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Original Article

Measuring of Abdominal Aortic Aneurysm with Three-Dimensional Computed Tomography Reconstruction before Endovascular Aortic Aneurysm Repair

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Purpose: Conventional computed tomography (CT) is the gold standard method for case planning for endovascular aortic aneurysm repair (EVAR). However, aortography with a marking catheter is needed for measuring the actual length of an aneurysm. With advances in imaging technology, a 3-dimensional (3D) workstation can obviate the need for the aortography. The objective of this study was to determine whether a 3D workstation could obviate the need for aortography for EVAR.
Materials and Methods: One vascular surgeon and 1 interventional radiologist retrospectively assessed axial CT scans and reformatted the 3D CT scans by using the iNtuition workstation (TeraRecon Inc., San Mateo, CA, USA) for 25 patients who underwent EVAR. Four measurements of diameter and length were obtained from each modality. The actual length of an aneurysm for the proper graft was decided by 2 observers by reviewing the aortography with a marking catheter.
Results: The measurements from the 2 modalities were reproducible with intra-observer correlation coefficients of 0.89 to 1.0 for conventional CT and 0.98 to 1.0 for 3D workstation. Interobserver correlation coefficients were 0.29 to 0.95 for conventional CT and 0.85 to 0.99 for the 3D workstation. The length of the aneurysm for proper main graft coincided in 18 and 14 patients according to the conventional CT scan and in 21 and 18 patients according to the 3D workstation, respectively.
Conclusion: The interobserver agreement in planning EVAR was significantly better with the iNtuition 3D workstation. But aortography with a marking catheter may still be needed for selecting the proper graft.

Key Words: Aortic aneurysm, Abdominal, Endovascular procedures, Aortography

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INTRODUCTION

Since endovascular aortic aneurysm repair (EVAR) was introduced in 1991 [1], it has been the main modality to treat abdominal aortic aneurysms (AAAs) [2]. Randomized controlled trials have shown that endovascular repair provides a less invasive method than the standard open surgery and reduces perioperative mortality and length of hospital stay and intensive care unit stay [1,3].

A successful EVAR relies on accurate preoperative imaging for proper patient selection and operative planning. Failure of correctly measuring the aneurysm may lead to endoleaks, graft thrombosis, graft misalignment, and failure to exclude the aneurysm [4]. Measurement has traditionally been accomplished using axial computed tomography (CT) with selective use of digital subtraction angiography. However, advances in imaging technology and 3-dimensional (3D) workstation programs allowing centerline path and vessel-stretch views may obviate the need for conventional aortography [5].

The 3D workstation uses a process in which CT data is reformatted in planes perpendicular to the vessel in 3D space. It is used to assist in proper endograft selection. The purpose of this study was to determine whether this advanced imaging modality could obviate the need for aortography to select the proper endograft.

MATERIALS AND METHODS

We selected patients who underwent EVAR with a bifurcated endograft. Each patient enrolled in the study underwent the standard preoperative assessment using axial CT scanning with a slice thickness of 1 mm to 3 mm. We excluded patients whose preoperative assessment was performed using axial CT scanning with a slice thickness of >3 mm or other imaging modalities. Aortography was performed in the operating room or angio-suite by using a 5F marking pigtail catheter with 20 marks at 1-cm intervals. Anterio-posterior (AP) and lateral views of the aorta combined with AP and oblique views of bilateral iliac arteries were obtained.

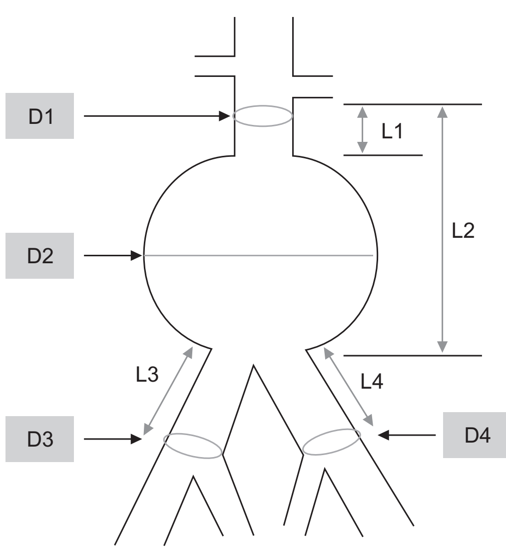

Fig. 1. Drawing demonstrating the locations of the 4 measurements of diameter and length used in this study with reference to the abdominal aortic aneurysm. D1, aneurysm neck diameter; D2, maximal aneurysm diameter; D3, diameter at right iliac landing zone; D4, diameter at left iliac landing zone; L1, length of aneurysm neck below lower renal artery; L2, length from lower renal artery to aortic bifurcation; L3, length from aortic bifurcation to right landing zone; L4, length from aortic bifurcation to left landing zone.

