral limb is inspected to determine the presence of Type III endoleaks. Furthermore, the presence of small jets of flow from the graft and filling the sac can be identified and represent transgraft flow or Type IV endoleaks. Additionally, velocity waveforms are obtained from each limb to evaluate for any potential stenosis from graft compression. A summary of the findings obtained with DUS of abdominal aortic aneurysm is listed in Table 1.

**CTA**

When performing CTA for postoperative surveillance, helical CT with a LightSpeed QXi multi-

![Fig 1. Circumference measurement of AAA following abdominal aortic stent graft on routine follow-up surveillance.](image1)

![Fig 2. Imaging in gray scale demonstrates separation of modular components.](image2)
detector row CT scanner (GE Medical Systems, Milwaukee, WI) is most commonly used. Pre- and postcontrast studies are routinely obtained. After preliminary timing of 15 mL of iodinated contrast bolus, 80 to 150 mL of nonionic iodinated contrast medium is injected at 4 mL/s. Multi-detector row CT scans are acquired at a 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 are obtained 90 seconds after initiation of contrast injection in 5-mm thick sections, through the aneurysm and stent graft.

A total of 407 postoperative duplex scans have been performed in 201 patients following endovascular abdominal aortic aneurysm repair (2.0 ± 1.9 scans per patient). These scans were obtained during follow-up ranging from 1 to 60 months, with a mean interval of 14.9 months. Six percent (24/407) of scans in 7% (14/201) of patients were technically unsuccessful. Ten patients were markedly obese and 4 patients had excessive bowel gas resulting in inadequate duplex studies. These patients were recommended for CTA follow-up. Patients who are morbidly obese with no adequate window to view the aorta even from coronal views, aortas that are heavily calcified producing posterior shadowing, and exams that are repeatedly limited by overlying bowel gas (postoperative patients) should be referred for CTA. With regards to aneurysm size, the maximal transverse diameter as measured by both methods (58.8 ± 8.5 mm on CT and 60.0 ± 9.8 mm on duplex) correlated closely ($r = 0.93$). No significant difference was found between the measurements of both studies. In 92% of scans, diameter measurements were within 5 mm of each other. Changes in aneurysm size throughout follow-up were $-2.6 \pm 5.8$ mm on DUS scan and $-2.4 \pm 4.7$ mm on CT without a significant difference.

The presence of absence of endoleak was diagnosed by means of both imaging tests with excellent correlation. In comparison with CT, diagnosis of endoleak 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.²

**Table 1. Duplex Ultrasound Imaging Criteria for Endovascular Grafts**

<table>
<thead>
<tr>
<th>Image quality</th>
<th>Note limitations and exclusion of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Location of aneurysm and device</td>
</tr>
<tr>
<td>Size</td>
<td>Diameter and circumference</td>
</tr>
<tr>
<td>Patency and integrity</td>
<td>Lumen reductions and device disruptions</td>
</tr>
<tr>
<td>Extrastent flow</td>
<td>Presence or absence and flow directions</td>
</tr>
<tr>
<td>Outflow</td>
<td>Ankle brachial indexes</td>
</tr>
<tr>
<td>Incidental</td>
<td>Note all findings</td>
</tr>
</tbody>
</table>

**DUPLEX COMPARED TO CTA**

A total of 407 postoperative duplex scans have been performed in 201 patients following endovascular abdominal aortic aneurysm repair (2.0 ± 1.9 scans per patient). These scans were obtained during follow-up ranging from 1 to 60 months, with a mean interval of 14.9 months. Six percent (24/407) of scans in 7% (14/201) of patients were technically unsuccessful. Ten patients were markedly obese and 4 patients had excessive bowel gas resulting in inadequate duplex studies. These patients were recommended for CTA follow-up. Patients who are morbidly obese with no adequate window to view the aorta even from coronal views, aortas that are heavily calcified producing posterior shadowing, and exams that are repeatedly limited by overlying bowel gas (postoperative patients) should be referred for CTA. With regards to aneurysm size, the maximal transverse diameter as measured by both methods (58.8 ± 8.5 mm on CT and 60.0 ± 9.8 mm on duplex) correlated closely ($r = 0.93$). No significant difference was found between the measurements of both studies. In 92% of scans, diameter measurements were within 5 mm of each other. Changes in aneurysm size throughout follow-up were $-2.6 \pm 5.8$ mm on DUS scan and $-2.4 \pm 4.7$ mm on CT without a significant difference.

