AUTOMATIC MULTI-VESSEL VOLUME FLOW CALCULATION FROM 4D FLOW MRI DATA

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Abstract

A method was developed to automatically calculate volume flow through planes located on the major vessels of the heart on 4D flow MRI data. An atlas was created from one subject and was used to locate the planes on more subjects using registration. Vessel motion over the cardiac cycle was also taken into account. Initial results of the volume flow on the aorta in healthy volunteers show good agreement with volume flows in the pulmonary trunk, pulmonary branches and vena cava.

Background

4D flow MRI[1] enables flow measurement everywhere in the cardiovascular system in one examination. The amount of data produced for every patient is quite large, which calls for new automatic methods to extract relevant information from it.

Clinical blood flow based assessment is usually done by locating a plane on a vessel, manually segmenting the vessel on each timeframe of the cardiac cycle, and calculating the volume flow over all these timeframes in order to assess the amount of blood that goes through the plane during a heartbeat.

Atlas-based segmentation allows us to segment specific areas in the cardiovascular image by registering the atlas to an unsegmented cardiovascular image. The deformed atlas will indicate the location of the areas it represents in the new image.

The presented method uses atlas-based segmentation to automatically locate planes on interesting vessel positions, identify the vessel's area on each timeframe of the cardiac cycle, and calculate the volume flow on each vessel.

Methods

An atlas was created using manual segmentation on 4D flow MRI data. Additionally, planes were located on the atlas' ascending aorta, pulmonary trunk, pulmonary branches and vena cava.

The images of the atlas and the new subject were registered in order to obtain a deformation that could transform the atlas' vessels into the subject's vessels (Fig 1).

Methods (continued)

