Intravascular ultrasound aids in the performance of endovascular repair of abdominal aortic aneurysm

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Purpose: **The purpose of this retrospective review was to assess the accuracy of aortic measurements with intravascular ultrasound scan (IVUS) compared with computed tomographic (CT) scan and to assess the role of IVUS in the performance of endovascular repair of abdominal aortic aneurysms (AAAs).**

Methods: **Seventy-eight patients undergoing repair of AAA with the AneuRx stent graft (Medtronic AVE, Inc, Santa Rosa, Calif) underwent measurement with CT scan and IVUS. The initial selection of stent graft size was made on the basis of the CT scan measurements, but the final decision for size was made on the basis of the IVUS measurements. Standard measurements of a phantom tube obtained with IVUS, CT scan, and digital caliper were also compared.**

Results: **IVUS measurements of the phantom standard agreed closely with CT scan measurements. However, stent graft size initially selected with CT measurement was altered in 28% of cases on the basis of intraoperative IVUS measurements. No type I endoleaks were encountered in our series, and no aortic cuffs were necessary for endoleak repair.**

Conclusion: **IVUS accurately measures the aorta for selection of stent grafts for endovascular repair of AAA and may prevent type I endoleaks and remedial procedures for their repair. (J Vasc Surg 2003;37:615-8.)**

Intravascular ultrasound (IVUS) has been used as a primary investigational tool and an adjunct to angiography in the diagnosis and treatment of cardiovascular disease. Other authors have shown the utility of IVUS in characterization of stenosis morphology, vessel diameter, and lesions in areas of angulation.[1-4]

The accuracy of measurements obtained from computed tomographic (CT) scans for sizing of stent grafts is affected by the size of the CT scan image and variations between software vendors in how the data are manipulated. Accuracy also depends on appropriate preventive maintenance with specific attention to measurement calibrations. Measurements obtained on smaller CT scan images magnify measurement errors. The greater the size of the image used for measurement, the less variability and the more reproducibility there is.

This review examines the accuracy of IVUS and CT scan measurements of a standard phantom tube. We then discuss how differences in aortic neck measurements with IVUS and CT scan are managed in endovascular repair of abdominal aortic aneurysms (AAAs).

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Competition of interest: Dr Hodgkiss is a paid consultant to Medtronic AVE. Dr Garrett has received fees for teaching in a Medtronic AVE-sponsored AneuRx training program. Drs Garrett and Hodgkiss are principal investigators and Ms Burgar a site coordinator for the Vanguard stent graft trials sponsored by Boston Scientific Medi-tech.

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METHODS

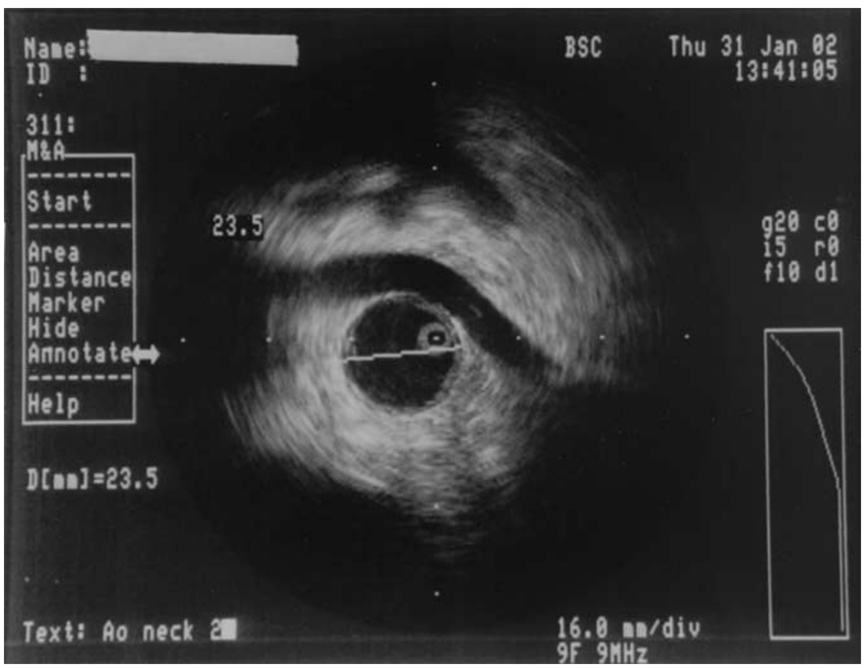
Measurement standardization. A 60-mL plastic syringe (Becton Dickinson & Co, Franklin Lakes, NJ) was used to obtain standard measurements of a round tube that could not only be filled with saline solution for ultrasound scan measurements but also visualized and measured directly. A 9-MHz Sonicath Ultrasound Imaging Catheter (Boston Scientific Medi-tech, Natick, Mass) was advanced through the needle end of the saline solution-filled syringe. Multiple measurements of the inner diameter of the syringe then were obtained at 18-mm intervals by the same authors (HG, SB) who did the patient IVUS measurements described in the clinical protocol. These measurements were recorded on a Boston Scientific Clearview IVUS unit and are listed in the Table.

