Accuracy and Variability of Semiautomatic Centerline Analysis versus Manual Aortic Measurement Techniques for TEVAR

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WHAT THIS PAPER ADDS

A previous study showed good reliability and low variability of diameter measurements for thoracic endovascular aortic repair (TEVAR) by semiautomatic centerline analysis among non-experts. This study demonstrates that semiautomatic centerline analysis provides not only the least variable diameter measurements in candidates for TEVAR but also the same accuracy as the current reference standard, double-oblique multiplanar reformation (MPR), as assessed by vascular experts. Furthermore, centerline analysis offers the possibility for fast and reliable length measurements. Therefore, semiautomatic centerline analysis should be used as the measurement technique of choice for preoperative assessment of TEVAR.

Objectives: This study aims to test whether inter-observer variability and time of diameter measurements for thoracic endovascular aortic repair (TEVAR) are improved by semiautomatic centerline analysis compared to manual assessment.

Methods: Preoperative computed tomography (CT) angiographies of 30 patients with thoracic aortic disease (mean age 66.8 $\pm$ 11.6 years, 23 males) were retrospectively analysed by two blinded experts in vascular radiology. Maximum aortic diameters at three positions relevant to TEVAR were assessed (P1, distal to left common carotid artery; P2, distal to left subclavian artery; and P3, proximal to coeliac trunk) using three measurement techniques: manual axial slices (axial), manual double-oblique multiplanar reformations (MPRs) and semiautomatic centerline analysis.

Results: Diameter measurements by both centerline analysis and the axial technique did not significantly differ from MPR ($p = 0.17$ and $p = 0.37$). Total deviation index for 0.9 was for P1 2.7 mm (axial), 3.7 mm (MPR), 1.8 mm (centerline); for P2 2.0 mm (axial), 3.6 mm (MPR), 1.8 mm (centerline); and for P3 3.0 mm (axial), 3.5 mm (MPR), 2.5 mm (centerline). Measurement time using centerline analysis was significantly shorter than for assessment by MPR.

Conclusions: Centerline analysis provides the least variable and fast diameter measurements in TEVAR patients with the same accuracy as the current reference standard MPR.

Article history: Received 24 July 2012, Accepted 6 December 2012, Available online 11 January 2013

Keywords: Thoracic aorta, Computed tomography, Three-dimensional imaging, Computer-assisted image analysis, Endovascular

Measurements on axial images, multiplanar reformations (MPRs) and by centerline analysis are used for planning thoracic endovascular repair (TEVAR) in patients with thoracic aortic aneurysms (TAAs) and penetrating atherosclerotic ulcers (PAUs) of the aorta.[1] For these patients, accurate morphologic assessment of proximal and distal landing zones is mandatory to allow for adequate selection of endograft size and type and thereby to reduce postoperative complications that still occur in almost every second patient after TEVAR.[2–4] While there are several imaging modalities for preoperative assessment of aortic dimensions, computed tomography angiography (CTA) is the favoured one, because of its speed, wide availability and various post-processing techniques.[1]

Strictly axial images only allow for measurements in one plane whereas double-oblique MPRs represent arbitrarily

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http://dx.doi.org/10.1016/j.ejvs.2012.12.003

adjusted planes perpendicular to the course of the aorta. Centerline analysis embodies a semiautomated image post-processing algorithm that calculates the geometric vessel centre and allows for diameter as well as distance measurements along its course.[5]

Measurements in earlier studies focussing on the thoracic aorta were mostly performed manually on axial CTA data.[6,7] Since the thoracic aorta exhibits physiological bending of the aortic arch and frequent significant bending in the descending aorta in older patients, recent studies show that strictly axial measurements often do not represent true dimensions.[8,9] Significant kinking, elongation and asymmetric dilatation of the abdominal aorta may cause the same drawbacks for axial measurements in the abdominal aorta.[10–12] MPR has therefore been advocated to be most accurate for diameter assessment of aortic pathologies.[1,8,9,13,14] Among non-expert readers centerline provided the most reliable and least variable preoperative measurements, whereas MPR showed significantly lower reliability and higher inter-observer variability.[15] However, to our knowledge variability for the different measurement techniques among expert readers in planning for TEVAR has not yet been investigated.

