Quantitative assessment of spatial and temporal pulmonary arterial regurgitation after repaired Tetralogy of Fallot

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Introduction

Tetralogy of Fallot (TOF), which is one of the most common congenital heart disorders, has been reported to exhibit chronic pulmonary regurgitation after surgical repair [1]. The use of phase-contrast cine magnetic resonance imaging (PC-MRI), providing noninvasive and accurate quantitative assessment of flow parameters, has therefore gained its prevalence for long-term follow-up after repaired TOF [2]. Specifically, the regurgitant fraction (RF), commonly used for distinguishing the severity of regurgitation and has become a significant determinant of valve replacement, is calculated based on definition of backward flow volume over forward flow volume within a cardiac cycle. Basically, the regurgitant flow is expected to occur during diastole in the presence of valve dysfunction. However, the inhomogeneous flow profile with forward and backward flow existing simultaneously in the same cross-sectional area that have been observed at a higher occurrence rate in the left pulmonary artery than the right [3], cannot be reflected in RF. In this study, we propose an inclusion of pixelwise calculation of backward flow velocities in each cardiac phase, such that both spatial and temporal regurgitation can be quantified in one index.

Methods

Imaging was performed on a 1.5T General Electric Signa CV/i system. PC-MR images of the main pulmonary artery (MPA) were obtained with retrospective ECG gating for a total of ten patients (age: 3.12±2.22 y/o, 6 males and 4 females) after repaired TOF, by double-oblique technique to acquire true perpendicular plane of the long axis of MPA. The image parameters were 120-180 mm FOV with 4-6 mm slice thickness, 256 by 256 matrix size, flip angle of 20° or 30°, and TR/TE = 7.3-8.0/3.4-3.7 ms with upper velocity limit (VENC) set as 200 cm/sec. A region of interest (ROI) was manually delineated for each phase based on corresponding anatomic MR images. The obtained data were then post-processed in built-in software on a commercial workstation (GE Medical System). Two methods were applied to the calculation of regurgitation fraction (RF, in %): The conventional one with mean velocity multiplied by the cross-sectional area for each cardiac phase (method1), and the other with forward and backward flow estimated in a pixelwise manner separately to reflect spatially inhomogeneous flow profile (method2).

Descriptive data was presented as mean±SD. Nonparametric test was used to analyze significance of differences between paired variables, which was programmed by Wilcoxon signed rank test of the built-in function in MatLab (MathWorks, MA). The probability value < 0.05 was considered to be statistically significant.

Results

Figures 1(a,b) illustrate the flow velocity maps of MPA from two selected cardiac phases of one patient. Figures 1(c,d) are the corresponding velocity profiles smoothed by cubic spline smoothing with factor of 0.65. While the flow pattern shows consistent uni-directional flow in Figs.1a,c, inhomogeneous flow profile also occurs in a substantial portion of cardiac phases (Figs.1b,d). Figure 2 is the boxplot of RF derived using different methods, where the estimated RF from method 2 (41.87±17.69 %) are significantly greater than that of method 1 (29.54±15.06 %; P<0.005), indicating that pulmonary regurgitation may actually be more severe than that estimated with the conventional method 1.

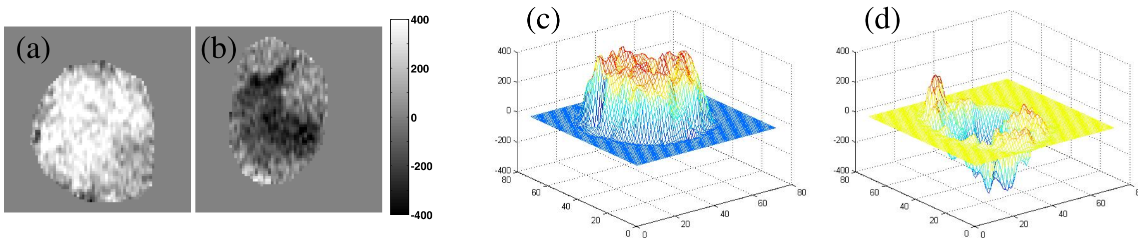

Fig. 1 (a, b) Flow velocity maps for two specific cardiac phases. (c, d) the corresponding surface profiles of flow velocity.

Discussion and Conclusion

The conventional definition of RF in MPA is an indicator of ineffective pumping function of the right ventricle [1]. Its temporal calculation nature, however, does not reflect the degree of simultaneous presence of forward and backward flow which may be a consequence of pulmonary valve defects [3]. Results from our study suggested that the proposed new definition could include information from spatial flow inhomogeneity, hence may provide additional assistance in treatment decision in patients with repaired TOF. While the usefulness of this newly defined parameter needs long-term longitudinal follow-up of patient outcome and thus cannot be concluded at this moment, the examination of spatial flow inhomogeneity in MPA exhibits potential assisting the understanding of TOF pathophysiology before and after surgical correction.

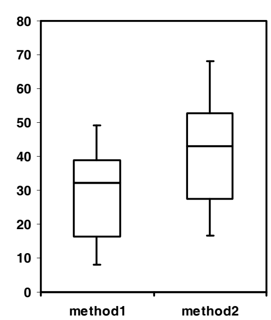

Fig. 2 Boxplot of estimated RF for method 1 and method 2.

References

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