

# Association of Wall Compliance with Intraluminal Thrombus, Calcification, and the Size of Infrarenal Abdominal Aortic Aneurysm: An in Vivo MR Phase-Contrast Angiography Study

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**Introduction:** Abdominal aortic aneurysm (AAA) is a chronic condition with high mortality, which frequently occurs in the portion of the vessel below the renal artery [1]. Despite growing innovation in therapeutic strategies, the overall mortality of ruptured AAA still reaches 80-90%. This may be due to the evidence that most aneurysms are asymptomatic until rupture [2]. Thus, the assessment of rupture related characteristics of AAA, such as the size, wall stress, compliance, intraluminal thrombus (ILT) and calcification may potentially improve the prognosis. The loss of wall compliance of AAA may lead to an increase of wall stress, which is a risk factor for AAA rupture. It has been shown that AAA wall compliance is correlated with ILT, calcification and maximum diameter [3]. However, most previous studies are either model based or have a small sample size. To evaluate these correlations *in vivo* with a larger population will be helpful for better understanding the relationship between mechanical stresses, wall structure and AAA rupture.

**Purpose:** This study sought to determine the association of wall compliance with ILT, calcification, and the size of infrarenal AAA using in vivo MR phase-contrast angiography (PC-MRA).

**Methods:** Forty-eight patients (mean age 70.6 years; 6 males) with infrarenal AAA, identified by ultrasound, underwent aorta CT angiography on a Toshiba Aquilion 64-slice CT scanner and True FISP and PC-MRA on a Siemens Sonata 1.5T MR scanner within a two week interval. The True FISP sequence was performed with breath hold and ECG-gating. PC-MRA parameters were as follows: TR/TE 70/4.7ms, FOV 275×400mm<sup>2</sup>, slice thickness 5mm, matrix 109×256, spatial resolution 2.0×1.3×5.0mm<sup>3</sup>, flip angle 30°. Twenty-five imaging frames were recorded throughout the cardiac cycle. The aneurysm wall on the cross-sectional view was divided into four equal quadrants by 90 degrees: anterior quadrant (AQ), left quadrant (LQ), posterior quadrant (PQ), and right quadrant (RQ). The calcium score (CS) for the aneurysm body in each quadrant was measured using Agatston algorithm on CT images. In addition, the area and maximum thickness of ILT in each quadrant and the AAA diameter were measured at the level of maximal diameter of AAA, as well as the aneurysm length on CT images. The aorta cross-sectional luminal areas at cardiac systolic (maximum area) and diastolic (minimum area) phases were measured at the following 7 levels: 1) 1cm above the level of renal arteries; 2) the level of renal arteries; 3) 1cm below the lowest renal artery; 4) AAA proximal neck; 5) maximal diameter of AAA (Fig. 1); 6) AAA distal neck; and 7) aortic bifurcation. The wall compliance at these seven aortic levels was calculated using the following equation [4]:  $C = (A_{max} - A_{min}) / [A_{max} \times (P_{max} - P_{min})]$ , where  $A_{max}$  and  $A_{min}$  are the measured areas of interest corresponding to systolic pressure ( $P_{max}$ ) and diastolic pressure ( $P_{min}$ ), respectively. The wall compliance at the seven aortic levels was compared. The correlation of compliance at the level of maximal AAA diameter with ILT area, calcium score, maximum diameter, and the length to maximum diameter ratio were analyzed.

**Results:** Of 48 subjects, 56.3% had a large AAA (maximum diameter >5cm), 100% had wall calcification (CS=3021±3379) and 95.8% had ILT. The CS in AQ and RQ was significantly higher than that in LQ and PQ ( $P<0.05$ ). The mean maximum diameter and length of 48 aneurysms were 5.10±1.15 cm and 7.74±2.44 cm, respectively. At the level of AAA maximum diameter, ILT areas in AQ (2.85±2.62 cm<sup>2</sup>) and LR (2.53±1.98 cm<sup>2</sup>) were higher than that in PQ (1.32±1.28 cm<sup>2</sup>) and RQ (1.78±2.05 cm<sup>2</sup>) ( $P<0.05$ ). Among the seven aortic levels, the level of maximum AAA diameter showed significantly lower wall compliance than that at the level of 1cm above the renal arteries, renal arteries and 1cm below the lowest renal artery ( $P<0.001$ , Fig. 2). In addition, the wall compliance at the distal neck of AAA was higher than that at level of maximum AAA diameter ( $P=0.046$ , Fig. 2). There was no significant difference between wall compliance at the proximal and distal necks of AAA, and between the level at the aorta below and above the aneurysm body ( $P>0.05$ , Fig. 2). No significant correlation was found between wall compliance at the level of maximum AAA diameter and aneurysm wall calcium score ( $r=0.116$ ,  $P=0.434$ ) and maximum diameter ( $r=-0.160$ ,  $P=0.276$ ). However, wall compliance was positively correlated with thrombus area at the level of maximum AAA diameter ( $r=0.332$ ,  $P=0.021$ , Fig. 3), particularly ILT in AQ ( $r=0.371$ ,  $P=0.009$ ). In addition, the length to maximum diameter ratio was positively correlated with compliance after adjusting for maximum ILT thickness at the level of maximum AAA diameter ( $r=0.317$ ,  $P=0.036$ ).