Next, the 60-mL syringe was scanned with a Somatom Volume Access CT scanner (Siemens Corp, Iselin, NJ). Sequential measurements were obtained 3 mm apart with a 30-cm field of view. These parameters are identical to those used when imaging patients for initial aneurysm evaluation. The same author (TH) who reported most of the patient CT scan measurements in the clinical protocol did the phantom tube CT scan measurements. These measurements ranged from 26.1 mm to 26.5 mm. Every sixth measurement is listed in the Table to correspond to the intervals of the IVUS measurements.

An individual unaware of the previous measurements then performed direct measurements of the lumen at each end of the same syringe with a digital caliper scaled to 1/100 of a millimeter. These measurements are also recorded in the Table.

Measurements of inner diameter of 60-mL syringe with IVUS, spiral CT scan, and digital caliper (mm)

							No. of observations	*Mean ± standard error*	P *value (difference compared with caliper measurements)*
IVUS (measurements 18 mm apart)		26.4	26.6	26.5	26.5	26.6			
		25.8	26.3	26.4	26.2	26.8	10	26.41 ± 0.08	.77
Spiral CT scan (measurements 18 mm apart)		26.1	26.3	26.4	26.4	26.4	5	26.32 ± 0.11	.40
Digital caliper	26.53	26.50	26.73	26.48	26.47	25.98	6	26.45 ± 0.10	



IVUS measurement of aortic neck at level of renal vein.

Clinical protocol. We conducted a retrospective review of our first 78 patients treated for infrarenal AAAs with the AneuRx (Medtronic AVE, Inc, Santa Rosa, Calif) bifurcated modular stent graft device. All patients underwent spiral CT scanning (2.5-mm collimation and a pitch of 2, with 3-mm separation between images) and preoperative angiography. Aortic diameter was measured transversely on CT scan from aortic wall to aortic wall, disregarding any intimal thickening or plaque. Patients were deemed acceptable candidates for aortic stent grafting if the aortic neck was 26 mm or less in diameter and 15 mm or more in length. Patients were excluded if the angulation of the aortic neck was more than 60 degrees. No patients were excluded because of iliac tortuosity. The stent graft diameter selected initially was 10% to 20% greater than the proximal aortic neck diameter as measured with CT scan.

IVUS measurements were performed at the time of preoperative angiography or, more often, immediately before stent graft selection at the time of endovascular grafting. IVUS measurements were obtained with a 6F, 12.5-MHz, "monorail" system catheter (Sonicath Ultrasound Imaging Catheter, Boston Scientific Medi-tech). Because of changes in market availability, the 9-MHz Sonicath IVUS catheter delivered through an 8.5F sheath was used later in the series. The sheath was positioned in the suprarenal aorta over a guidewire, and the IVUS catheter was positioned at the top of the sheath with fluoroscopy with the guidewire removed. IVUS imaging was obtained as the probe was withdrawn through the aorta (Figure) into the ipsilateral iliac artery.