The iNtuition 3D workstation (TeraRecon Inc., San Mateo, CA, USA) was used to measure the diameter and length for 3D CT. The evaluation using this system begins by importing a Digital Imaging and Communications in Medicine CT data set into the iNtuition workstation. One vascular surgeon and 1 interventional radiologist assessed the axial CT scans and reformatted 3D CT scans with the iNtuition workstation for patients who underwent EVAR. Four measurements of diameter and 4 measurements of length were made from each modality to determine the proper graft for EVAR (Fig. 1). The actual length of the aorta and iliac arteries was measured with a marking catheter, and then the proper endograft was determined by aortography with a marking catheter (Fig. 2).

Intraclass correlation coefficients (ICCs) and 95% confidence intervals were used to assess the reproducibility of an observer for each measurement (i.e., intraobserver reliability) and the extent of the correlation between the 2 observers (i.e., interobserver reliability) for the measurements made from each modality. We compared exact agreement with the endograft predicted by each imaging modality and the proper endograft determined by aortography with a marking catheter. SPSS ver. 15.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

The Institutional Review Board of Kyung Hee University Hospital at Gangdong waived the patients' informed consent because all records were anonymized and we surveyed data retrospectively.

Fig. 2. The actual length of the aorta and iliac arteries was measured with a marking catheter.

RESULTS

Twenty-five patients who underwent EVAR were enrolled in this retrospective study. The patients comprised 19 men and 6 women ranging in age from 44 to 84 (mean age, 68.6) years. Other patient demographics are shown in Table 1. The main body was inserted through the right side in 11 patients (44%) and the left side in 14 patients (56%). Embolization of the right internal iliac artery was performed in 5 patients (20%) and of the left internal iliac artery in 9 patients (36%). We used 3 kinds of devices: Zenith (Cook Inc., Bloomington, IN, USA) in 7 patients (28%), Excluder (W.L. Gore & Associates Inc., Flagstaff, AZ, USA) in 12 patients (48%), and AneuRx (Medtronic, Santa Rosa, CA, USA) in 6 patients (24%).

Intraobserver reliability for each observer and each imaging modality including axial CT, 3D CT, and aortography with a marking catheter is shown in Table 2 which

Table 1. Patient demographics and procedures (n=25)

Patient demographic	Result
Age (y)	68.6±9.5
Sex (male/female)	19/6
Body mass index	23.4±1.9
Smoking	10 (40)
Cerebrovascular attack	6 (24)
Hypertension	19 (76)
Hypercholesterolemia	15 (60)
Diabetes mellitus	3 (12)
Coronary artery disease	6 (24)
Chronic renal failure on dialysis	3 (12)
Chronic obstructive pulmonary disease	7 (28)
Peripheral arterial occlusive disease	4 (16)
Procedures	
Main endograft insertion (right/left)	11 (44)/14 (56)
Embolization of IIA (right/left)	5 (20)/9 (36)
Devices used	
Zenith	7 (28)
Excluder	12 (48)
AneuRx	6 (24)

Values are presented as mean±standard deviation, number only, or number (%).
IIA, internal iliac artery.

Table 3. Interobserver reliability

Variable	Intraclass correlation coefficient		
	Axial CT	3D CT	A-MC
D1	0.91	0.97	-
D2	0.95	0.99	-
D3	0.45	0.85	-
D4	0.29	0.87	-
L1	0.79	0.89	0.93
L2	0.85	0.98	0.97
L3	0.57	0.98	0.87[a]
L4	0.62	0.99	0.89[b]

CT, computed tomography; 3D, 3-dimensional; A-MC, aortography with a marking catheter; D1, aneurysm neck diameter; D2, maximal aneurysm diameter; D3, diameter at right iliac landing zone; D4, diameter at left iliac landing zone; L1, length of aneurysm neck below lower renal artery; L2, length from lower renal artery to aortic bifurcation; L3, length from aortic bifurcation to right landing zone; L4, length from aortic bifurcation to left landing zone.
[a]Available in 14 patients, [b]Available in 9 patients.

