Medical Sensors Project

Changes in Aortic Distensibility and Pulse Wave Velocity Assessed With Magnetic Resonance Imaging Following Beta-Blocker Therapy in the Marfan Syndrome

Supervisor: Pro. Alain Lalande

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Umamaheswaran RAMAN KUMAR

Content

1. Introduction

Aortic distensibility and aortic pulse wave velocity (PWV) are two parameters closely related to the bioplastic function of the aorta and serve as pathogenic markers in cardiovascular disease. Quantification of aortic distensibility and PWV by Magnetic Resonance Imaging (MRI) has been shown to be accurate and reproducible and could help in identifying early Marfan Syndrome. Thus, this project is to work on MRI blood flow quantification on the aortas.

2. Background

Central arteries like the aorta play a crucial role in buffering and attenuating the pulsatile nature of blood flow. Over time, the aorta gets stiffer, dilates and becomes more tortuous. Stiffening of the aorta is associated with increased pulse pressure, which promotes ventricular stiffening and hypertrophy, ultimately leading to diastolic dysfunction and heart failure. Increased aortic stiffness has also been found to be associated with a variety of physiological conditions and cardiovascular diseases like Marfan syndrome.

Marfan syndrome (MFS) is a genetic disorder of the connective tissue. The degree to which people are affected varies. People with Marfan tend to be tall, and thin, with long arms, legs, fingers and toes. They also typically have flexible joints and scoliosis. The most serious complications involve the heart and aorta with an increased risk of mitral valve prolapse and aortic aneurysm. Management often includes the use of beta blockers such as propranolol or if not tolerated calcium channel blockers or ACE inhibitors.

It has been shown that beta-adrenergic blocking agents may reduce the rate of aortic root dilation and the development of aortic complications in patients with the Marfan syndrome. This may be due to beta –blocker-induced changes in aortic stiffness, of which distensibility and pulse wave velocity are in vivo measurable derivatives. For Clinical treatment, aortic stiffness in Marfan syndrome, together with mean blood pressure, is reduced by beta - blocker therapy, and MRI is well suited to detect these changes by measuring distensibility and pulse wave velocity.

As we know, distensibility is the ratio of aortic diameter (or area or volume) and pulse pressure. Pulse Wave Velocity (PWV) is a measure of arterial stiffness, or the rate at which pressure waves move down the vessel. As blood flows through the vessels of the circulatory system, it moves out of the left ventricle and into the aorta where it is then pushed through the rest of the circulatory system. During systole, the contraction of the left ventricle and the ejection of blood into the ascending aorta acutely dilates the aortic

wall and generates a pressure wave that moves along the arterial tree. The velocity of this movement gives a measurement of arterial compliance. With Marfan syndrome, these vessels become stiffer and the speed at which the pressure wave moves through the system is increased.

Both distensibility and pulse wave velocity can be investigated by MRI. Thus, the Objective of our project is to calculate the velocity and blood flow.

3. Method

Every MR imaging data acquisition generates information about the signal magnitude as well as the phase of each voxel. Signal intensities are processed into an anatomic image: the magnitude image. The magnitude images resemble a normal bright blood image that is used for anatomical orientation. One magnitude image is shown in Figure 1. The phase images are constituted by tones of gray for each pixel that represents velocity information, with higher signal intensities demonstrating higher flow velocities. Blood flowing in the direction opposite to the flow-encoded gradient will return no signal and thus appear dark.

As we know, quantification relies on inflow effects or on spin phase effects and therefore on quantifying the phase shifts of moving tissues relative to stationary tissues. With properly designed pulse sequences (see Flow_(Phase) sequence, one flow image is shown in Figure 2.),the pixel by pixel phase represents a map of the velocities measured in the imaging plane. Velocity can be determined quantitatively on a pixel-by-pixel basis. From the figure 2, it can be seen that the ascending aorta and descending aorta have the opposite color as there is opposite direction according to main orientation. Once, this velocity is known, the flow in a vessel can be determined by multiplying the pixel area with the pixel velocity. Summing this quantity for all pixels inside a vessel results in a flow volume, which is measured, e.g. in ml/sec.
The mathematical relationship between pixel (gray level) of the flow images and the velocities can be described as:

Speed=(Average Grey level * Maxspeed * 2/greylevel)- Maxspeed

In this case, the maximum velocity is Maxspeed 150 cm/sec. We coded from -150cm/sec(Black) to 150cm/sec(white).

