Variability of Regurgitation Fraction values by MRI according to the Flow Quantification Method

Pablo Bächler[1,2], Gerard Crelier[3], Lida Toro[4], Myriam Ferreiro[4], Marcelo Andia[1,2], Cristian Tejos[2,5], Pablo Irarrazaval[2,5], and Sergio Uribe[1,2]

[1]*Department of Radiology, School of Medicine, Pontificia Universidad Católica de Chile, Santiago, Chile,* [2]*Biomedical Imaging Center, Pontificia Universidad Católica de Chile, Santiago, Chile,* [3]*Institute for Biomedical Engineering, University and ETH, Zurich, Switzerland,* [4]*Hospital Sótero del Río, Santiago, Chile,* [5]*Department of Electrical Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile*

Background: Regurgitant flow fraction (RF) is an important parameter for monitoring valvular insufficiency. On the basis of regurgitant severity and the hemodynamic consequences on the right or left ventricle surgical management might be recommended. The standard method to quantify flow by magnetic resonance imaging is to average the flow across the lumen of a vessel for each heart phase [1]. Then, the averages of each heart phase are summed according to the flow direction to obtain forward and backward flow. Therefore, regurgitant flow is detected only if the average of flow velocities is negative in one or more cardiac phases. Nonetheless, there are situations in which there are both forward and backward flow across a vessel lumen in the same heart phase. Since flow is being averaged in each heart phase, backward flow might be missed in these situations and therefore underestimated (see Standard method in Fig. 1.). We propose to quantify flow by summing the individual flow components (voxel-based) for forward and backward flow in each heart phase. This method would provide a better estimation of regurgitation fraction when forward and backward flows are present in the same heart phase (see Voxel-based method in Fig. 1.).

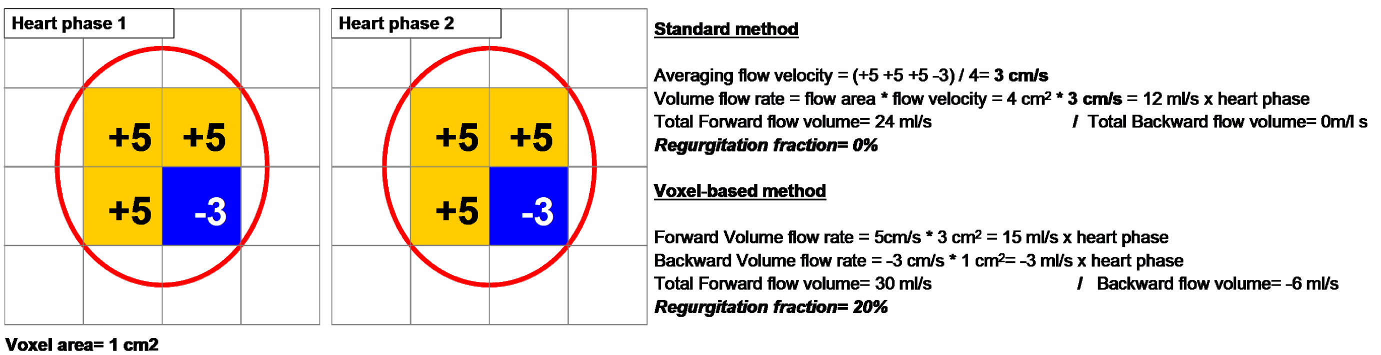

Figure 1. This figure represents a situation where both forward flow (yellow voxels) and backward flow (blue voxels) are present in the same heart phase. Standard method to quantify flow: Flow velocities from voxels inside the region of interest (red circle) are averaged. Since forward flow is predominant in these heart phases, backward flow is masked by the forward flow and the regurgitation flow fraction is 0%. B) Voxel-based method: In this case flow is quantified by summing the individual voxels for forward and backward flow. Since forward and backward flow are quantified separated, backward flow is not missed and the regurgitation flow fraction is 20%.

Purpose: To determine whether RF is underestimated by the standard method compared to the voxel based-method.

Methods: RF was estimated in the pulmonary artery by both methods in 17 patients with repaired Tetralogy of Fallot (TOF). TOF is the most common cyanotic congenital heart disease. These patients were chosen to compare both methods since pulmonary insufficiency exists after surgical correction. A 2D phase-contrast sequence was acquired in the pulmonary artery of these patients on a 1.5 T MRI scan. The protocol was approved by the local ethic committee. Informed consent was obtained. Values of forward flow volume, backward flow volume, net forward flow volume and regurgitation fraction were quantified by using the standard method and the voxel-based method. All flow data analysis was carried out using the commercially available software GTFlow (v. 2.0.4). Statistical analysis of the difference between both methods was performed using Bland-Altman plots and the non-parametric test for related samples Wilcoxon signed-rank test.

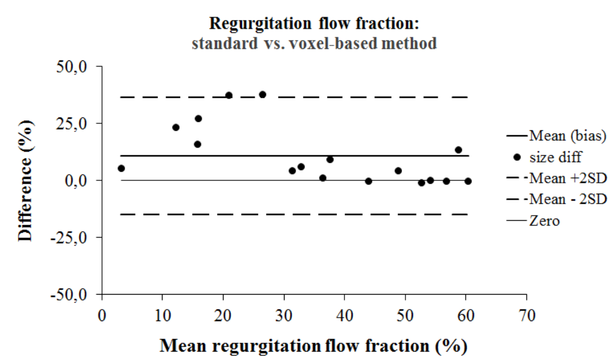

Figure 2. Bland-Altman plot showing a systematic bias with greater values of regurgitation fraction obtained by the voxel based-method.

Results: Mean RF was 30 ± 22 % with the standard method vs. 41 ± 15% with the voxel-based method (p-value <0.01). Bland-Altman plot (Fig 2.) showed a systematic bias, with greater values of RF obtained by the voxel based-method (mean difference between both methods: 10.9 %; range: -1% to 38%). 6 patients had a mean difference of more than 10%. 2D flow profile from patients with greater values of RF by the voxel based-method revealed forward and backward flow simultaneously across the pulmonary artery during systole (Fig. 3).

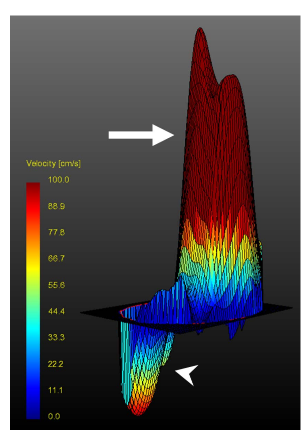

Figure 3. 2D flow profile from the patient with the highest mean difference between methods (38%) at 20% of the cardiac cycle revealed forward flow (arrow), but also backward flow (arrow head) simultaneously in the same heart phase.

Conclusion: Calculation RF using the average flow volume of each heart cycle might result in underestimation of RF, when both forward and backward flows are present in the same heart phase. As we have shown in patients with repaired TOF, calculating the RF by the standard method results in lower values of RF compared to the voxel based-method. Since surgical management might be recommended for TOF patients with high RF to avoid right ventricle failure, the standard method may not reflect the real hemodynamic and not detect patients who might benefit from surgical intervention.

References: 1. Lee V, et al. AJR 1997;169:1125. **Acknowledgment**: Fondecyt 11100427, Conycit ACT 079