Table 2. Intraobserver reliability

Variable	Intraclass correlation coefficient					
	Observer 1			Observer 2		
	Axial CT	3D CT	A-MC	Axial CT	3D CT	A-MC
D1	0.99	0.99	-	0.99	0.99	-
D2	1.0	1.0	-	1.0	1.0	-
D3	0.95	0.99	-	0.98	0.99	-
D4	0.97	0.99	-	0.96	0.99	-
L1	0.98	0.98	0.92	0.98	0.98	0.92
L2	0.99	0.99	0.99	0.99	0.99	0.99
L3	0.91	0.99	0.96[a]	0.89	1.0	0.95[a]
L4	0.95	1.0	0.96[b]	0.92	0.99	0.97[b]

CT, computed tomography; 3D, 3-dimensional; A-MC, aortography with a marking catheter; D1, aneurysm neck diameter; D2, maximal aneurysm diameter; D3, diameter at right iliac landing zone; D4, diameter at left iliac landing zone; L1, length of aneurysm neck below lower renal artery; L2, length from lower renal artery to aortic bifurcation; L3, length from aortic bifurcation to right landing zone; L4, length from aortic bifurcation to left landing zone.
[a]Available in 14 patients, [b]Available in 9 patients.

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shows that the intraobserver correlation coefficients were between 0.89 and 1.0 for axial CT, 0.98 and 1.0 for 3D CT, and 0.92 and 0.99 for aortography with a marking catheter.

Interobserver reliability is shown in Table 3 for each modality with correlation coefficients between 0.29 and 0.95 for axial CT, 0.85 and 0.99 for 3D CT, and 0.87 and 0.97 for aortography with a marking catheter.

Intermodality correlations for length measurement are shown in Table 4. When measurements using axial CT were compared with those using aortography with a marking catheter, the ICCs were 0.68 for L1, 0.70 for L2, 0.71 for L3, and 0.80 for L4. In comparison with 3D CT and aortography with a marking catheter, ICCs were 0.71 for L1, 0.85 for L2, 0.74 for L3, and 0.72 for L4.

Table 5 shows the exact agreement between the endograft predicted by the imaging modalities listed and the actual graft implanted in the patient. For the main endograft, the agreement was 72% and 84% when observer 1 measured the length, using axial CT and 3D CT, respectively. For observer 2, the agreement was 56% and 72% for axial CT and 3D CT, respectively. Data regarding the contralateral endograft were available for 21 patients. For axial CT, the lowest and highest values of agreement were 52% and 81%, respectively. For 3D CT, the lowest and highest values were 71% and 86%, respectively.

DISCUSSION

Conventional CT is widely used as the ideal preoperative imaging modality because of its accurate and precise reflection of the aneurysmal morphology. In our study, intraobserver reliability presented by ICCs was 0.85 to 1.0 for the measurement of diameter and 0.89 to 0.99 for the measurement of aneurysm length. However, interobserver reliability was 0.29 to 0.95 and 0.57 to 0.85 for the measurement of diameter and length, respectively, showing a difference in the measurements between the observers. However, intraobserver and interobserver reliability values for 3D CT were higher than that for axial CT. The exact agreement of endograft selection by 3D CT was higher than that of axial CT.

The implantation of an aortic endograft is a relatively simple procedure but requires detailed preoperative length and diameter measurements and accurate longitudinal device placement. Essential information needed for the preoperative assessment of the AAA includes the relationship of the aneurysm to the aortic branches, the degree of iliac arterial involvement by the aneurysm, and the presence of other coexisting iliac arterial or aortic aneurysms. Software designed to assist EVAR planning using 3D workstations have been developed during the past

Table 4. Intermodality correlation of length measurements

Variable	Axial CT/A-MC		3D CT/A-MC	
	ICC	95% CI	ICC	95% CI
L1	0.68	0.09-0.85	0.71	0.18-0.89
L2	0.70	0.16-0.90	0.85	0.51-0.97
L3[a]	0.71	0.21-0.92	0.74	0.38-0.91
L4[b]	0.80	0.39-0.95	0.72	0.15-0.95

CT, computed tomography; 3D, 3-dimensional; A-MC, aortography with a marking catheter; ICC, intraclass correlation coefficient; CI, confidence interval; L1, length of aneurysm neck below lower renal artery; L2, length from lower renal artery to aortic bifurcation; L3, length from aortic bifurcation to right landing zone; L4, length from aortic bifurcation to left landing zone.
[a]Available in 14 patients, [b]Available in 9 patients.