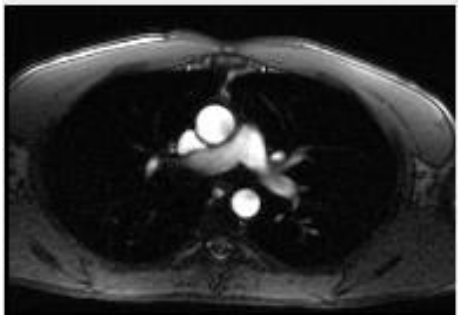

Figure 1. Magnitude image

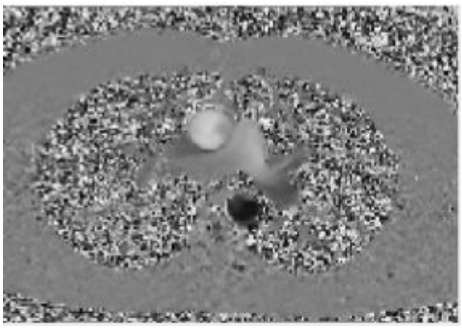

Figure 2. Phase image. The ascending thoracic aorta (upper circle) appear white, and the descending thoracic aorta (lower circle) is black because the flow-encoded gradient is chosen as inferior to superior.

4. Experimentation and Discussion

We analyze one sequence of images coded as magnitude images, and the other as phase images. The two series are acquired at the same moment, then the first image of one series is acquired at the same moment of the first image of the other series. The anatomical and flow data can be matched exactly.

First of all, we detect the ascending and descending arteries from the magnitude images and find the contours of the aorta, encompassing the velocity-encoded area on the corresponding phase image. Then, create a mask of the region of interest from the phase images and calculate the average gray level. At last, calculate the velocity by using the algorithm as above and multiply the area with the velocity to get the real-time blood flow.

4.1 Find the contours of the aortas

There are 60 magnitude images in a cardiac cycle and related 60 phase images. The ascending and descending aortas can be detected manually or automatically. In our project, we propose a method to find the circle contour of aorta automatically by using the

“imfindcircles” function. Before the detection, “imadjust” function is used to do the pre-processing. However, there are the following two problems with “imfindcircles” function. One is that it may return more than one circle. Another one is that it may not detect the aortas in some images as the circles of some are not clear enough. To address this issue, we set the range of radius and make the estimation of the centers for some circles to make sure the accurate detection as the radius and the positions of the centers do not change too much between adjacent images in one sequence. It leads to a good result by creating the “distancecheck” function and careful analysis. The results of circle detection of ascending and descending aortas are shown in Figure 3,4.

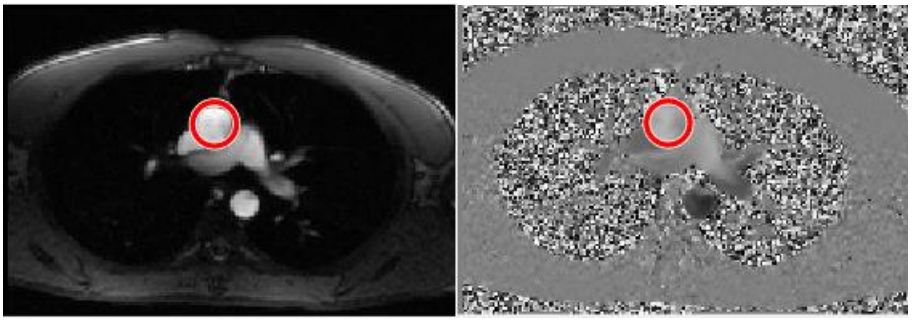

Figure 3. The contour of ascending aorta in magnitude and phase images

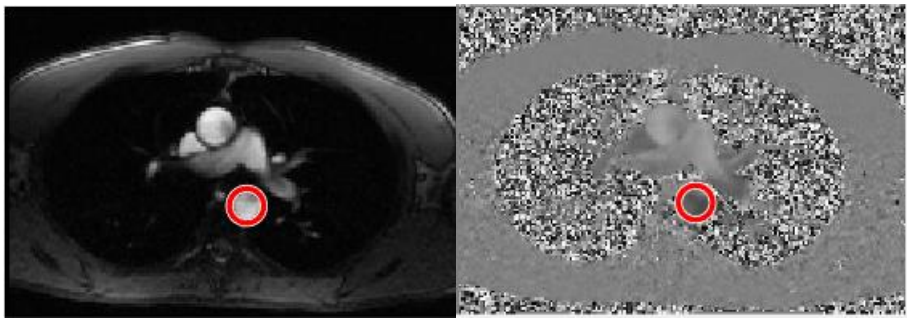

Figure 4. The contour of descending aorta in magnitude and phase images

4.2 Calculate the real-time velocity and blood flow

After detecting the region of interest, we can create a mask of the region and segment, then calculate the average gray level. One of the segmentation images is shown in Figure 5. With the average gray level and the maximum speed, the velocity is calculated as the equation mentioned above. Multiply the area with velocity, the blood flow can be also calculated. The results of velocity and blood flow calculation are shown as Figure 6.