The presence of absence of endoleak was diagnosed by means of both imaging tests with excellent correlation. In comparison with CT, diagnosis of endoleak 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.²
QUANTITATIVE ASSESSMENT OF TYPE II ENDOLEAKS

Duplex can be used to determine presence or absence of flow in the aneurysm sac and branch vessels of type II endoleaks (Fig 4). Quantitative assessment of flow velocities and direction is performed within the aneurysm sac near the aneurysm wall with a constant angle of less than 60 degrees to the branch vessel (Fig 5). Spectral velocities are obtained at the entrance of the feeding vessel to the aneurysm sac only. No velocities are obtained within the aneurysm sac or in the outflow vessel. Intrasac Doppler flow velocities of type II endoleaks immediately post-procedure were obtained. Patients with type II endoleaks that sealed in less than 6 months without intervention had significantly lower intrasac AAA flow velocities at the time of hospital discharge than patients with persistent type II endoleaks (75.5 ± 78.8 cm/s, range, 15-230) versus 138.2 ± 36.2 cm/s (range 100-200), P < .01). These elevated intrasac AAA flow velocities were directly related to whether or not the IMA was patent (P < .01) and whether or not more than two paired lumbar arteries were patent (P < .0001) on the preoperative CTA.

Three patients with sealed endoleaks had high flow velocities of 200 cm/s or greater. However, in these patients the diameter of the IMA was less than 4 mm and no lumbar arteries were visualized preoperatively. The other 11 patients all had intrasac flow velocities less than 80 cm/s. Intrasac flow velocity had decreased to zero in all patients with sealed endoleaks within 6 months and lack of endoleak was confirmed with CTA in each instance. Patients with persistent endoleaks continued to have elevated intrasac flow velocities that remained greater than 100 cm/s during the follow-up period and did not change significantly over time.19

COMBINING DUS AND KUB COMPARED TO CTA

The sensitivity, specificity, positive predictive value, and negative predictive value of KUB/DUS compared to CTA were 96%, 94%, 90%, and 98%, respectively. KUB/DUS correctly identified the need for further imaging with a CTA to plan a secondary procedure based on an increase in aneurysm diameter, presence of endoleak, migration, or a combination of the three. Three graft migrations were identified on KUB/DUS and not seen on CTA in group II. These migrations on KUB were measured at 3 to 4 mm in each instance. On independent review of the CTA data in these three cases no evidence of migration was noted. If no CTA had been obtained in these 31 patients with long-term follow-up, no graft events would have been missed. Thus, 15 of 114 (13%) CTA would have been necessary for confirmation of the DUS/KUB and preoperative planning of secondary procedures; the remaining 99 (86%) CTA scans were clinically unnecessary and could have been avoided with no adverse clinical sequelae.
POSTOPERATIVE IMAGING OF THE ENDOVASCULAR STENT GRAFT

On the basis of our findings, a well-performed DUS scan delivers results comparable to high-quality CTA. With the results of duplex and CTA being equivalent, economic factors are critical in this time of decreasing healthcare reimbursement. The charge of a complete aortic DUS scan at our institution is $1000 as compared to $4700 for CTA. As the number of patients treated with endovascular stent grafts increases, especially following US Food and Drug Administration approval of an increasing number of devices, more cost-effective surveillance will result in a significant savings in healthcare dollars.

DUS is a reliable and reproducible method for evaluating patients following endovascular repair of AAA. It has the advantage of reduced cost, no radiation exposure, and no nephrotoxicity as compared to CTA. It is limited by certain anatomic (obesity) and physiologic (intestinal gas) circumstances. However, in those in whom proper imaging can be obtained it is equivalent to and can be used in favor of CTA. In our opinion, follow-up with DUS scanning will result in reduced cost, radiation exposure, and potential nephrotoxicity with the use of contrast materials, without comprising patient care.

In conclusion, it is possible that DUS may replace CTA as the primary long-term follow-up imaging modality for most patients following endovascular repair of AAA. If abnormalities are detected on duplex scan, then further evaluation of the endovascular graft and aneurysm should be performed with CTA.

REFERENCES