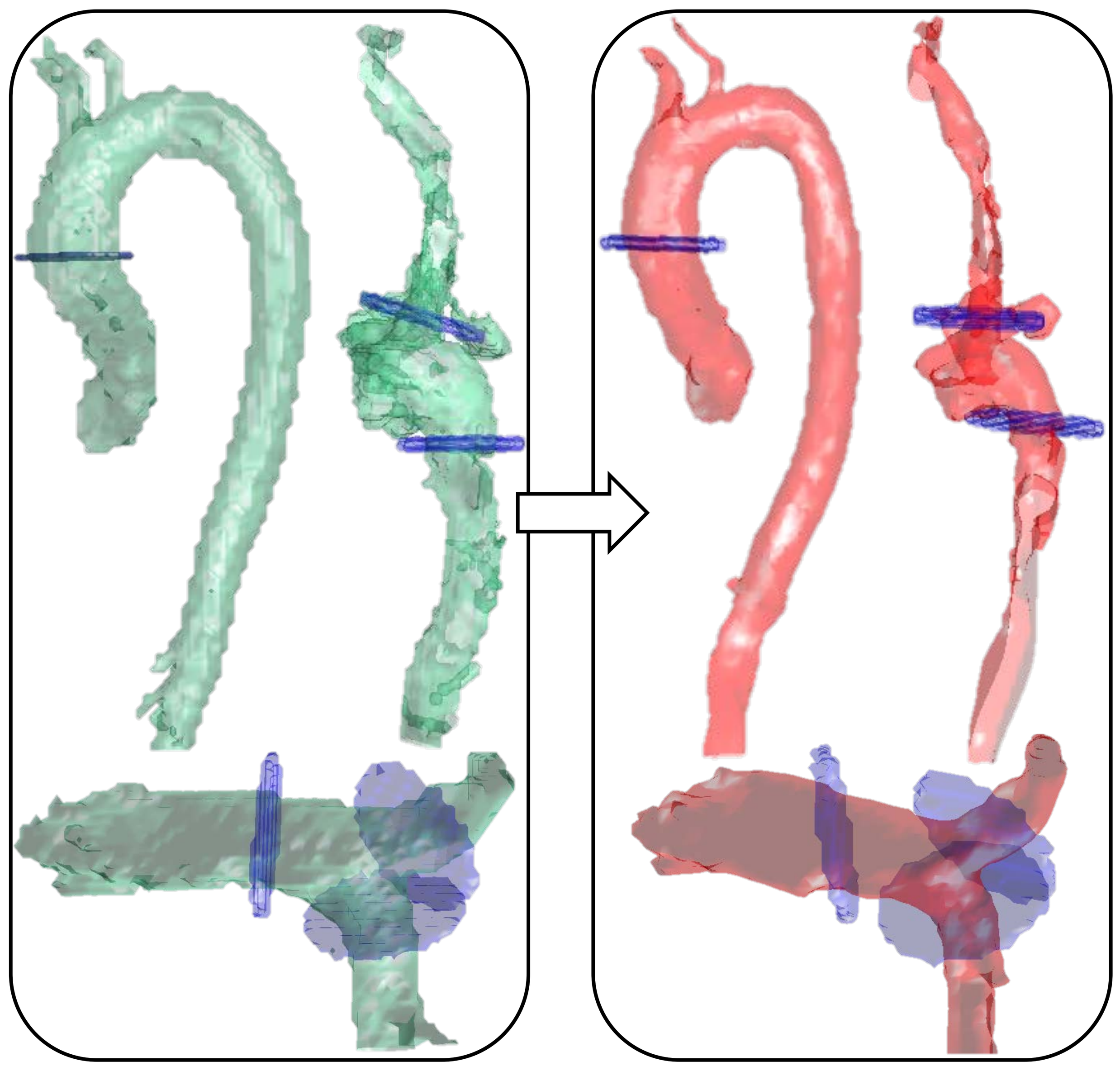

Fig. 1 The vessels of the atlas before (green) and after registration to the subject's vessels (red). The located planes are also visible.

Deformation and movement of the vessels over the cardiac cycle was accounted for by executing a series of registrations between one of the subject's systolic timeframes and each of the other available timeframes.

The result was a set of deformations able to transform the chosen timeframe into any of the rest. These deformations were then applied to the already transformed atlas to create a time-resolved mask and define selected analysis areas (Fig 2).

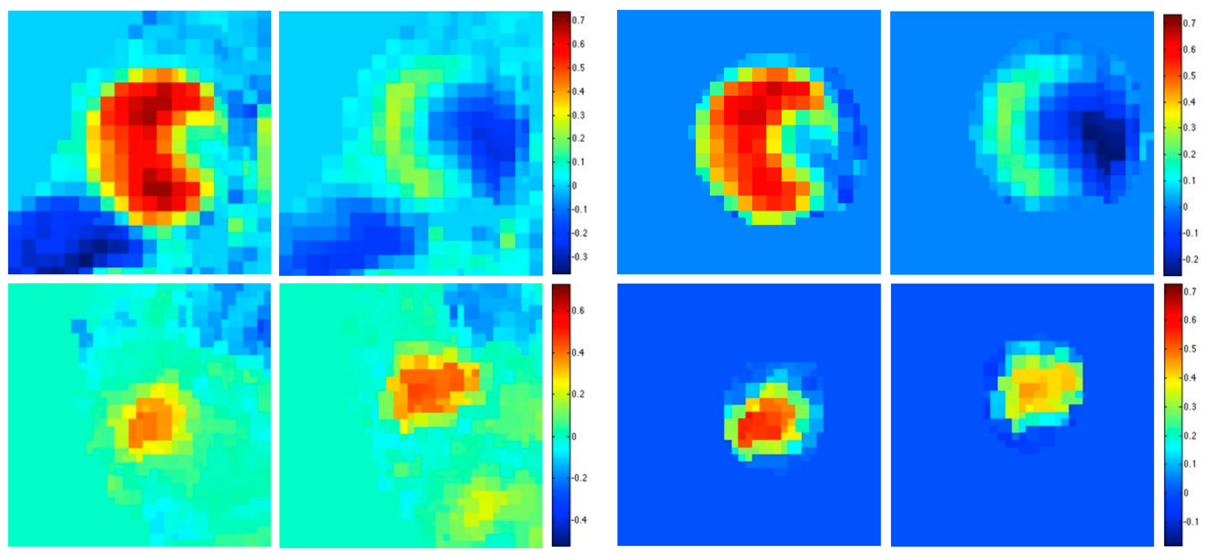

Fig. 2 Velocities through planes on the aorta (higher row) and superior vena cava (lower row) without (left) and with (right) the time-resolved mask that accounts for vessel location and shape in different timeframes during the cardiac cycle.

