Quantification of *in vivo* wall motion of the descending thoracic aorta using 4D-CT

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Introduction

Relatively little is known about the wall dynamics of the human thoracic aorta, in particular the longitudinal motion. Previous studies have reported circumferential strain using an Eulerian frame, but no studies heretofore have quantified longitudinal strain, nor have any implemented a Lagrangian frame. It is vital to understand the dynamics of this region because it affects stents and other medical implants. The aim of this study is to characterize the longitudinal strain, and to compare the diameter and circumferential strain of the proximal and distal descending thoracic aorta (DTA) over the cardiac cycle.

Methods and Materials

We examined the DTA of seven patients (6M and 1F, 46±5 yrs) with no aortic pathology using 4D cardiac gated-CT. Each data set contained ten 3D volumes of the vasculature, each volume representing 1/10th of the cardiac cycle. Because it has been shown that strain and pressure peak nearly simultaneously in the cardiac cycle, all measurements were made at peak-systole and end-diastole [1]. To determine peak-systole and end-diastole, we calculated the cross-sectional area at four proximal and distal locations along the DTA. We referred to the frame with maximal area as systole and with minimal area as diastole. Using SimVascular [2], the center-line path of the DTA was created, as shown in Figure 1(b), and the location and centroid of the ostia of the two most proximal and distal intercostal arteries were marked, as shown in Figure 2(a). The ostia serve as a Lagrangian reference frame, versus the previously used [3] Eulerian frame. A Lagrangian frame is fixed to the object in motion, whereas the Eulerian frame is fixed in space. The centroids were projected to the center-line path, as shown in Figure 2(b). We defined the length of the DTA as the arc length of the center-line path between the most proximal and distal projected centroids.

We computed the length of the DTA at end-diastole Z^D and peak-systole Z^S, and the effective diameter of each cross-section just below the ostia at end-diastole D^D and peak-systole D^S. The longitudinal and circumferential strains were calculated from $(Z^S-Z^D)/Z^D$ and $(D^S-D^D)/D^D$, respectively.

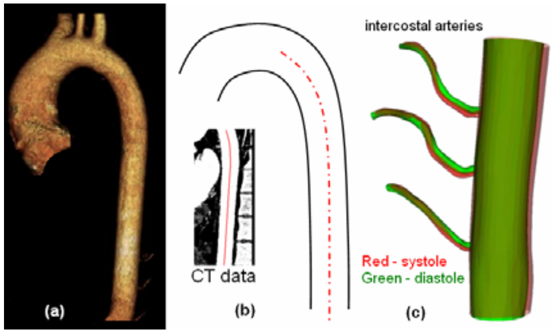

Figure 1. (a) Volume-rendered image of a non-pathologic thoracic aorta. (b) Sketch of thoracic aorta, with CT-data inset with center-line path in red. (c) Computer models of the distal part of the DTA at systole and diastole, showing deformation over the cardiac cycle.

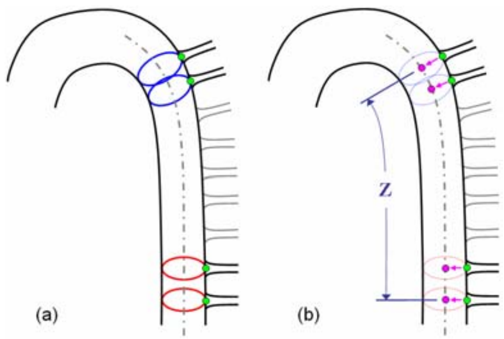

Figure 2. A center-line path was created down the length of the DTA. (a) The two most proximal and distal intercostal arteries and their centroids were marked. (b) The centroid of the two most proximal and distal intercostal arteries were projected onto the center-line path, defining the arc length of the DTA as **Z**.

Results

The area peaked at frame 3 (peak-systole) and its nadir occurred at frame 10 (end-diastole), as shown in Figure 3. This trend was similar for all patients. The effective proximal and distal diameters at peak-systole were 23.4±1.3 and 21.8±1.1mm ($p < 0.005$), and the effective proximal and distal diameters at diastole were 21.8±1.2 and 20.1±1.0mm ($p < 0.001$), as shown in Figure 4(a). The length of the DTA at peak-systole was 12.0±1.3cm, longer than at end-diastole 11.8±1.3cm ($p < 0.001$), shown in Figure 4(b). The longitudinal strain of the DTA was 1.9±0.7%. The proximal and distal circumferential strains were 7.4±3.5 and 8.7±2.2%, but not statistically different, as shown in Figure 4(c).

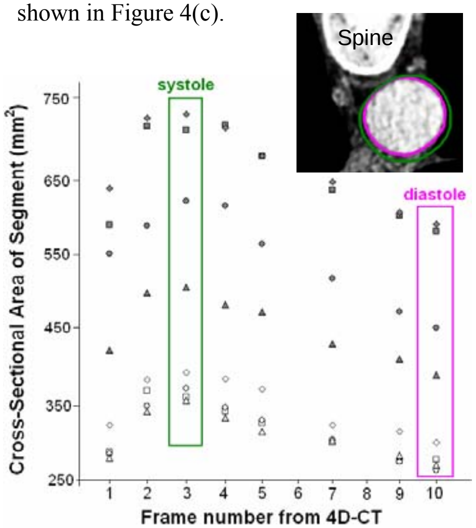

Figure 3. The cross-sectional area of 4 proximal and 4 distal segments on the DTA were computed in 8 of the 10 cardiac frames. The area peaked at frame 3, systole, and its nadir occurred at frame 10, diastole. The inset displays representative circumferences at systole and diastole. Notice the nonuniform distention and location of spine.

Conclusions

Reported for the first time is the *in vivo* longitudinal strain of the human descending thoracic aorta (≈2%), which is 1/4th of the circumferential strain (≈8%). The descending thoracic aorta tapers with the proximal diameter larger than the distal diameter. These results may prove useful in clinical and engineering applications. Future work lies in extending this study to patients with disease of the descending thoracic aorta, for example aneurysms and dissections.

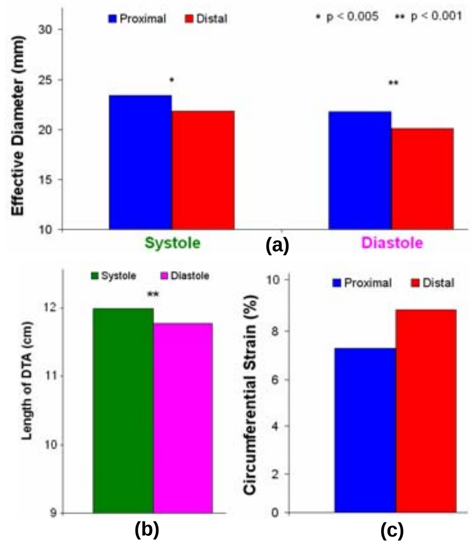

Figure 4. Wall motion of the descending thoracic aorta. (a) The effective diameter varies from 20mm to 21.8mm in end-diastole and 21.8mm to 23.4mm in peak-systole (approx 8% on average). (b) The length changes from 11.8cm to 12cm over the cardiac cycle (approx 2% on average). (c) The circumferential strain varies from 7 to 9 %.

References

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[2] Wilson *et al*, Lec Notes Com Sci, 2208:449-456 (2001)
[3] Draney *et al*, Proc Ann Mtg Soc Vasc Surg (2005)

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