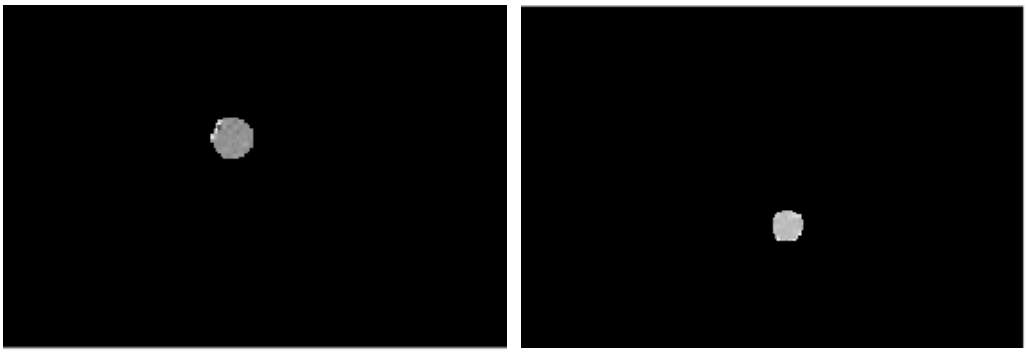

Figure 5. The segmentation of ascending and descending aortas in phase image

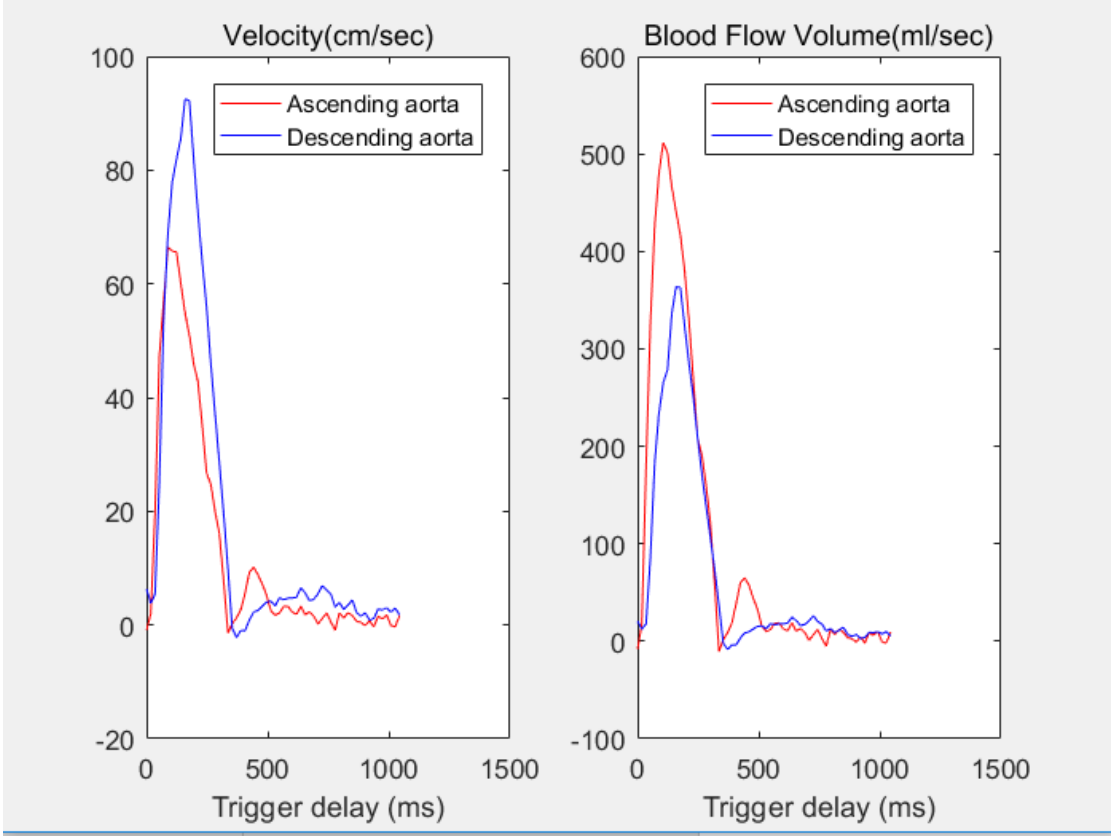

Figure 6. The results of velocity and blood flow

4.3 Improvement

In this report, the blood flow quantification of aorta from MRI images is described. If we can get the sagittal plane images, we can further calculate the Pulse Wave Velocity by Transit-time method. ***PWV = Δx/Δt,*** where Δx is the distance between the two locations and Δt is the time difference between the two velocity curves.

In other words, we can draw a line in the artery between the two locations and measure the length of the line with prior knowledge of the pixel spacing or get the approximated length by using automatic function.

What's more, MRI flow measurements have multiple applications for the evaluation of cardiac function, central and peripheral vessels. coronary flow, cardiac valves and congenital heart disease and Marfan Syndrome. The data we obtained will help doctor diagnose the disease.