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# Influence of age and sex on aortic distensibility assessed by MRI in healthy subjects

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## Abstract

Magnetic resonance imaging (MRI) is particularly well adapted to the evaluation of aortic distensibility. The calculation of this parameter, based on the change in vessel cross-sectional area per unit change in blood pressure, requires precise delineation of the aortic wall on a series of cine-MR images. Firstly, the study consisted in validating a new automatic method to assess aortic elasticity. Secondly, aortic distensibility was studied for the ascending and descending thoracic aortas in 26 healthy subjects. Two homogeneous groups were available to evaluate the influence of sex and age (with an age limit value of 35 years). The automatic postprocessing method proved to be robust and reliable enough to automatically determine aortic distensibility, even on artefacted images. In the 26 healthy volunteers, a marked decrease in distensibility appears with age, although this decrease is only significant for the ascending aorta ($8.97\pm2.69\ 10^{-3}\ \mathrm{mmHg}^{-1}$ vs. $5.97\pm2.02\ 10^{-3}\ \mathrm{mmHg}^{-1}$). Women have a higher aortic distensibility than men but only significantly at the level of the descending aorta ($7.20\pm1.61\ 10^{-3}\ \mathrm{mmHg}^{-1}$ vs. $5.05\pm2.40\ 10^{-3}\ \mathrm{mmHg}^{-1}$). Through our automatic contouring method, the aortic distensibility from routine cine-MRI has been studied on a healthy subject population providing reference values of aortic stiffness. The aortic distensibility calculation shows that age and sex are causes of aortic stiffness variations in healthy subjects.

*Keywords:* Aorta; Elasticity; MRI; Healthy subjects; Automatic processing

## 1. Introduction

The aorta and the major arteries tend to smooth out pulsatile flow and deliver the blood in a more continuous fashion into the capillary beds [1]. This property can be described by the aortic distensibility [2]. An estimation of aortic elasticity and, in particular, aortic distensibility can provide useful supplementary information. Aortic elasticity could be a relevant parameter in aortic wall pathologies (such as Marfan’s syndrome, Elhers Danlos syndrome, Loeys–Dietz syndrome, familial aortic dissection syndrome) with thoracic aortic aneurysm complicated with aortic dissection in young patients. In particular, stiffness of the aortic wall seems to increase among patients with Marfan’s syndrome [3]. A surgical indication is often based on the aortic diameter (50–55 mm for the ascending aorta and 60 mm for the descending aorta) [4]. Unfortunately, some of these young patients suffer from aortic dissection when their aortic diameter is much smaller than the recommended dimensions. The distensibility studies could support surgical indication for young patients who may undergo earlier surgical procedures. Thus, aortic dissection could be prevented.

This distensibility measurement might also be worthwhile for patients with borderline dilatation (45–50 mm) of the ascending aorta. For abnormal distensibility results, a surgical indication could be considered much earlier. This

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hypothesis may also be proposed for patients presenting bicuspid aortic valve. Indeed, the risk of dilatation and dissection is higher because of histological changes found in the bicuspid aortic valve [5].

Furthermore, the distensibility measurement might prove to be an important tool in the follow-up and evaluation of treatments in diseases with known altered aortic distensibility (Marfan's syndrome, Elhers Danlos syndrome). These patients are usually prescribed beta-blocker agents [6,7]. More recently, they have been prescribed angiotensin-converting enzyme II inhibitors (such as Losartan [8]), which seem to stabilize aortic diameters.

The morphology of the arterial system can be depicted very accurately using magnetic resonance imaging (MRI). Aortic distensibility can be assessed using MRI either by measuring the pulse wave velocity [9,10] or the ease with which the aorta expands during systole [11]. The latter method relies upon a measure of compliance, estimated by the change in vessel cross-sectional area per unit change in blood pressure [12]. This area is usually measured by manual outlining the aortic wall [13–16] or from segmentation provided by semiautomatic or fully automatic techniques [17,18]. It is noteworthy that manual outlining of the aortic wall is somewhat subjective [17] and is a very time-consuming process.

