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# Thoracic Endovascular Aortic Repair: Proximal Landing and Dynamic Morphology of the Ascending Aorta

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## Abstract

In order to determine a good proximal landing zone and suitable aortic size for the most proximal Thoracic Endovascular Aortic Repair (TEVAR), the dynamic segmental architecture of the entire Ascending Aorta (AA) was examined. The complete AA was imaged using Electrocardiogram Gated-Computed Tomography Angiography (ECG-CTA) in the systolic and diastolic phases in patients with a non-operated AA (diameter 40 mm). The maximum and smallest diameters in the systole and diastole phases for each plane of each segment were noted. Aortic size measurements were compared using the Wilcoxon signed rank test. 100 patients in total (53% men, 82.1 years old on average, 76.8-85.1) were enrolled. Systolic values for the AA during the cardiac cycle were significantly greater than diastolic values, according to analysis of the dynamic plane dimensions of the AA. Analysis of the proximal AA segment revealed a reversed funnel structure, with bigger distal plane values than proximal plane values (p 0.001). The dynamic values at the mid-ascending segment showed a cylindrical shape since there was little difference between the proximal and distal segmental planes. The proximal plane values were greater than the distal segmental plane values at the distal segment of the AA (p 0.001), resulting in a funnel shape.

**Conclusions:** Throughout the cardiac cycle, the whole AA displayed larger systolic than diastolic aortic dimensions. When a typical cylindrical endograft was used, the mid-ascending and distal-ascending portions displayed favourable shapes for Tevar. Since the most proximal segment of the AA had a clearly conical shape, a particular endograft design should be taken into account.

**Keywords:** Tevar of ascending aorta • Endograft of ascending aorta • Dynamic morphology of ascending aorta • Thoracic endovascular aortic repair • Cylindrical endograft

## Introduction

For some individuals for whom open surgery represents a significant risk, Thoracic Endovascular Aortic Repair (TEVAR) with landing in the Ascending Aorta (AA) is an alternative for treating a range of proximal aortic diseases [1]. The morphology of the Proximal Landing Zone (PLZ) plays a significant role in the outcome of any tevar treatment, with suboptimal aortic and endograft sizing allegedly linked to rising rates of Endoleaks (ELs), endograft migration, and intervention. Poor tevar results may result from the AA's pulsatile nature and its fluctuating segmental geometry during the cardiac cycle, which may be detrimental to proximal endograft placement [2]. The segmental anatomy of the entire AA is still understudied, and few studies have examined the dynamic slice anatomy and motility of specific AA and aortic arch regions. Although tevar in the AA has positive results, it is also accompanied by significant rates of Retrograde Aortic Dissection (RAD), conversion, and ELs. To progress tevar in the AA and to enhance the existing clinical and technical outcomes of this treatment, additional research into the dynamic segmental architecture of the AA is therefore necessary [3].

The goal of the current study was to evaluate the dynamic segmental anatomy of the entire AA in order to select an advantageous PLZ and the right aortic size for the tevar that is closest to the heart [4].

Using a 64-slice CT scanner while lying flat and holding an inspiratory breath, images were acquired. We used the following protocol parameters: Tube potential of 120 kVp, automatic tube current modulation, 80 mL of iodinated contrast medium followed by a 50 mL saline bolus to get the results for ECG gated CTA scans of the heart, ascending aorta, and aortic arch [5]. The pictures were rebuilt using the IMR-1 cardiac routine kernel, a slice thickness of 0.67 mm, a slice increment of 0.33 mm, and 5% steps of the RR interval. The diastolic phase was identified as the reconstruction at 40% of the RR interval, and the systolic phase as the reconstruction at 75% of the RR interval [6].

## Literature Review

The entire AA's systolic and diastolic phases of the ECG-CTA was analysed. The CTA picture series was transferred from the institutional database to a different workstation outfitted with the post-processing program "3 mensio vascular" (Pie medical imaging BV, Maastricht, the Netherlands). Manual aortic segmentation was carried out following a three dimensional centerline reconstruction of the systolic and diastolic imaging series of the complete AA (from the sinotubular junction to the brachiocephalic trunk). In accordance with the required length of the proximal landing zone for tevar in the proximal thoracic aorta, a centerline length of 25 mm for each AA segment was acquired for this segmentation [7].

Each segment's planes were automatically adjusted to be perpendicular to the centerline. Segment A's proximal plane was at the junction of the sinotubules, segment B's length was in the center of the AA, and segment C's distal border was at the proximal circumference of the brachiocephalic trunk. The area and maximum and lowest diameters in the systole and diastole phases were automatically recorded for each plane of each segment. Two independent study collaborators each independently examined each image sequence [8].

The brachiocephalic trunk's proximal boundary and the sinotubular junction made up the AA's centerline length. The biggest difference between the systole and diastole values in terms of area and diameter was used to determine segmental pulsatility, which was defined as the radical change in the aortic lumen during the cardiac cycle. The difference between the distal and proximal diameters of the aorta planes in the systole and diastole phases was used to identify the segmental morphologies of aortic segments. A 2D aortic slice that was positioned perpendicular to the centerline was used to define the aortic plane. The 3D portion of the AA between the proximal and distal segmental planes that is cylindrical, conical, or reversely conical was designated as the aortic segment.

