European Journal of Radiology 85 (2016) 1322–1328

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Right ventricular long axis strain—validation of a novel parameter in non-ischemic dilated cardiomyopathy using standard cardiac magnetic resonance imaging

Nisha Arenja [a], Johannes H. Riffel [a], Charly Noel Djiokou [a], Florian Andre [a], Thomas Fritz [a], Manuel Halder [a], Thomas Zelniker [a], Arnt V. Kristen [a], Grigorios Korosoglou [a], Hugo A. Katus [a,b], Sebastian J. Buss [a,*]

[a] Department of Cardiology, Angiology and Pneumology, University of Heidelberg, Im Neuenheimer Feld 410, 69120 Heidelberg, Germany
[b] DZHK (German Centre for Cardiovascular Research), partner site Heidelberg, Germany

ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form 22 April 2016
Accepted 28 April 2016

Keywords:
Cardiac magnetic resonance imaging
Non-ischemic dilated cardiomyopathy
Right ventricular function
Long axis strain

ABSTRACT

Purpose: Right ventricular longitudinal axis strain (RV-LAS) is a simple measure of RV longitudinal function. The purpose of this study was the evaluation of its diagnostic performance in non-ischemic dilated cardiomyopathy (NIDCM) and the determination of reference values in controls.
Methods: 217 NIDCM patients and 200 healthy controls were analysed retrospectively regarding the diagnostic performance of RV-LAS using receiver operating characteristic curves in comparison with RV ejection fraction (RVEF), tricuspid annular plane systolic excursion (TAPSE) and global longitudinal strain (RV-GLS). Hereby, four different approaches were evaluated to assess RV-LAS based on different reference points. RV-LAS LVapex/mid was defined as the change in distance between the LV apex and the middle of a line connecting the origins of the tricuspidal valve leaflets in systole and diastole. The ethical approval was obtained in all participants.
Results: NIDCM and controls were 48 years in mean. Controls were equally gender distributed, while the proportion of men with NIDCM was higher with 77%. Among the four approaches RV-LAS LVapex/mid provided the highest diagnostic performance for discrimination between NIDCM and controls (AUC = 0.94). Of all RV functional parameters RV-LAS LVapex/mid preformed significantly better than RVEF (delta AUC = 0.05; $p = 0.003$), TAPSE (delta AUC = 0.23; $p < 0.0001$) and RV-GLS (delta AUC = 0.31; $p < 0.0001$). A significant correlation was found between RV-LAS LVapex/mid and RVEF ($r = -0.65$; $p < 0.0001$). The reference mean values for RV-LAS LVapex/mid were -17.4 ± 3.5 for men and -18.5 ± 3.7 for women.
Conclusion: RV-LAS showed better diagnostic accuracy for RV dysfunction than RVEF, TAPSE and RV-GLS. Furthermore, it has a rapid accessibility and low intra- and interobserver variability.

1. Introduction

Non-ischemic dilated cardiomyopathy (NIDCM) is defined as systolic dysfunction, either of the left ventricle (LV) alone or biventricular, with concomitant dilatation in the absence of abnormal loading conditions or coronary artery disease [1].

Right ventricular (RV) dysfunction is known to come along with limited exercise capacity and to worsen significantly the prognosis in NIDCM. Therefore, the evaluation of the RV function is of crucial importance in patients with NIDCM [2–4].

Compared with the LV measurement, RV function is often difficult to assess, due to the complex geometry and motion of the RV. For the assessment of RV function cardiac magnetic resonance (CMR) imaging has been shown to be both, accurate and repro-

Abbreviations: ARVC, arrhythmogenic right ventricular cardiomyopathy; AUC, area under curve; CMR, cardiac magnetic resonance; ECG, electrocardiogram; EDV, end-diastolic volume; EF, ejection Fraction; ESV, end-systolic volume; FTI, feature tracking analysis; FOV, field of view; GLS, global longitudinal strain; LAS, long axis strian; LV, left ventricle; NIDCM, non-ischemic dilated cardiomyopathy; NYHA, New York heart association-classification; ROC, receiver operating characteristic; RV, right ventricle; RV-GLS, right ventricular global longitudinal strain; RVEF, right ventricular ejection fraction; RV-LAS, right ventricular longitudinal axis strain; SD, standard deviation; SSFP, steady state free precession sequence; SV, stroke volume; TAPSE, tricuspid annular plane systolic excursion; TE, echo time; TR, repetition time.

* Corresponding author.
E-mail address: sebastian.buss@med.uni-heidelberg.de (S.J. Buss).

http://dx.doi.org/10.1016/j.ejrad.2016.04.017
0720-048X/

ducible [5]. Nowadays, CMR is the non-invasive technique of choice for the evaluation of RV function [6,7]. However, manual measurement of the RV volumes by CMR in short-axis is time consuming and prone to a low reproducibility owing to the complex geometry of the RV [8]. Further, the longitudinal RV function is not well represented by RV ejection fraction (RVEF). In addition to standard methods for RV functional analysis, a simple, rapidly determinable and reproducible parameter is of great interest for clinical practice.

In routine examination many clinicians quantify the longitudinal RV function by tricuspid annular plane systolic excursion (TAPSE), which is a simple method, but with variable results [9]. CMR myocardial feature-tracking imaging (FTI) analysis for the RV longitudinal strain has been recently described as a reliable method to estimate global and regional myocardial contraction [10]. However, it requires special post-processing software and presents semi-manual tracing of the endocardial borders. Furthermore, it has not been sufficiently studied for routine use in the clinics.

