Comparison of Aortic Diameter and Area After Endovascular Treatment of Aortic Dissection

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Background. **Different methods have been used to assess remodeling of the thoracic aorta after endovascular treatment of Stanford type B aortic dissections. Changes in morphology may be described using diameter, area, or volume. The aim of this study was to determine if aortic diameter measurements could be used to approximate aortic area in order to refine reporting standards.**

Methods. **The study population encompassed 100 patients enrolled in the VIRTUE registry (designed to assess thoracic endografting with the Valiant Stent Graft System [Medtronic, Minneapolis, MN] for the treatment of type B aortic dissections). Diameter and area measurements of the true lumen, false lumen, and whole aorta were made using three-dimensional computed tomographic (3D CT) workstations, at different anatomic locations. Measurements included preoperative, postoperative, and follow-up scans. The Pearson test was used to determine general correlation between diameter and volume at each location. Scatter plots were drawn and linear regression models were used to draw a line of best fit. Comparison of these with nonlinear models was performed.**

Results. **Aortic true and false lumen diameter and area showed good correlation ($p < 0.001$) in the majority of anatomic locations. This relationship was present preoperatively and during follow-up ($p < 0.001$). The linear regression models fit well with high R^2 values. At very large aortic sizes nonlinear models were a slightly better fit, but this was not significant.**

Conclusions. **Aortic diameter measurements correlate with luminal areas in patients with type B aortic dissection. This implies area increases proportionately with diameter over time. Therefore, diameter measurements using multiplanar reconstructions based on a central luminal line appear to be adequate when assessing aortic remodeling after endovascular treatment of aortic dissection.**

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Various measurements have been used to describe morphologic changes in the thoracic aorta after endovascular treatment of Stanford type B dissection [1]. These vary from simple diameter measurements from axial scans to complex volumetric studies of the true and false lumen [2, 3]. Recent evidence has emerged to suggest that favorable aortic remodeling after endovascular treatment is associated with a positive clinical outcome [4, 5]. A significant limitation of existing studies is that most report different parameters over variable follow-up intervals [1]. There are no sufficiently large studies to allow analysis of factors such as length of coverage, timing of treatment, and preoperative morphology that may potentially influence remodeling. A standardized protocol that could be reported for all studies of aortic morphology would allow for more detailed analysis and ideally would contain readily obtainable measurements. Measuring luminal areas and volumes would seem to be the most sensitive way to detect changes in aortic morphology, but these measurements are time consuming and are not part of routine clinical practice. Area and volume estimation are also subject to greater interobserver variability, whereas aortic diameters can be measured with excellent reproducibility [6].

The aim of this study was to determine the relationship between area and diameter in both the true and false lumen. A linear relationship between luminal diameter and area would suggest that area increases in proportion to diameter, and allow the formulation of pragmatic morphology reporting standards based on aortic diameters.

Material and Methods

Patient Population and Morphology Data

The study population consisted of patients enrolled into the VIRTUE registry, which is described in detail elsewhere [7]. The VIRTUE registry consists of a total of 100 patients who were treated with the Valiant endovascular stent-graft

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system (Medtronic, Minneapolis, MN) for aortic dissection. Fifty patients were treated for acute aortic dissection within 2 weeks of presentation; 24 for subacute dissection 15 to 92 days, and 26 treated for chronic dissection more than 92 days after the initial diagnosis. Patients were followed up at intervals of 6, 12, 24, and 36 months. Informed consent was gained from all patients enrolled and the study was approved by local ethical review boards in all cases (clinicaltrials.gov identifier number NCT01213589). Computed tomographic scans obtained at each follow-up visit were measured by a core lab according to an agreed protocol using the 3Mensio system (3Mensio Medical Imaging BV, Bilthoven, The Netherlands). This system has previously been validated for use when measuring morphology in the infrarenal aorta with excellent intra and interobserver agreement [6].

The area and diameters of the whole aorta (WA), true lumen (TL), and false lumen (FL) were measured at the ascending aorta, the left subclavian artery (LSA), 20-mm beyond the LSA, 100-mm beyond the LSA, the celiac axis, and at the point of maximum aortic diameter within the descending thoracic aorta (Fig 1). A central luminal line was installed within the aorta and "stretch views" were obtained. Multiplanar reconstructions of these images in the plane orthogonal to the central luminal line allowed for accurate estimates of diameter and area by correcting for parallax error (Fig 2A, B). The area of the WA was measured using the manual area calculation tool to draw around the outside of the aortic wall as it appeared on the multiplanar reconstructions image. The area of the TL and FL were measured by drawing around the corresponding lumens. The diameter of the WA was measured from outside wall to outside wall through the central luminal line and taking the greatest measurement obtained. The diameters of the TL and FL were taken using the same line but only measuring the relevant lumen.