Ultrasound scan measurements included proximal aortic neck diameter, neck length, pull back length from the lowest renal to ipsilateral hypogastric artery, and the ipsilateral iliac artery diameter at the distal sealing zone. Proximal aortic neck measurements were obtained immediately below the lowest renal artery and at 1-cm increments below this level. These measurements were compared with those obtained with spiral CT scanning. In cases where the difference between the CT scan and IVUS measurements was equal to or greater than 2 mm, the stent graft size selected for implantation was 10% to 20% greater than the proximal aortic neck diameter as measured with IVUS. AneuRx modular bifurcated aortic stent grafts were used in all cases. After device implantation, completion angiograms were obtained. A 3-cm low-pressure elastomeric angioplasty balloon was initially used routinely in this series and then was used selectively on the basis of angulation or endoleak of the proximal neck to ensure satisfactory graft apposition to the aortic wall. Plain abdominal radiograms were obtained on the first postoperative day and annually thereafter. Follow-up CT scans were obtained at 1 month and 6 months. If no type I or II endoleaks were present at 6 months, CT scanning was continued every 6 months for the first 2 years, then annually.

RESULTS

There was remarkable agreement of measurements taken with IVUS, CT scan, and digital caliper of a phantom tube approximating the size of an infrarenal aortic neck. With one-way analysis of variance with preplanned contrast, no significant difference was seen in the measurements taken with the two imaging methods and direct caliper measurements ($P = .77$ for IVUS and .40 for CT scan).

In 22 of 78 actual endovascular cases (28%), however, the measurements obtained with IVUS were different enough from previous CT scan measurements to alter stent graft size selection. In 14 of 78 cases (18%), IVUS indicated that the proximal aortic neck diameter was smaller by at least 2 mm than that shown with CT scanning. In five cases (6%), IVUS indicated a larger proximal aortic neck diameter by at least 2 mm, necessitating a larger device than predicted with CT scan. In one case, graft size was altered on the basis of iliac artery size. In two of 78 patients (3%), device length was increased on the basis of IVUS pull back measurements from aortic neck to distal landing zone. (In one of these cases, the proximal graft diameter was also increased.) In one case, the device length was decreased.

No proximal type I endoleaks were found at surgery in our series. No proximal aortic extender cuffs were placed for inadequate proximal sealing. For the first 50 cases, at a mean follow-up period of 20 months (range, 13 to 25 months), no proximal type I endoleaks or aneurysm ruptures have occurred in the 47 surviving patients. Three of the 50 patients died between 1 and 6 months after the procedure of causes unrelated to the aneurysm or endovascular repair. No aneurysm enlargement has been noted on follow-up CT scans. In four cases, patients who were thought to have unacceptable conditions for stent graft repair because of a large diameter aortic neck with spiral CT scan measurement were found to have acceptable conditions with IVUS measurement. These patients underwent successful implantation without type I endoleak.

DISCUSSION

White et al[5] defined type I endoleak as perigraft blood flow from inadequate seal at the proximal or distal ends of the endovascular device. Accurate measurement of the aortic neck is critical for selection of patients for endovascular repair of AAA and selection of an appropriately sized endograft. Conventional and spiral CT scans, however, are performed over a wide range of scale and accuracy. Standardization for scans performed at other institutions may not always be known. Measurements taken from small-scale CT scan images such as the standard 7 × 7-cm format are more likely to magnify measurement errors than measurements taken from images closer to life size.

Potential for measurement error is also introduced by vessel tortuosity, especially when measured with two-dimensional techniques such as CT scan or IVUS. Within the tortuous segment of the vessel, measurements are not taken in the true axial plane at a 90-degree angle to the central flow line of the blood column. With a two-dimensional CT scan image, the smallest diameter of the oval shape more accurately approximates the true diameter. The IVUS is a flexible catheter and introducer sheath without a guidewire. It follows the course of tortuous vessels with little straightening effect and perhaps more accurately reflects the orientation of the endograft, which also does not always precisely follow the central flow line of the blood column.