Recently, it has been validated and reported on longitudinal axis strain (LAS), which is a reliable and fast determinable measure for the analysis of global LV longitudinal function in CMR. LV-LAS was rapidly and reliably assessed from standard CMR images and it showed non-inferiority compared to other functional LV parameter in discriminating healthy controls from patients with cardiomyopathies. The decisive advantage of this method was that it was feasible without the need of additional pulse sequences and off-line processing using dedicated software tools [24].

The objectives of the current study were therefore to evaluate the diagnostic value of RV-LAS in patients with NIDCM and to determine reference values in healthy controls.

2. Materials and methods

2.1. Study population

This retrospective study used data from a well-defined cohort of consecutive patients with NIDCM at our institute. The study population consisted of 217 NIDCM patients with a clinical indication for CMR and 200 healthy volunteers. CMR was performed as part of the routine diagnostic workup, unless one of the following contraindications to CMR was present: cardiac pacemaker or implantable cardioverter defibrillator (ICD), other metallic implants not compatible with CMR, severe claustrophobia, severe obesity preventing patient entrance into the scanner bore, pregnancy and lactation. Chronic renal failure with an estimated GFR <30 ml/min/1.73 m^2 was added as an exclusion criterion for administration of intravenous CMR contrast agents after July 2007. All patients were in clinical stable condition (NYHA $\leq$ III). The study was carried out, after approval of the local Ethics Committee and in accordance with the Declaration of Helsinki.

2.2. CMR acquisition protocol

CMR was performed on a 1.5 T clinical scanner (Achieva, Philips Healthcare, Best, The Netherlands) equipped with a dedicated cardiac phased array receiver coil. Cine images were obtained using a standard breath-hold segmented-k-space balanced fast-field echo steady state free precession sequence (SSFP) employing retrospective electrocardiography (ECG)-gating in long axis planes (2, 3 and 4 chamber views), as well as in contiguous short axis slices (2 mm gap) covering the whole ventricles from the annulus of the atrioventricular valves to the apex (35 phases per cardiac cycle). Typical CMR imaging parameters were: field-of-view (FOV) = 350 × 350 mm^2, repetition time/echo time (TR/TE) = 2.8/1.4 ms, acquired voxel size = 2.2 × 2.2 × 8 mm^3, flip angle = 60°, reconstructed voxel size = 1.3 × 1.2 × 8 mm^3.

2.3. CMR analysis of standard cardiac parameters

All analyses were performed on a commercially available workstation (IntelliSpace Portal (ISP) Version 7, Philips Healthcare, Best, The Netherlands) equipped with a software for volumetric analysis. Results for ventricular volumes and ejection fraction (EF) were derived from short axis slices after manually tracing the *epi*- and endocardial borders, including trabecular and papillary muscles to the LV volume. For the RV volumetric analyses only the endocardial borders of the short axis slices were manually traced. RVEF was calculated by dividing the RV stroke volume (SV) by the RV end diastolic volume (EDV). RV trabecular and papillary muscles were also included in RV volumes.

2.4. Longitudinal function using tricuspid annular plane systolic excursion (TAPSE)

TAPSE is defined as the maximal excursion of the tricuspid annular plane. This method is established in echocardiography and CMR for the evaluation of the RV longitudinal function [11]. A 4-chamber view was selected for the measurement of TAPSE. The distance between the lateral origin of the tricuspidal valve and the RV apex or alternatively a reference point outside the RV apex was measured in end-diastole and end-systole. TAPSE was calculated as difference between both lengths.

2.5. Feature tracking imaging (FTI)

The retrospective CMR myocardial FTI analysis were performed using dedicated software (2D CPA CMR, TomTec Imaging Systems, Munich, Germany). This software algorithm has been validated previously in experimental and clinical studies [12–14]. In our study only the endocardial border of the RV was taken into account. First it was traced manually in 4-chamber view in end-diastole. Eventually, it was tracked automatically software-driven throughout the whole cardiac cycle. The quality of automatic tracking was checked and the contours were manually adjusted, if necessary. Measurements were repeated three times and then averaged, resulting in the mean right ventricular global longitudinal strain (RV-GLS). The technique has been described in detail recently [15].

2.6. Right ventricular long axis strain (RV-LAS)

RV-LAS was assessed in the 4-chamber view by measuring the displacement of the tricuspid annulus. We evaluated and compared four different approaches for measuring RV-LAS, which a described in the following.

RV-LAS Ins/peri: The length between the epicardial border at the insertion point between RV and LV and the lateral insertion of tricuspid valve was measured in endsystole as well as in enddiastole (Fig. 1a).

RV-LAS Ins/mid: The length between the epicardial border at the insertion point between RV and LV and the middle of a line connecting the origins of the tricuspidal valve leaflets was measured in both endsystole and enddiastole (Fig. 1b).

RV-LAS LVapex/peri: The length between the epicardial border of the LV apex and the lateral insertion of tricuspid valve was measured in endsystole as well as in enddiastole (Fig. 1c).

RV-LAS LVapex/mid: The length between the epicardial border of the LV apex and the middle of a line connecting the origins of the tricuspidal valve leaflets was measured in both endsystole and enddiastole (Fig. 1d).