Update: Quantitative Duplex Ultrasound Assessment of Aortic Aneurysms After Endovascular Repair

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ABSTRACT  

Purpose.—To describe the current Stanford duplex protocol for ultrasound scanning of abdominal aortic aneurysms after endovascular repair. This technique has been used for more than 7 years in the Stanford Vascular Laboratory and has been validated against computed angiography. It provides quantitative information on aneurysm sac size and flow characteristics, as well as endograft patency and integrity.

Technique.—Abdominal aortic duplex scans are obtained after the patient has been fasting to minimize bowel gas. An internally standardized duplex scanning protocol is used for assessing the abdominal aorta. The aorta is imaged in gray scale from the diaphragm to the aortic bifurcation to determine the presence of wall defects and to measure the greatest diameter and circumference. Measurements are obtained from the largest segment of the supraceliac aorta, infrarenal aorta, and common iliac arteries. Additional measurements are obtained to document disease of the hypogastric or external iliac artery when not obscured by overlying bowel gas. Circumference measurements using calculation software tools available in most ultrasound equipment are also obtained to more easily monitor the morphologic changes in the aneurysm over time. Color and spectral Doppler are used to evaluate for potential extrastent flow. In addition, velocity waveforms are obtained from each limb to evaluate for changes suggesting potential stenosis from graft compression or outflow obstruction.

Conclusions.—Duplex ultrasound scanning after endovascular repair of abdominal aortic aneurysms can be used successfully to determine aneurysm size and presence or absence of extrastent flow in 94% of patients. Thus, this technique is applicable to most patients after endovascular repair.

Introduction

Duplex ultrasound scanning has been widely used for surveillance of abdominal aortic aneurysms (AAA) for many years. It is well established and the procedure of choice for noninvasive imaging of the AAA.\(^1\)\(^,\)\(^2\) It offers the advantages of wide availability, lower cost, no radiation exposure, noninvasiveness, and no nephrotoxicity compared with computed angiography (CTA), magnetic resonance angiography (MRA), and arteriography.\(^3\) The ease and reliability of duplex allows it to be used to determine whether the aneurysm is enlarging to select patients for treatment.

The risk-benefit ratio of surgery versus continued surveillance has been based on duplex ultrasound determinations of aneurysm diameter. Little controversy exists about duplex scanning for preoperative patient evaluation or surveillance of patients with small aneurysms.\(^1\)\(^-\)\(^4\) However, the use and reliability of duplex scanning in the evaluation and surveillance of patients after endovascular repair is controversial. This controversy arises from the perception that duplex scanning lacks reliability, is technologist dependent, and reproducible results cannot be obtained.

The purpose of this communication is to demonstrate that ultrasound can be reliable and reproducible if a protocol is standardized, the technical staff properly trained, and current ultrasound equipment with sufficient Doppler penetration and sensitivity is used. A standardized technique using duplex ultrasound for evaluating patients after endovascular repair of AAA was developed and used for the past 7 years in the ICAVL-accredited Stanford University Vascular Laboratory, Division of Vascular Surgery. This technique has been validated against CTA and found to be reliable and accurate.\(^2\)

Technique

Duplex ultrasound assessment of AAA after endovascular repair is more detailed compared with the standard protocol for gray scale ultrasound of the abdominal aorta. Knowledge of the abdominal aorta and its branches with regard to aneurysmal disease is crucial. In addition, a general understanding of the different types of endovascular grafts is essential.
Examination of the endovascular AAA repair begins with a brief history and physical examination. 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 on the first postprocedure visit to document outflow status.

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 ultrasound scanning system (Siemens/Acuson, Mountain View, CA), 3.0–4.0 MHz sector V4 transducer or SonicT HDI 5000 (Philips/ATL, Bothell, WA), and C5-2 MHz transducer are used. An internally standardized duplex scanning protocol is used for assessing the abdominal aorta (Figure 1).

The examination 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 anteroposterior diameters and to note any wall defects. The iliac arteries are imaged to the inguinal ligament when possible. Measurements are obtained outer wall to outer wall from the largest segment of the suprarenal aorta, infrarenal aorta, and common iliac arteries. An additional measurement might be needed if aneurysmal dilation occurs in more than one region of an aortic segment. Measurements are also obtained if hypogastric or external iliac artery aneurysms are present. Because aneurysm morphology changes over time, circumference measurements using software tools are useful when comparing serial scans (Figure 2).

In gray scale, attention is given to the endograft to determine the presence of graft compression, luminal defect, and separation of modular junctions (Figure 3). 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, sensitive scale settings also produce excessive color Doppler artifacts, such as “bleed-over” of color beyond the stent wall, and enhance 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. It is important to note, 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 to determine the velocity and direction of flow when imaging any suspected extrastent flow. It is important to note that in the absence of extrastent flow by color Doppler, it remains necessary to use spectral Doppler to assess any localized regions of pulsatility within the thrombus-filled aortic sac. When assessing for endoleak, the graft is closely inspected at the proximal and distal fixation sites to document the presence or absence of type I endoleaks (Figure 4).5 The finding of a late type I endoleak might represent migration of the device.

