QUANTIFICATION OF CAVAL CONTRIBUTION TO FLOW IN THE RIGHT AND LEFT PULMONARY ARTERY OF FONTAN PATIENTS WITH 4D FLOW MRI

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Background: The Fontan procedure was introduced to treat cardiac malformations characterized by only having one functional ventricular chamber. Measuring the caval contribution to flow in the Right and Left Pulmonary Artery (RPA and LPA) of Fontan patients is of great interest, because uneven flow distribution might lead to Pulmonary Arteriovenous Malformations (PAVMs) decreasing systemic oxygenation [1]. In Fontan circulation more than one source of flow to the RPA and LPA is present, which makes difficult to quantify the flow distribution with standard methods. A novel MRI application was developed to quantify caval contribution; however, it is not applicable to patients with turbulent flow in the Pulmonary Arteries (PA) [2]. Here, we propose a new method to easily quantify the caval contribution to the lungs in Fontan patients.

Methods: A 4D flow sequence was acquired in 12 healthy volunteers and 9 Fontan patients on a 1.5T Philips scan. The protocol was approved by the local ethic committee and informed consent was obtained from all the subjects or their guardians. Flow distribution was quantified with particles traces using the software "GTFlow" [3]. The new method consists of emitting particles from a Region Of Interest (ROI) with a temporal resolution of ~40 ms. Then, we quantified the flow distribution by counting the particles arriving to different ROI along the cardiac cycle. To validate this method, two independent observers compared the flow contribution of the main PA to the RPA and LPA in healthy volunteers. This was done calculating net forward flow, which was used to validate the distribution of flow obtained with our new method. Thereafter, we quantified the flow distribution of the Superior and Inferior Vena Cava (SVC and IVC) to the RPA and LPA in Fontan patients. Statistical analysis was performed with Wilcoxon signed-rank test and Bland Altman plots.

Results: There was good agreement when calculating flow distribution of the PA to the RPA and LPA using net forward flow and particle traces in volunteers. Mean flow distribution to the RPA was:
- Observer 1: 53.3% ± 2.4% with forward volume vs. 53.9% ± 3.2% with particle traces; p-value=0.64
- Observer 2: 53.4% ± 3.6% with forward volume vs. 53.9% ± 3.8% with particle traces; p-value=0.81

Figure 1 shows a Bland Altman plot representing the mean differences of flow distribution between both methods. Variability of measurements between observers was low (forward volume: mean difference=0.1%, p-value=0.88; Particle traces: mean difference=0.02%, p-value=0.88).

In Fontan patients, the SVC blood flow was mainly directed to the RPA (mean=83% ± 13%, range=66-99%). Instead, the IVC blood flow was predominantly directed into the LPA, but its distribution was variable among patients (mean=53% ± 19%, range=21-76%) (Fig. 2).

Conclusions: We have validated a novel method to calculate the flow distribution when more than one vessel contributes with blood flow, such as Fontan patients. This approach revealed that in this group of Fontan patients the SVC blood flowed mainly to the RPA, and the IVC blood to the LPA. Quantification of caval flow contribution to the RPA and LPA may identify Fontan patients at risk for developing complications secondary to uneven flow distribution, such as PAVMs.

References:
1. Fogel MA et al. Circulation 1999;99:1215-21.
2. Dasi LP et al. J Thorac Cardiovasc Surg 2011;141:207-14.
3. Nordmeyer S et al. J Magn Reson Imaging 2010; 32:677-83.

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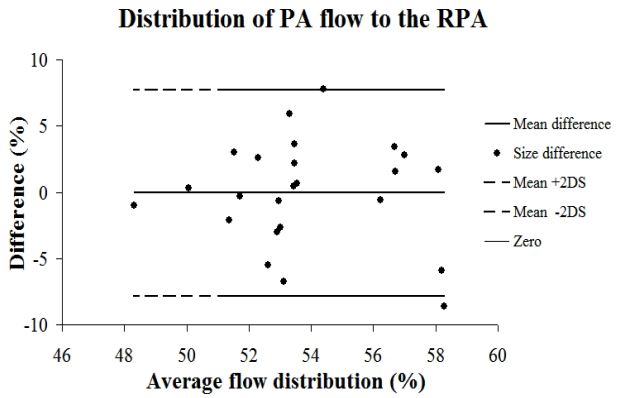

Figure 1. Bland Altman plot representing the mean differences of flow distribution between both methods. Mean difference: 0.04%, range: -8.6 to 7.8%). PA=Pulmonary Artery, RPA=Right

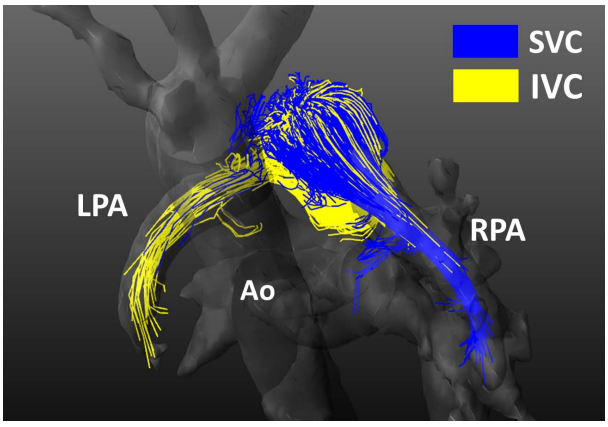

Figure 2. Particle traces emitted from the SVC (blue) and IVC (yellow) into the pulmonary arteries at 70% of the cardiac cycle. SVC: Superior Vena Cava, IVC: Inferior Vena Cava, RPA: Right Pulmonary Artery, LPA: Left Pulmonary Artery, Ao: Aorta.