Table 5. Exact agreement in endograft selected by each modality

Variable	Observer 1		Observer 2	
	Axial CT	3D CT	Axial CT	3D CT
Main endograft (n=25)				
Zenith	18 (72)	21 (84)	14 (56)	18 (72)
Contralateral endograft (n=21)				
Zenith	12 (57)	15 (71)	11 (52)	18 (86)
Excluder	15 (71)	16 (76)	17 (81)	17 (81)
AneuRx	15 (71)	16 (76)	16 (76)	18 (86)
Talent	16 (76)	16 (76)	17 (81)	17 (81)

Values are presented as number (%).
CT, computed tomography; 3D, 3-dimensional.

10 years [6]. As with any postprocessing task, the output is only as good as the input data, and therefore, proper acquisition of high-quality CT images is paramount in producing high-quality 3D images. The slice thickness of the original CT scan should be <3 mm [7,8]. This system allows the measurement of the diameter of the aneurysm with a perpendicular axis, thus enabling measurement of the real diameter. Sobocinski and coworkers [9] showed clinical evidence that software-assisted sizing is associated with reductions in the incidence of type 1 endoleaks and their related secondary interventions.

The generation of a centerline path and vessel-stretch view allows visualization of a tortuous aorta as though it were straightened and greatly aids in the design of the endograft particularly in accurate measurement of the correct length of the graft between key anatomic targets such as branch locations and vessel bifurcations [10-12]. Our study shows that the intraobserver reliability of 3D CT was higher than that of aortography with a marking catheter for the length measurement. Parker and coworkers [13] reported on 3D CT compared with aortography with intraobserver correlation coefficients of 0.79 to 1.0 for aortography and 0.96 to 1.0 for 3D CT and interobserver correlation coefficients of 0.70 to 0.97 for aortography and 0.73 to 0.99 for 3D CT. They concluded that as a single imaging modality, 3D CT appears to have the best correlation for both diameter and length measurements.

The interobserver reliability of axial CT in the measurement of diameter and length varied. Especially, the interobserver reliability of measurement for iliac arteries with axial CT scan was relatively low. It is presumed by the anatomical tortuosity of iliac artery. The exact measurement of diameter is important to avoid postoperative complications such as type I endoleak which can especially be caused by poor endograft sizing [14,15]. The greatest interobserver variability for the measurement of diameter was due to measuring the oblique diameter. The Abdominal Aortic Aneurysm Detection and Management (ADAM) study, a large multicenter trial, was the first to report interobserver variability values for aortic CT measurements [16]. Interobserver variability was ≤2 mm in 65% of cases, with 17% of cases differing by ≥5 mm.

Although several sizing software programs before EVAR have been used, only a few studies have reported on the assessment of software. Kaladji and coworkers [17] compared the advanced vessel analysis workstation (General Electric Medical Systems, Milwaukee, WI, USA) and automatic 3D sizing software (Endosize; Therenva Inc., Rennes, France). Comparison of the two measurement methods showed a good correlation (minimum ICC=0.697; maximum ICC=0.974), although less than that observed using Endosize. Matthew and coworkers [18] evaluated the agreement between anatomic measurements obtained from 3D CT reconstructions using 3 commercially available software programs including Preview (M2S Inc., Lebanon, NH, USA), AquariusNet Thin Client (TeraRecon Inc.), and Osirix MD (Pixmeo, Geneva, Switzerland). ICCs between the programs for diameter measurements were comparable (≥0.82 for all diameter comparisons and ≥0.88 for all length comparisons), indicating good correlation. In Korea, three softwares such as advanced vessel analysis workstation, Osirix MD, and iNtuition workstation were available.

In conclusion, the ICCs indicating intraobserver reliability were 0.89 to 1.0 for axial CT and 0.98 to 1.0 for 3D CT. ICCs indicating interobserver reliability were 0.29 to 0.95 for axial CT and 0.85 to 0.99 for 3D CT. ICCs indicating intermodality correlation for length measurement were 0.68 to 0.80 between axial CT and aortography and 0.71 to 0.85 between 3D CT and aortography. The disagreement rate of selected endografts was 19% to 48% by axial CT and 14% to 29% by 3D CT. Intraobserver reliability for each modality was similar. Interobserver reliability was better with 3D CT than with axial CT. It is suggested that the liberal use of 3D CT workstation for measuring the diameter and length before EVAR can obviate the need for the aortography. Because of the relatively high disagreement rate in selected endografts (14%–48%), it is necessary to perform aortography with a marking catheter for selecting the proper endograft.

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