Manual right ventricle segmentation on short-axis SSFP views: quantification of the regional inter-observer variability.

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Background: Short-axis cine-MRI sequences have become the gold standard for Right Ventricle (RV) function assessment. This process requires a manual segmentation of RV endocardium with known low reproducibility. Ejection fraction confidence limits are usually between 10 and 15% (1,2,3,4). Many reasons have been proposed to account for these variations (1): 1/ the presence of trabeculations in the RV. 2/ the infundibular contours may be difficult to trace because the pulmonary valve isn't always clearly seen. 3/ it is often hazardous to separate the ventricle from the atrium in the basal slices 4/ some basal structures often appear with partial volume effect (Figure 1). We designed this study to localize the areas with the most important variations and to quantify these variations in a mixed sample of normal, dilated or hypertrophic RV.

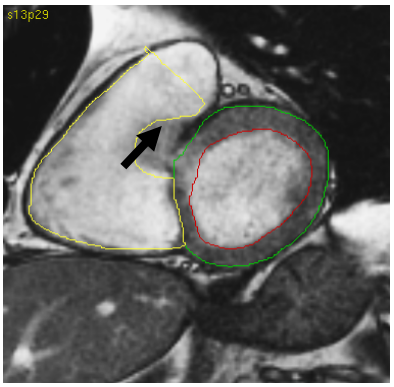

Figure 1: Example of segmentation difficulty due to partial volume effect: Should the dark area partially corresponding to the aorta (under the black arrow) be included in the RV (yellow contour) or not?

Figure 2: Example of segmentation inter-observer variations. Observer 1 (green) and observer 2 (yellow) segmentations differs mainly in the infundibular region (represented by the blue polygon)

Method:

30 adults born with Tetralogy of Fallot and operated in their first year of life, 30 adults with pulmonary hypertension and 30 healthy adult volunteers were included. Short-axis views with 2D-SSFP sequences were acquired at 1.5T (8mm slices, 224x224 pixels, flip angle = 45°, 30 phases, 8-13 slices). Two independent observers manually traced the endocardial right ventricle contours. The manually segmented RV were semi-automatically split into 4 anatomic regions: apical, median, tricuspid and infundibular. A third independent observer manually separated the infundibular and tricuspid regions (Figure 2). The responsibility of each region in the global variability was assessed using global (confidence limits and Dice score) and topological (maximum and sum of Haussdorf distances) metrics (5,6). Three of these metrics are represented in Figure 3.

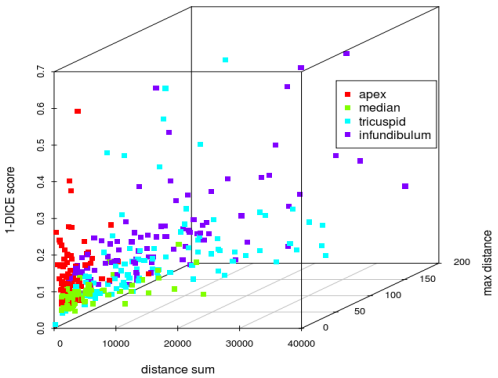

Figure 3: This plot represents the topological distances and Dice scores of the segmentation inter-observer variations. The apex (red) and median region (green) in the lower left corner have better Dice-score and lower Haussdorf distances. The variability is however much higher for the infundibular (violet) and tricuspid (blue) regions.

Results:

1. The global inter-observers variability was in the scope of the most recent studies results (1,2,3,4). The global ejection fraction confidence limit was 12.3% (8.8%, 9.5% and 16.5% in the normal, Fallot and Pulmonary Hypertension subgroups).
2. The observers' choices of the end-systolic and end-diastolic phases differ of more than one phase in 30% of the cases, especially in the pulmonary hypertension subgroup. There is a trend towards an increase in variability when the chosen phases are different.
3. The most difficult regions to segment are the infundibular and tricuspid ones. They account each for 35 to 40% of the global variability whatever the choice of the metric. They share the higher topological distances and the smaller dice scores.

	Fallot (n=30)	Pulmonary Hypertension (n=30)	Control (n=30)
RV characteristics			
RV ejection fraction, mean [95%]	45% [33,57]	41% [20,62]	56% [45,67]
RV end-diastolic Volume, mean [95%]	254ml [57,451]	182ml [42,322]	141ml [81,201]
Regional volume contribution [a]	13%, 32%, 36%, 19%	11%, 32%, 41%, 17%	9%, 39%, 32%, 20%
Global variations : RV Ejection Fraction, RV end-diastolic Volume, RV end-systolic Volume			
Global Confidence Limit	8.8%, 31ml, 30ml	16.5%, 26ml, 32ml	9.5%, 23ml, 16ml
Regional variations localisation (expressed as apical, medial, tricuspid, infundibular)			
Regional Volumes confidence limits [ab]	13%, 17%, 33%, 37%	13%, 17%, 50%, 20%	7%, 24%, 42%, 26%
Regional Dice scores [a]	0.9, 0.94, 0.9, 0.82	0.85, 0.93, 0.8, 0.79	0.85, 0.92, 0.86, 0.83
Regional Hausdorff distances sum [ab]	9%, 15%, 41%, 35%	6%, 12%, 49%, 33%	4%, 11%, 38%, 46%

a : regional data are expressed as (apical, medial, tricuspid, infundibular) and correspond to a mean value between the systolic and diastolic phases
b : data are expressed as percent of the global variability

Conclusions:

- The systolic and diastolic phase selection needs some improvement. A better standardisation of the selection process should be possible.
- The infundibular and the tricuspid regions segmentations are responsible each for 35-40% of the measures variability in our population.
- This study highlights the main difficulties in the manual RV segmentation process. These data could be helpful to determine guidelines for the RV segmentation as well as to develop automatic segmentation tools.

References:

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