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Right ventricular end-systolic area as a simple first-line marker predicting right ventricular enlargement and decreased systolic function in children referred for cardiac magnetic resonance imaging

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AIM: To assess the accuracy of simple cardiovascular magnetic resonance imaging (CMR) parameters for first-line analysis of right ventricle (RV) dysfunction in children to identify those who require in-depth analysis and those in whom simple assessment is sufficient.

MATERIALS AND METHODS: Sixty paediatric CMR studies were analysed. The following CMR parameters were measured: RV end-diastolic and end-systolic area (4CH EDA and 4CH ESA), fractional area change (FAC), RV diameter in end-diastole (RVD1), tricuspid annular plane systolic excursion (TAPSE), and RV outflow tract diameter in end-diastole (RVOT prox). They were correlated with RV end-diastolic volume (RVEDVI) and RV ejection fraction (RVEF).

RESULTS: RVEDVI correlated best with 4CH ESA (r=0.85, <0.001) and EDA (r=0.82, <0.001). For RVEF only a moderate reverse correlation was found for 4CH ESA (−0.56, <0.001), 4CH EDA (−0.49, 0.001) and positive correlation for FAC (0.49, <0.001). There was no correlation between TAPSE and RVEF and only weak between RVD1 and RVEDVI. A 4CH ESA cut-off value of 8.5 cm^2/m^2 had a very high diagnostic accuracy for predicting an enlarged RV (AUC = 0.912, p<0.001, sensitivity 92.3%, specificity 79%) and a cut-off value of 10.5 cm^2/m^2 was also a good predictor of depressed RV systolic function (AUC = 0.873, p<0.001, sensitivity 83%, specificity 89%).

CONCLUSION: For routine screening in clinical practice, 4CH ESA seems a reliable and easy method to identify patients with RV dysfunction.

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Introduction

Cardiac magnetic resonance imaging (CMR) is a non-invasive reliable diagnostic method for imaging the heart to evaluate the anatomy, haemodynamics, and tissue characteristics in children.[1–3] It is considered the reference standard method for the assessment of mass, volume, and systolic function of both the left and right ventricle (LV and RV).[1,4,5] Current indications for CMR as a second choice imaging method (after echocardiography) include a wide range of cardiac conditions in children extending from congenital heart diseases, suspicion of cardiomyopathies, confirmation of myocarditis, and tumour tissue characteristics.[3–7]

CMR is of particular value in the detailed assessment of the RV, where the use of echocardiography can be limited due to problems with visualisation, complex RV anatomy, and motion.[1,5,8,9] Detailed assessment of the RV is very important in patients where the CMR criteria have an essential value (i.e., in the diagnosis of arrhythmogenic RV cardiomyopathy or in the planning of further management in corrected tetralogy of Fallot [TOF]). In these cases CMR is used for quantitative assessment of RV size and function as an essential element of the imaging protocol, which is one of the strengths of the CMR.

CMR is free from any problems with imaging plane. Both ventricles can be quantitatively assessed in terms of their end-diastolic/end-systolic volumes, stroke volume, ejection fraction and mass. This is done after delineation of epicardial and endocardial contours of both ventricles on a set of slices in short or long-axis.[9–11]

Available software usually allow for semi-automatic and therefore quite fast assessment of LV parameters, while assessment of the RV requires more time-consuming manual delineation of contours. It is related to the thinner myocardial wall and therefore inaccurate automatic detection of RV wall borders.[9,12,13] Currently, no clinically available software tool can overcome this limitation; however, a lot of indications for the CMR examination in paediatric patients concern only suspicion of the LV disease, such as LV enlargement, cardiomyopathy, or myocarditis. In these cases, it would be practical to find simple one- or two-dimensional parameters assessing RV volume and systolic function without a need for time-consuming manual delineation of RV contours. These parameters could be rapidly used as a screening tool to determine those who require more detailed RV analysis limiting time for study evaluation in many patients. Therefore, some common echocardiographic as well as newly proposed one- or two-dimensional parameters may serve as the first-line markers of RV size and systolic function in CMR in children to dichotomise those who require in-depth analysis with dedicated software and those in whom this simple assessment is sufficient in daily clinical practice.

Materials and methods

Subjects

The CMR images of 65 children consecutively hospitalised between March 2016 and March 2017 and referred by paediatric cardiologists and cardiac surgeons for the examination were analysed retrospectively. Children included in the study were representative of current routine indications for CMR.[1,4,6] Five studies were initially excluded because of poor quality of the CMR images (mainly due to problems with ECG gating in severe arrhythmias). The 60 patients included in the final analysis were diagnosed because of (in order of frequency): evaluation of corrected congenital heart diseases (TOF, ventricular septal defect, atrial septal defect, coarctation of the aorta, transposition of great arteries or pulmonary atresia) ($n = 16$), diagnostic work-up for ventricular arrhythmias (n=10), suspicion of myocarditis or assessment after myocarditis (n=8), suspicion of cardiomyopathies: hypertrophic (n=6), arrhythmogenic right ventricular (n=5), LV non-compaction (n=4), or dilated cardiomyopathy (n=4), evaluation of cardiac tumours (n=3), and other rare causes (n=4).

CMR

All CMR studies were acquired with a Siemens Magnetom Skyra 3 T system (Siemens, Erlangen, Germany). Only three children (age 5–10 months) required general anaesthesia. Two of the youngest children were examined while asleep. The routinely used CMR protocol to assess LV and RV size and function included initial scout images, followed by cine steady-state free precession (SSFP) breath-hold sequences in two-, three-, and four-chamber views to set up final imaging planes and a stack of short axis images from the atrioventricular annulus to the apex. Imaging parameters were as follows: 340 mm field of view, 208x256 matrix, approximately 39.24 ms repetition time, 1.43 ms echo time, 39° flip angle, 6–8 mm section thickness (depending on the child age), 1–2 mm gap, 1.6 × 1.6 mm in-plane image resolution, temporal resolution consisted of 25 phases per cardiac cycle. In all study examinations, flow measurements using the phase contrast sequence, in the aorta at the level of the sino-tubular junction (STJ), and in some cases in the pulmonary trunk, were registered.[1]

Image analysis

Images were analysed with the use of dedicated software. Initially, short-axis SSFP cine images were previewed from the base to the apex in a cinematic mode, then endocardial and epicardial contours for end-diastole and end-systole were manually traced. Trabecule and papillary muscles were included in the RV cavity. Delineated contours were used for the quantification of RV end-diastolic and end-systolic volumes (RVEDV, RVESV), stroke volume (RVSV), ejection fraction (RVEF), and mass (RVM). Values obtained were internally validated against flow measurement in the ascending aorta and in some cases in the pulmonary artery taking into consideration regurgitation of the atrio-ventricular valves. Then the parameters were indexed for body surface area (BSA) calculated according to the Mosteller formula[14] and presented as RVEDVI, RVESVI, RVSVI, and RVMI.

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