Finally, the velocity was integrated over the vessel lumen and cardiac cycle to obtain volume flows in the aorta, pulmonary artery and vena cava (Fig 3).

Experiments

4D flow MRI acquisitions where obtained from 9 healthy subjects between the ages of 60 and 71 (mean age 66.5).

One of these subjects was chosen to be the atlas, the rest of the subjects were analyzed using this atlas.

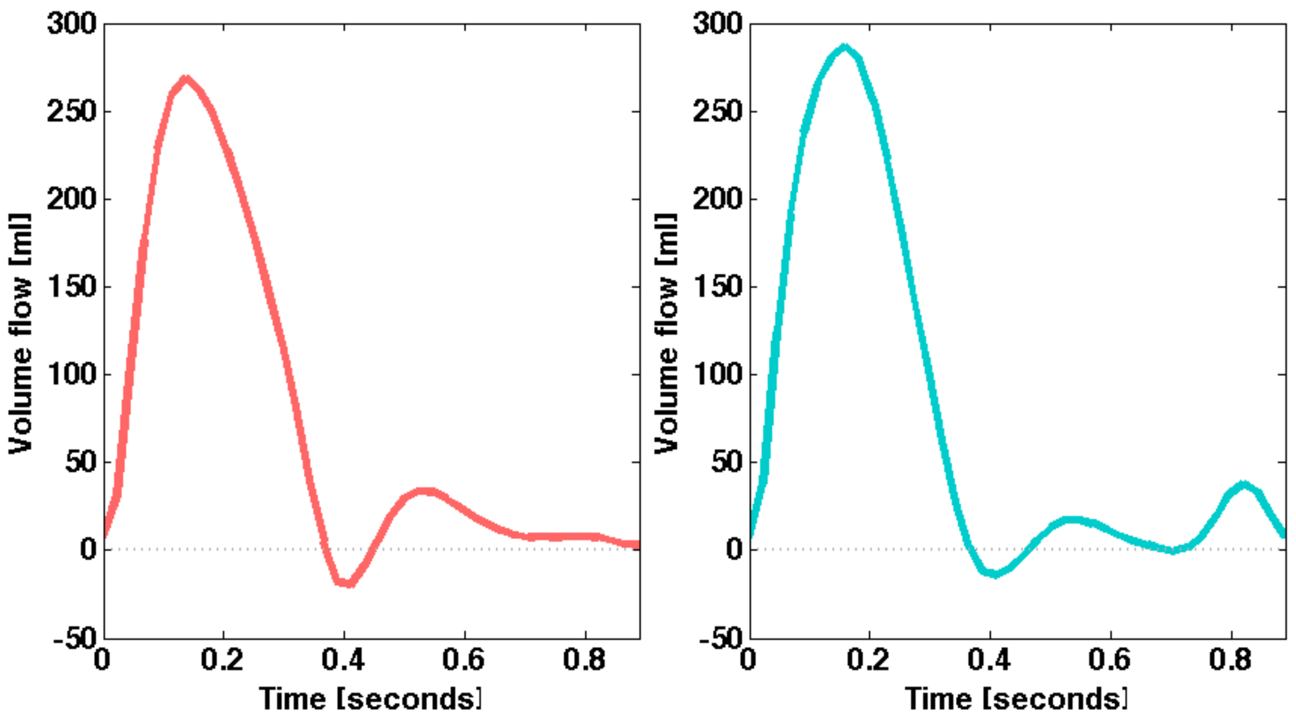

Fig. 3 Volume flow on the planes on the aorta (red) and pulmonary trunk (cyan) over the cardiac cycle.

Results

Using the proposed method, the volume flow could be obtained in each of the planes in all 8 subjects. Values that should be closely related were compared (Fig 4).

