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Assessment of myocardial function using MRI-based feature tracking in adults after atrial repair of transposition of the great arteries: Reference values and clinical utility

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ABSTRACT

Background: Echocardiographic parameters of ventricular deformation of the systemic right ventricle (sRV) predict adverse clinical outcome in patients after atrial repair of transposition of the great arteries (TGA). We assessed myocardial deformation on cardiac MRI (CMR) and correlated these with clinical and conventional CMR parameters in TGA patients.

Methods: Retrospective analysis of CMR studies in 91 TGA patients (66% male; mean age 30.1 ± 5.1 years) at two tertiary adult congenital heart centers was conducted. Myocardial deformation was assessed by CMR-based feature tracking (FT), providing longitudinal (LS), radial (RS), and circumferential (CS) global strain for the sRV and the subpulmonary left ventricle. A subgroup of optimal TGA was defined (NYHA class I, NT-proBNP <300 pg/ml, max. exercise work load ≥100 watt, no significant clinical events) as a reference cohort.

Results: There was a significant correlation between FT and conventional CMR parameters. Left ventricular ejection fraction (LVEF) correlated significantly with LV LS, RS, and CS (r between 0.24 and 0.34, p values between 0.03 and 0.005). sRVEF correlated with RV CS ($r = 0.56$, $p < 0.001$), and RV RS ($r = 0.32$, $p = 0.007$). QRS duration showed a negative correlation with RV CS ($r = -0.53$, $p < 0.001$), LV RS ($r = -0.34$, $p = 0.008$), and LV CS ($r = -0.34$, $p = 0.006$). Reference values for the novel FT method in clinically optimal TGA patients are provided.

Conclusion: Assessment of myocardial function using CMR-based FT is feasible in TGA patients. FT measurements related to important prognostic clinical parameters. Furthermore, we provide for the first time reference values for TGA patients in an optimal clinical status.

1. Introduction

The atrial switch procedure for transposition of the great arteries (TGA) was a major step in the treatment of congenital heart disease [1,2]. The major disadvantage of this procedure is that the morphological right ventricle has to support the systemic circulation long-term as the so-called systemic right ventricle (sRV). While in the first two to three decades of life, outcome is reasonably good, in the longer term sequelae including arrhythmias, baffle-related complications, and especially right ventricular dysfunction, ensue [3]. Detection of ventricular dysfunction at an early stage may enable early initiation of treatment to avoid or delay further deterioration. Echocardiographic parameters of ventricular deformation of the sRV have been reported as potentially useful in this setting [4]. Furthermore, echocardiographic parameters seem to predict adverse clinical outcome in TGA patients [5]. However, reliable assessment of ventricular deformation using echocardiography is hampered by complex ventricular anatomy and physiology. Therefore, cardiac MRI (CMR) remains as the gold standard for the assessment of biventricular function and quantification of volumes in patients with a sRV [6]. CMR feature tracking (FT) – a novel technique using standard cine steady-state free-precession sequences – allows quantifying myocardial deformation from CMR imaging [7]. Recent studies in ACHD patients showed good inter-observer reproducibility for

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measures of global left and RV strains, suggesting that this approach could have clinical relevance and deserves further study [6–8]. Data regarding FT in patients with TGA with a sRV after atrial switch repair are lacking. In this study, we aim to assess myocardial function using FT technique and to study its clinical utility in this patient group.

2. Methods

We retrospectively identified patients with a TGA after the atrial switch from the databases of two large tertiary adult congenital heart centers (Hannover Medical School and University Hospital of Münster, Germany), in which a CMR study was available. All patients underwent clinical examination at the time of CMR due to their routine follow-up, and clinical/surgical history and New York Heart Association (NYHA) functional class were recorded. The majority of patients (n = 77) underwent cardiopulmonary exercise testing.

Furthermore, a group of patients in an optimal clinical status characterized by a NYHA functional class I, NT-proBNP levels below 300 pg/ml, a maximum exercise work load ≥100 watt, and no history of significant clinical events (such as arrhythmias or heart failure) was defined as a reference cohort.

2.1. CMR study

All patients underwent CMR studies employing a standardized protocol. The total time for cine imaging was 15–20 min. For cine imaging, a steady-state free precession (balanced-SSFP) sequence in breath-hold technique with retrospective ECG triggering was used. Imaging parameters were chosen as follows: echo time (TE) and repetition time (TR) were set to shortest resulting in an average TR of around 4 ms and a TE of 2 ms, slightly varying with slice orientation (typically 25 phases per cardiac cycle; reconstructed in- plane resolution 1 mm; slice thickness 6 mm for axial planes and 8 mm for short axis planes). The typical temporal resolution of the cine SSFP sequences was 30–40 ms depending on heart rate. The sequences were exported in DICOM-Format without special adjustments. Further details on CMR acquisition and analysis have previously been reported by our group [7,9,10].