The presence of a “to-and-fro” flow pattern during systole and diastole involving the inferior mesenteric arteries (IMA) and/or the lumbar arteries within the aneurysm sac is used to define the presence of type II endoleaks (Figure 5) representing patent side branches. The direction of the systolic peak is important in determining the origin of inflow. Normally, the aorta supplies the IMA and lumbar arteries (side branches), and the flow moves away from the aorta. After AAA exclusion by the stent graft, the flow to these branches is excluded, but the IMA and lumbar arteries might be collateralized from the SMA and hypogastric arteries, respectively, and resulting in backbleeding into the AAA sac during systole and out again during diastole. The region near the junction of the main body and contralateral limb is inspected to determine the presence of type III endoleaks (Figure 3) representing device separation. Type IV endoleaks are represented as transgraft flow seen by angiography during the deployment process following the dye injection. Here small jets of flow from the graft can be seen filling the sac immediately after device deployment. Such leaks usually seal quickly, thus type IV endoleaks are not likely to be seen by ultrasound at later follow-up examinations.

In addition, velocity waveforms are obtained from each limb to evaluate for any potential stenosis from graft compression. A summary of the findings obtained with duplex ultrasound of abdominal aortic aneurysm is listed in Table 1.

**Results**

This technique has been developed and used in the Stanford Vascular Laboratory, an ICAVL accredited laboratory, at Stanford University Medical center between October 1996 and June 2003. Between October 1996 and July 2001, a total of 407 postoperative duplex scans were performed in 201 patients after endovascular AAA 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. Duplex scans were technically successful in 94% of examinations (383 of 407 scans). Six percent (24 of 407) of scans in 7% (14 of 201) of patients were technically unsuccessful. Ten patients were markedly obese, and four 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, aortas that are heavily calcified producing posterior shadowing, and examinations that are repeatedly limited by overlying bowel gas are not considered candidates for future ultrasound monitoring and should be referred for CTA. In addition, we have found patients to have excessive bowel gas in the immediate postprocedure period, making ultrasound nondiagnostic in most cases. Thus CT should be used in the immediate postprocedure period to confirm po-
sion of the fixation sites and surrounding aortic region.

We have previously reported our results comparing concurrent scan pairs of CTAs and duplex ultrasound scans. Concurrent duplex scans and CTAs were performed in 166 instances in 76 patients. We have also demonstrated the importance of branch flow velocity in the likelihood of a type II endoleak sealing.

Discussion

As we await the long-term results of endovascular AAA, long-term and perhaps lifelong surveillance
Duplex ultrasound circumference measurement of abdominal aortic aneurysm after endovascular stent graft repair (gray scale).

might be required. However, the most appropriate, cost-effective, and least morbid imaging modality is as yet undefined.

In this communication, we have described our technique of routine surveillance of AAA after endovascular repair. We have previously demonstrated that high-quality duplex ultrasound scanning is comparable to CTA for measuring aneurysm size and for identifying endoleaks after endovascular exclusion of AAA. The maximal transverse diameter as measured by duplex scanning (60.0 ± 9.8 mm) correlated closely (r = 0.93; p < 0.001) with CTA (58.8 ± 8.5 mm). In 92% of the scans, diameter measurements were within 5 mm of each other. Changes in aneurysm size throughout follow-up were -2.4 ± 5.8 mm on duplex scanning and -2.4 ± 4.7 mm on CTA without a significance difference.

The presence or absence of endoleak was diagnosed by means of both methods with excellent correlation (p < 0.001). In comparison with CTA, the 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 were small, posterior, and seemed to be associated with lumbar arteries. Three endoleaks were identified with duplex imaging that were not seen on CTA and represented to-and-fro flow in the IMA.

Graft patency was 99% as measured by both CTA and duplex scans. One late graft occlusion occurred 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 both CTA and duplex scan 2 months before thrombosis but was not treated prophylactically. A second patient was diagnosed with limb compression solely by duplex imaging; the finding was confirmed with arteriography and treated with percutaneous balloon angioplasty.

A retrospective analysis of intrasac Doppler velocities and CT scans performed at our institution suggests velocities and vessel size might play a role in predicting spontaneous sealing of side branch vessels associated with type II endoleaks. Looking at both CT and Doppler velocities, our findings indicate low-velocity (<100 cm/sec) type II endoleaks have a higher incidence of spontaneous seal. And high-velocity (>100 cm/sec) type II endoleaks associated with multiple patent side branches or with large branch vessel diameter (>4 mm diameter), as determined by preoperative CT, suggests resistance to transarterial endovascular treatment.
On the basis of our findings, a well-performed duplex ultrasound 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 health care reimbursement. The charge of a complete aortic duplex ultrasound scan at our institution is $1,000 compared with $4,700 for CTA. As the number of patients treated with endovascular stent grafts increases, especially after FDA approval of an increasing number of devices, more cost-effective surveillance will result in a significant savings in health care dollars.

Duplex ultrasound is a reliable and reproducible method for evaluating patients after endovascular repair of AAA. It has the advantage of reduced cost, no radiation exposure, and no nephrotoxicity compared with CTA. It is limited by certain anatomic (obesity) and physiologic (intestinal gas) circumstances. However, a KUB (flat plate x-ray) of the abdomen can be used to monitor overall device position in relation to bony anatomic landmarks. With this in mind, in patients in whom proper duplex imaging can be obtained, duplex is equivalent to and can be used in favor of CTA. In our opinion, follow-up with duplex ultrasound scanning will result in reduced cost, radiation exposure, and potential nephrotoxicity with the use of contrast materials without compromising patient care.

In conclusion, it is possible that duplex ultrasound along with a KUB (flat plate x-ray) to document overall stent position might replace CTA as the primary long-term follow-up imaging modality for most patients after endovascular repair of AAA. If abnormalities are detected, further evaluation of the endovascular graft and aneurysm by CTA should be considered.

References