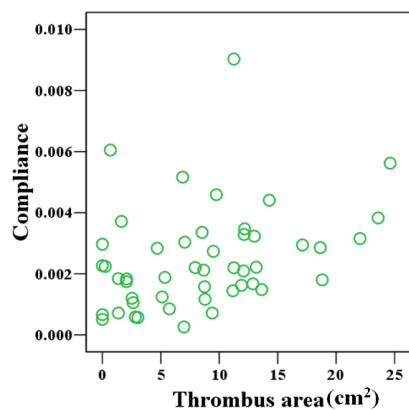


Fig 3. Correlation between compliance and thrombus area at the level of maximum AAA diameter.

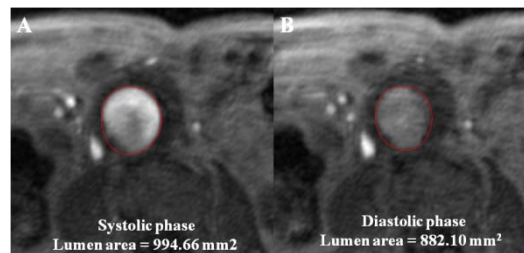


Fig 1. The lumen area of cardiac systolic (A) and diastolic phase (B) at level of AAA maximum diameter on MR images

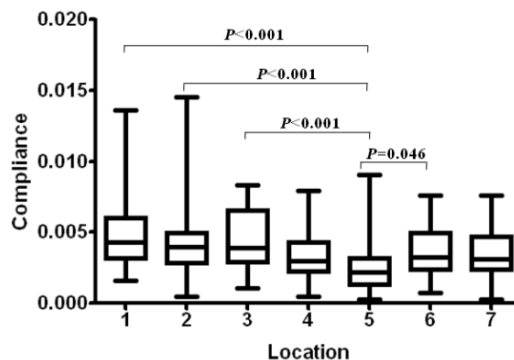


Fig 2. Comparison of compliance among 7 levels of aorta. The error bars represent maximum and minimum values.

**Discussion:** In this study, we found that the level of maximum AAA diameter showed the lowest wall compliance across all the measured locations. This finding was expected according to the pathological hypothesis of elastin degradation in aneurysm wall [5]. Our finding of the association between ILT area and wall compliance is consistent with the literature. This finding can be explained by the 'cushioning effect' of ILT for AAA proposed by Inzoli et al [6]. ILT's role in AAA rupture is controversial, according to previous studies. Our findings suggest that ILT increases the wall compliance and potentially reduces the wall stress, which indicates that ILT may be a protective factor for AAA rupture. Wall calcification has been demonstrated to be able to increase the AAA peak wall stress, indicating that calcification may decrease the biomechanical stability of AAA. In our study, however, wall calcium scores were not correlated with wall compliance. This may be due to the fact that our compliance measurements are based on luminal area changes. To further explore the effect of calcification on wall compliance, our future studies will include measuring the area changes based on the outer wall boundaries. In addition, we found that wall compliance was associated with length to maximum diameter ratio rather than maximum diameter alone. This finding suggests that taking into account both length and maximum diameter rather than only absolute diameter may be better for the assessment of wall mechanical characteristics.

**Conclusions:** Wall compliance was positively associated with ILT, particularly in the anterior wall, which indicates that thrombus may be a protective factor for AAA rupture. The size of the aneurysm, as measured by length to maximum diameter ratio, may be a stronger indicator for wall compliance changes.

#### Reference:

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