FT analysis was performed by two investigators (OT and SO) using the TomTec 2D CPA MR software (TomTec, Unterschleissheim, Germany, V.1.1.2.36-B). This was done separately for the subpulmonary left ventricle (LV) and the systemic right ventricle (sRV). Analysis consisted of marking the endocardium and triggering the automatic computation (Fig. 1). The consistency of the movement of myocardium and the tracking contour was assessed visually and the tracking analysis was repeated if needed. Longitudinal strain (LS) of the LV and sRV were assessed in a four-chamber view. Circumferential (CS) and radial strain (RS) of both ventricles were assessed in the short axis view at the level of the papillary muscles. The details of the FT algorithm have been published previously [11,12]. The current study focused entirely on global systolic strain.

2.2. Statistical analysis

Values are presented as mean ± standard deviation (SD) or median and interquartile range (25th and 75th percentile), depending on variable distribution. Comparisons between groups were made using a two-tailed Student t-test or non-parametric methods depending on data distribution. Statistical analyses were performed using MedCalc 12.4.0 (MedCalc Software, Mariakerke, Belgium).

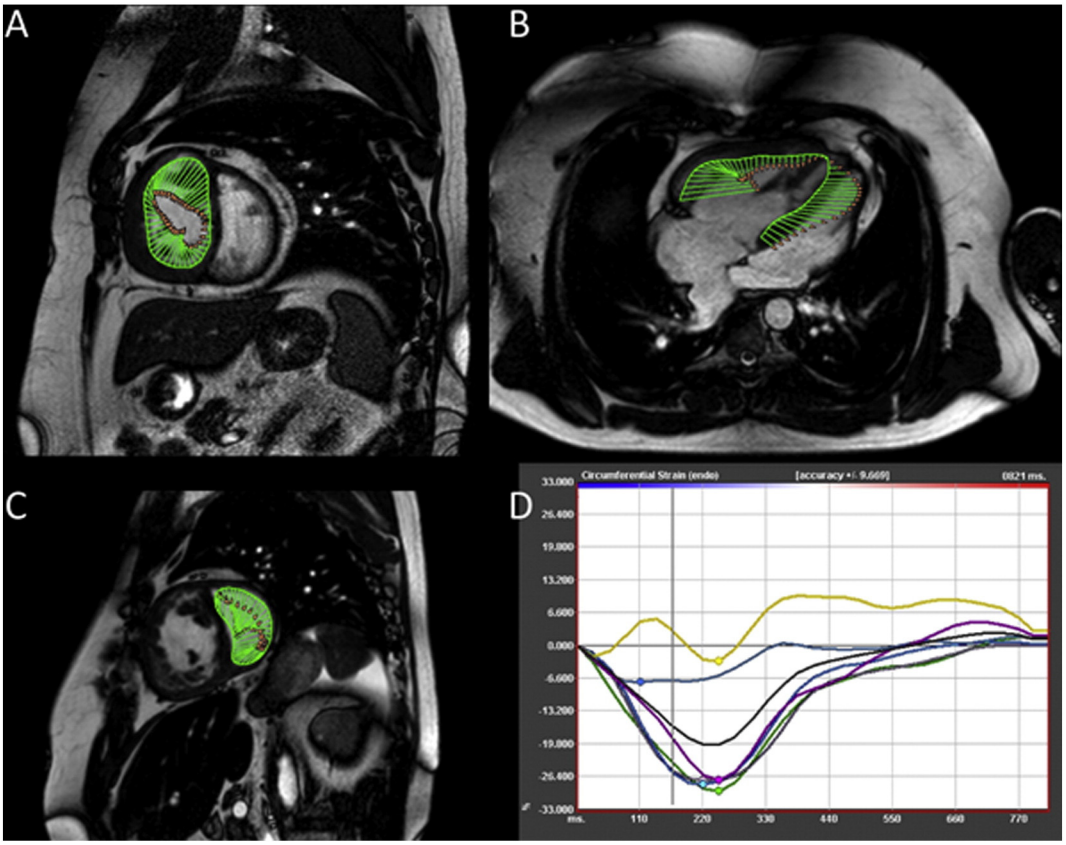

Fig. 1. Example of the CMR-based feature-tracking measurement using the Tom Tec software with delineation of the myocardial border and vector arrows of late systolic velocity tracing. A and C: Short axis with radial strain of the systemic right ventricle (A) and subpulmonary left ventricle (C). B: Four-chamber view with measurement of longitudinal strain of the systemic right ventricle. D: Example of measurement of circumferential strain.