

# Evaluation of the coherence of local indices of aortic stiffness calculated from magnetic resonance data using a theoretical model derived from the Moens-Korteweg equation

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## INTRODUCTION

Aortic stiffness indices such as aortic deformability (AD) and aortic pulse wave velocity (PWV) are considered as independent predictors of cardiovascular risk [1]. These two indices can be assessed directly and non-invasively from morphological and hemodynamic Magnetic Resonance (MR) data. The aim of this study was to evaluate the consistency of these indices by using a theoretical model derived from the Moens-Korteweg equation [2]. This model gives a relationship between AD, PWV, the aortic pulse pressure (APP) as well as the blood density ( $\rho$ ):  $AD = APP / (\rho \times PWV^2)$ . To achieve this aim: 1) the local AD of the ascending aorta, and the regional PWV derived from the propagation speed of the velocity waveform in the aortic arch were estimated from MR data, and 2) the global aortic deformability (ADe) was estimated from PWV and carotid pulse pressure (CPP) using the above equation. Finally, the relationship between AD and PWV and between ADe and AD were studied.

## METHODS

Axial and coronal cine acquisitions and axial phase contrast (PC) acquisitions at the level of the pulmonary artery bifurcation were recorded on forty volunteers. The AD was calculated as the ratio between the variation in the areas of the ascending aorta lumen between systole and diastole and the diastolic area. These areas were automatically measured on cine MR acquisitions using a custom snake based automatic contouring. The PWV was calculated by using the 3D length of the aortic arch and the transit time of the systolic flow curves between the ascending and descending aorta. The 3D length of the aortic arch was calculated by interpolating the centers of the aortic lumen selected on the axial and coronal cine acquisitions using a 3D cardinal spline. The transit time was automatically calculated from PC sequences using an algorithm based on the least squares minimization applied on the upslope of the normalized flow curves in the ascending and descending aorta. ADe was finally estimated using the pulse pressure measured at the carotid artery by applanation tonometry according to the theoretical model derived from the Moens-Korteweg equation. Of note, the CPP was accepted as representative for APP.

## RESULTS

According to the power regression, the relationship between PWV and AD was better characterized with a second order model ( $r^2=0.61$ ) and, thus, was consistent with the theoretical model between aortic deformability and pulse wave velocity. Moreover, the change of the estimated global index ADe according to the local index AD was linear ( $r=0.7$ , slope=0.82) (Figure 1). The corresponding Bland-Altman showed a good agreement between AD and ADe, resulting in a mean difference of 0.05 and a standard deviation of 0.1.

## CONCLUSION

The AD and PWV were separately measured from MR acquisitions using a local and automated approach. These indices which provided a direct characterisation of the aortic stiffness were inversely related and were well described by the theoretical model derived from the Moens-Korteweg equation. In addition, the global index ADe estimated from the theoretical model gave a similar description of stiffness of the ascending aorta as the local index AD.

## REFERENCES

- [1]Laurent S, Boutouyrie P, Asmar R, et al. Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients. *Hypertension* 2001;37:1236–41
- [2] Marque V, Van Essen H, Struijker Boudier H, Atkinson J, Lartaud Idjouadiene I. Determination of Aortic Elastic Modulus by Pulse Wave Velocity and Wall Tracking in a Rat Model of Aortic Stiffness. *J Vasc Res* 2001;38:546–550

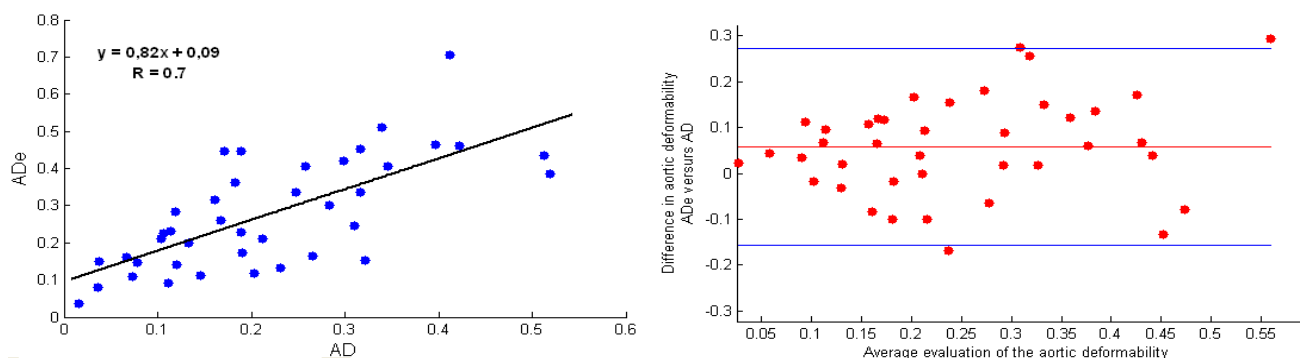


Figure 1. Comparison between AD and ADe. Correlation between the direct measurements of the aortic deformability in the ascending aorta (AD) and the estimated aortic deformability (ADe) from the analytic equation and the Bland–Altman plot corresponding to the comparison between AD and ADe (mean=0.05;SD=0.1)