## Discussion

The current study demonstrates that throughout the whole cardiac cycle, at all levels of the ascending aorta, systolic diameter predominates over diastolic diameter. Each aortic plane showed a 2D morphology that was oval in shape, with a 10% preference for large plane diameters over smaller ones. Additionally, our data showed that the mid-ascending aortic segment had a cylindrical shape, the distal ascending segments had a slightly funneled shape, and the majority of the proximal segments of the AA had a clearly conical shape.

The reports that are currently accessible in the literature indicate the pulsatility of some AA segments. According to de Heer, et al., the aortic diameter at the sinotubular junction is bigger during systole than it is during diastole. According to Jian-ping, et al., the distal AA's aorta diameter significantly changed throughout the cardiac cycle, with the aortic size being bigger during the systole phase than the diastole phase. In healthy individuals, Rengier, et al. demonstrated the AA's strong mid-ascending pulsatility, where the systolic aortic dimension was almost 10%higher than the diastolic aortic dimension. The cross sectional dimensions of the aorta varied widely throughout the cardiac cycle, with systolic dimensions at all levels of the AA being noticeably bigger than diastolic measurements, consistent with these earlier results. The AA experienced asymmetrical distension during the cardiac cycle, which was more pronounced along the AA's larger curvature and was congruent with the jet flow direction during heart output, according to Satriano, et al., 3D. Reconstruction of the ECG-CTA series. Some aorta planes have non-circular forms during the cardiac cycle, according to other reports.

To prevent retrograde aortic dissection, Liu, et al., studied the accurate sizing for tevar in the AA and reported that if the diameter differences were greater than 5%, the real aortic diameter should be determined as the average between the highest and minimum diameters. The segmental planes at all levels of the AA have an oval form, with a relative difference between the maximum and lowest diameter that varies over the cardiac cycle of around 10%. Therefore, it would appear appropriate to estimate the AA diameter precisely using the average diameter.

In the present investigation, we found an AA strain of up to 5% and increased aortic diameter in the systole phase compared to the diastole phase. For the entire AA, Satriano, et al., found 10.2 6.0% peak primary strain amplitude. Redheuil, et al., discovered an AA strain of up to 15 ± 8% in patients 40–49 years old and identified a similar AA strain (8 ± 4%) in patients over 70 years old. Thus, independent of the patient's age, the data from our current investigation and the existing literature suggest the use of a systolic CTA series for the most accurate sizing of tevar in the AA, whereby 5%–15% of the aortic diameter size may be balanced out in comparison to CTA in the diastolic phase.

Muetterties, et al., found an 18.6% rate of early term EL Ia after tevar in the AA in a recent systematic evaluation. Similar results were found by Baikoussis, et al., in their meta-analysis, which showed a high pooled rate of late EL Ia (16.4%) after tevar in the AA. These outcomes are most likely due to the endograft's improper alignment with the aortic wall. Therefore, it is essential to comprehend the PLZ's 3D shape. In a study, van Prehn, et al., defined the 3D motions of 2D aortic planes and documented the dynamic plane morphology at the three AA levels. The 3D segmental morphology of AA, however, which is crucial for comprehending the volume geometry of a putative proximal landing zone, was not taken into account by the authors.

The standard cylindrical construction of the endograft seems appropriate in this situation because the mid-ascending portion of the AA maintained its cylindrical shape throughout the cardiac cycle. Although the distal AA segment exhibited a funnel shape, the 1.5 mm diameter difference between the proximal and distal segmental planes did not appear to be important for practical sizing, therefore a cylindrical endograft design might also be taken into account in this situation.

Contrarily, the majority of proximal AA segments exhibited a reversed funnel (conical) morphology, which is thought to be detrimental to aortic endograft alignment. Additionally, the 18% (5.5/29.6 mm) systolic diameter difference between the proximal and distal segmental planes is corresponding to the >5 mm difference between the proximal (smaller) and distal (larger) diameters of segmental planes. As a result, using the traditional cylindrical endograft design in these situations may not be appropriate.

The current study contains a number of drawbacks. First, patients with severe aortic stenosis were included since this condition may affect aortic asymmetry during the cardiac cycle and the strength and direction of jets. However, prior research has shown that severe aortic stenosis increases arterial stiffness throughout the entire arterial tree, including the AA; however, if cardiac output and stroke volume were preserved, there was no difference in the distensibility of non-calcified AA compared to patients without multiple aortic stenosis. Additionally, bias in terms of absolute diameter and area numbers may be introduced by equally distributed AA stiffness. The aortic plane size ratios are unlikely to change as a result, though. As a result, it is likely that the volumetric form of the AA segments will not change.

Aortic distensibility may be impacted by advanced age and atherosclerosis, which were included in our patient group. One may hypothesize that younger subjects exhibit higher levels of AA compliance. Third, the longitudinal motions, side deviations, or angulation of the AA during the cardiac cycle were not examined in this study. These motions may be important for a thorough explanation of the 3D aortic geometry during the cardiac cycle.

## Conclusion

Throughout the cardiac cycle, the whole AA displayed dynamic architecture that was changeable. The average aortic diameter and the systolic CTA series may be used to size AAs precisely. When a typical cylindrical endograft was used, the mid-ascending and distal-ascending portions displayed favorable shapes for tevar. Since the most proximal segment of the AA had a clearly conical shape, a particular endograft design should be taken into account.

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