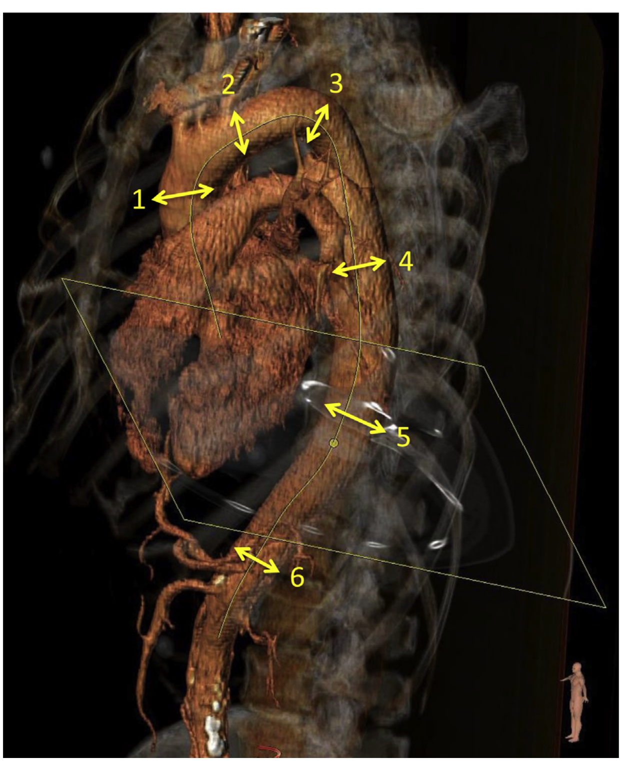

Fig 1. Location of area and diameter measurements of the thoracic aorta: 1 = maximum ascending aorta diameter; 2 = at the left subclavian artery; 3 = at 2 cm beyond the left subclavian artery; 4 = 10 cm beyond the left subclavian artery, 5 = the widest part of the descending thoracic aorta; and 6 = at the level of the celiac axis.

Statistical Analysis

Statistical analysis was performed using the SAS 9.3 statistical package (SAS Institute Inc, Cary, NC) and SPSS 20 (IBM, Armonk, NY). Graphs were drawn with R 3.0.1. Mean and median diameters and standard deviations were calculated for each anatomic point for the WA, TL, and FL. The Pearson correlation coefficient was used to compare the area and diameter measurements for the WA, the FL, and the TL in the different anatomic locations at the different follow-up intervals with significance testing to the p less than 0.05 level of stringency. The purpose of this analysis was to determine if there was a correlation between the 2 measurements in each anatomic location and to see if this relationship was consistent over follow-up. Observations with zero value for area and diameter were removed from the calculation to avoid inflating the correlation. Scatter plots were produced to determine the nature of the relationship between diameter and area. Linear regression models were fitted using only the corresponding measures of diameter as a fixed effect. The within patient correlation was estimated using scan time as random effect with an unstructured variance and covariance matrix. The R-square value, which refers to the fraction of variance explained by the model, of each model was reported. Finally, a comparison was made with both exponential and quadratic regression models to see if these accounted for a potentially nonlinear or curved distribution, and more accurately reflected the distribution of the scatter plots.

Results

There were 82 patients who had analysis of preoperative scans and 81 with discharge scans available for analysis. At follow-up there were 71, 66, 64, and 61 scans at 6, 12, 24, and 36 months, respectively. There were 26 patients who had scans performed at other time intervals for unscheduled visits. The Pearson test for correlation between area and diameter was performed for all measurements at all time periods between diameter and area measurements taken at the same anatomic location, as was the R^2 value obtained from the linear regression model. A sample of 14 scans were tested for interobserver variability in area, with a mean and median of 2% in the relative difference between 2 observers and a standard deviation of 9% noted. There was 1 episode of a significant disagreement between measurements and this was discussed and resolved by consensus at an investigators meeting.