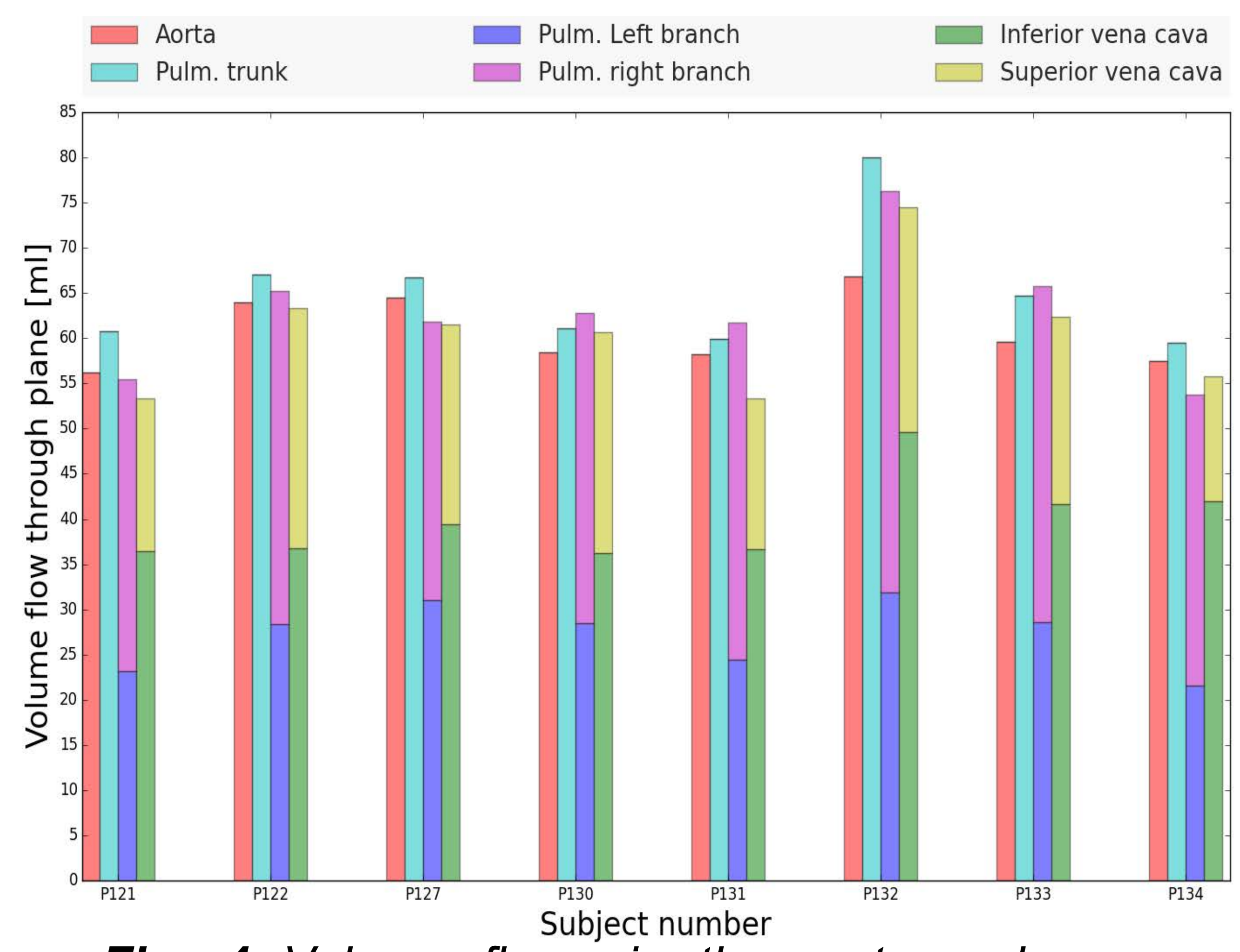

Fig. 4 Volume flows in the aorta, pulmonary trunk, sum of pulmonary branches, and sum of superior and inferior vena cava for each subject.

Discussion

The proposed method allows for automatic segmentation and analysis of the volume flow in the thoracic cardiovascular system. The volume flows obtained correspond quite well with each other when comparing the values that are expected to agree on a healthy heart.

The results depend partly on a good outcome from the registration between the atlas and the new image. Also, problems in the velocity data such as noise or background correction issues could affect the result's accuracy.

The method enables quick assessment of 4D flow MRI data, which could be a good first step towards clinical use of this technique. Future works include further improvements to the method and evaluation in a larger cohort.

References

1. Markl M, Kilner PJ, Ebbers T. *J Cardiovasc Magn Reson* 2011.