Several authors have already published automatic aorta segmentation methods for aortic elasticity measurements. Yang et al. [19] have restricted the automatic segmentation to two static images acquired at diastole and systole. A deformable model tracks the wall of the aorta, but the weakness of this method lies in the impossibility to follow the evolution of the aortic cross-sectional area during the cardiac cycle. Some authors take into account the whole cardiac cycle, allowing the creation of cross-sectional area versus time curves [17,18].

In the present study, a previously described robust automatic segmentation method [20] for the aortic wall was used to evaluate the aortic stiffness over the entire heart cycle from MR images in a pilot study including 26 healthy volunteers. For each subject, cross section area and distensibility were estimated. In particular, the influence of sex and age on aortic distensibility was studied.

## 2. Methods

### 2.1. Study population

Twenty-eight healthy subjects were recruited for this study, carried out at the Montreal Heart Institute. Of the 28 imaging data sets, two were excluded. One data set was rejected because the images were too noisy, thus preventing reliable post-processing. In the second, through plane movement corrupted the cross-sectional area estimation.

The study population therefore consisted of 26 healthy subjects (13 men, 13 women, 35±8 years, range 23–61 years) with no history of cardiovascular disease (no aortic dilatation, no aortic valvular disease, no atherosclerosis and no hypertension). The population was divided in different groups in order to evaluate the influence of sex and age. As age is an essential factor of aortic stiffness in healthy subjects [14,21,22], the subjects were divided into two groups with a limit value of 35 years old [23]. There were 14 subjects in the younger group (seven men, seven women, 29±4 years, range 23–34 years) and 12 in the older group (six men, six women, 42±7 years, range 35–61 years). When evaluating the influence of sex, two groups of 13 subjects with similar ages [33±5 years for women and 36±10 years for men, *P*=non-significant (NS)] were formed. The study was approved by the ethics committee of the Montreal Heart Institute, and informed consent was obtained for all subjects.

### 2.2. Magnetic resonance imaging

Magnetic Resonance images were acquired on a 1.5-T whole body imager (Philips Intera CV 1.5 T, Philips Medical System, BEST, the Netherlands), with an electrocardiogram-gated Steady State Free Precession (SSFP)-type sequence (TR=3.1 ms, TE=1.5 ms, matrix size=256×204 interpolated to 512×512, FOV varied from 330 to 400 mm according to the subject, slice thickness=5 mm, number of lines in k-space per excitation=19). One breath-hold acquisition provides images at different phases of the cardiac cycle and thirty-two images were acquired in order to cover the whole cardiac cycle. The temporal resolution varied according to the RR interval (RR/32). The aorta was imaged in the transverse plane at the level of the bifurcation of the pulmonary trunk. Thus, the ascending and descending aortas appeared in the same image and could be studied simultaneously. Before and after image acquisition, the arterial diastolic and systolic blood pressures were measured in the brachial artery using a sphygmomanometer, and the mean values were retained.

### 2.3. Automatic segmentation of vessel wall contours

From MR images, the ascending or descending thoracic aorta contour was detected on the whole axial MR images acquired at the level of the pulmonary trunk. The user intervention is limited to the indication of only one point near the center of the aorta on the first image. Our automatic method of vessel wall contour segmentation has already been described in detail in a previous publication [20]. It was applied sequentially on each image of the series. All the steps of the automatic detection are illustrated in the flow diagram (Fig. 1). The first step consists in creating two maps, the "Edge" and the "ROI" maps. The "Edge" map is obtained from the filtering of the image by the Haralick filter following smoothing with a Gaussian filter and a contrast enhancement step. A rigorous study of filter parameters was performed in order to determine the Haralick filter as the optimal edge detection filter to be used in the segmentation method. The "ROI" map takes into account a priori knowledge provided by the segmentation of the previous image of the series. Indeed it can be expected that the aorta be roughly located at the same area from one image to