Spiral CT with three-dimensional reconstruction has been touted as the gold standard for preoperative imaging for endovascular repair of AAAs. The success of three-dimensional CT scan as an imaging method has been defined by a lack of both conversions to open repair and graft-related endoleaks.[6,7] This method has only recently become available at our institution and is not currently used by many endovascular surgeons. Although three-dimensional reconstruction CT scan has replaced preoperative arteriography in some institutions, the accuracy of three-dimensional CT scan has certain limitations. It is based on complex software programs that must be validated.[6] Some three-dimensional CT scan measurements can only be made at the workstation, with select representative images given to the endovascular surgeon or interventionalist responsible for choosing and deploying the stent graft. Such measurements are subject to individual decisions regarding which part of the vessel to measure and where to place the cursor.

If these decisions are made by the radiologist alone, the endovascular surgeon is dependent on the radiologist not only for what size stent graft will be placed but for whether a stent graft should be placed at all. To produce quality results, three-dimensional reconstruction CT scanning requires a dedicated radiologist/technologist/surgeon team and possibly a commercial management service.[6] IVUS allows real-time, intraoperative measurement of the aortic neck and other critical areas, leaving final control of the measurement process in the hands of the endovascular surgeon.

We believe IVUS accurately sizes the proximal aortic neck for aortic stent grafting. This conclusion is based on the fact that we have seen no proximal type I endoleaks in our series. Our data compare favorably with the 3.8% proximal type I endoleak rate reported by the AneuRx multicenter clinical trial[8] and the 3.6% type I endoleak rate reported in the Ancure (Guidant, Menlo Park, Calif) 4-year clinical update.[9]

IVUS changed stent graft size selection in 28% of our cases. In a series by Nolthenius, van den Berg, and Moll,[10] similar results were obtained. They reported a 31% decrease in stent graft size on the basis of IVUS measurements of proximal aortic neck diameter and an 8% increase in graft size. They also reported a change in stent graft length selection in 39% of cases.

IVUS has been used as a diagnostic tool for many other vascular applications. Various authors have shown reproducible results, correlation with other established vascular investigation techniques, and superiority to two-dimensional angiography in characterizing vascular morphology.[1,2,11,12]

IVUS allows us to assess the proximity of the hypogastric arteries to aneurysmal or tortuous segments of the common iliac artery, an area that can be difficult to assess with CT scan or angiography. Errors in choosing device length can lead to use of additional costly components or occlusion of the hypogastric artery.[11] Calcification or stenosis at the aortic bifurcation can be precisely imaged and measured with IVUS, which aids in the anticipation and management of deployment problems in this potentially difficult area. After stent graft deployment, IVUS can show conditions often missed by other imaging methods, such as residual stenosis or intimal flaps distal to the device.[6] Finally, IVUS is recognized as the best method available to confirm adequate deployment of the endovascular device, which is critical for prevention of type I endoleaks.[13]

The time added by IVUS is minimal. Measurements can be easily obtained in 10 minutes or less. With the supervision of the surgeon or interventional radiologist, the unit can be easily operated by the same radiology technician who is usually on hand to operate the fluoroscopy equipment or by a surgical assistant.

Not infrequently, patients are seen from surrounding communities with conventional or spiral CT films in hand. In some cases, these patients have already undergone routine aortography. Rather than adding the expense and radiation exposure of a three-dimensional CT, we have supplemented the data provided by less than ideal studies with intraoperative, predeployment IVUS measurements with good results. We have had no adverse events related to IVUS in our patients.

CONCLUSION

We believe that IVUS determines proximal aortic neck diameter as well as conventional CT scan or angiography and in some cases more accurately sizes aortic stent grafts for endovascular aneurysm repair. With proper sizing of grafts, type I endoleaks from undersized grafts are minimized, as are endoleaks from oversized grafts with wrinkling of redundant graft material. Obtaining optimal proximal sealing may also reduce the need for remedial endograft procedures such as proximal aortic extension cuffs.

In a few cases, IVUS has allowed us to offer endovascular repair of aortic aneurysms to patients who would otherwise be excluded on the basis of conventional studies. It has been a useful adjunct to contrast angiography to confirm critical maneuvers during placement of these devices. Even with the advent of CT scan with three-dimensional reconstruction, IVUS still serves a useful function by providing critical real-time data from the aortic neck, bifurcation, and distal landing zones.

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