The purpose of this study was to test our hypothesis that measurements by centerline analysis provide reduced inter-observer variability and shorter measurement times compared to manual assessment on axial slices and MPR with the same accuracy as measurements with the current reference standard MPR.

MATERIALS AND METHODS

Patients

Institutional review board approval and informed consent were obtained. This retrospective single-centre study comprised patients with TAAs or PAUs who received a CT scan at our institutions prior to elective TEVAR.

Between January 2004 and April 2008, 47 patients fulfilling all inclusion criteria received CT scans prior to elective TEVAR in our institution. The inclusion criteria were as follows: pathology PAU of the aorta or TAA, CT scan with arterial phase and slice thickness 1 or 3 mm. Exclusion criteria were as follows, leading to exclusion of 17 patients: pathology not located in the descending thoracic aorta ($n = 12$) or second pathology in the descending thoracic aorta ($n = 5$). These exclusion criteria were defined to allow for standardised measurements in the descending thoracic aorta at three measurement positions as described below in patients with comparable pathologies. Thirty patients (7 females, 23 males) with a mean age of 66.8 $\pm$ 11.6 years (age range, 30–87 years) were finally included.

Procedures

Image acquisition. All CTA studies were performed on two clinical multidetector CT scanners, 17 patients on scanner A (Aquilion-16, Toshiba Medical Systems, Tokyo, Japan) and 13 patients on scanner B (Volume Zoom, Siemens Medical Systems, Erlangen, Germany). For scanner A, scan and reconstruction parameters were as follows: 120 kV, 120 mAs, slice thickness 1.0 mm, increment 0.8 mm, pixel spacing 0.6–0.75 mm and 90 ml contrast medium (iomeprol with 400 mg iodine per ml, Imeron 400, Bracco Diagnostics, Princeton, NJ, USA) with 40 ml saline chaser. For scanner B, scan and reconstruction parameters were as follows: 120 kV, 120 mAs, slice thickness 3.0 mm, increment 3.0 mm, pixel spacing 0.6–0.75 mm and 120 ml contrast medium (iopromide with 370 mg iodine per ml, Ultravist 370, Bayer Health Care, Berlin, Germany) with 40 ml saline chaser.

Image data preparation. For blinded investigation, a research assistant prepared the data as follows: Three measurement techniques as detailed below were integrated by creating a unique identification for each combination of patient and measurement technique, resulting in a total of 90 data sets (30 patients $\times$ 3 measurement techniques). The order of those 90 data sets was randomised separately for each reader to randomly disperse the three analyses for each patient. Each reader was given a list containing only the measurement techniques attributed to the individual order from 1 to 90, blinded to patient identification.

Image analysis. Image analysis of all 90 data sets was performed by two vascular expert readers. Both had more than 2 years of experience in vascular image post-processing, one a tutor in a Continuing Medical Education (CME)-certified vascular image post-processing course. For each reader, the 90 randomised and anonymised data sets were transferred to a commercially available image post-processing workstation (Aquarius, v.3.6.2.3, TeraRecon, Inc., San Mateo, CA, USA).

A standardised protocol for the three measurement techniques was established by two independent, vascular expert radiologists: manual measurements on axial data, manual measurements using MPR and semiautomatic centerline analysis.

Three measurement positions relevant to TEVAR were defined for all three measurement techniques: P1, distal to left common carotid artery; P2, distal to left subclavian artery; and P3, proximal to the coeliac trunk. The target parameter was maximum aortic diameter from inner to inner wall (including thrombus and excluding calcium). Window and levelling were set to 700/200 and individually adjusted if necessary. Required time per patient in all three techniques was evaluated using a stopwatch. The time needed for centerline preparation was assessed separately.

Measurements in axial data comprised identification of an appropriate axial plane and manual measurement of maximum aortic diameter. In the case of oblique projections, that is, aortic kinking, the shorter diameter was assessed.

For MPR, adjustments of the sagittal, coronal and axial planes were made to allow for orientations perpendicular to the aorta. Manual assessment of maximum aortic diameter was performed (Fig. 1).

Prior to acquiring measurements using centerline analysis, a standardised preparation protocol following published