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Cardiothoracic ratio may be misleading in the assessment of right- and left-ventricular size in patients with repaired tetralogy of Fallot

M. Śpiewak [a,b,c,*], Ł.A. Małek [a,d], E.K. Biernacka [e], M. Kowalski [e], I. Michałowska [b], P. Hoffman [e], J. Miśko [a,b], M. Demkow [c], W. Ruzyłło [f], M. Marczak [a,b]

[a] Magnetic Resonance Unit, Institute of Cardiology, Warsaw, Poland
[b] Department of Radiology, Institute of Cardiology, Warsaw, Poland
[c] Department of Coronary Artery Disease and Structural Heart Diseases, Institute of Cardiology, Warsaw, Poland
[d] Department of Interventional Cardiology and Angiology, Institute of Cardiology, Warsaw, Poland
[e] Department of Congenital Heart Diseases, Institute of Cardiology, Warsaw, Poland
[f] Institute of Cardiology, Warsaw, Poland

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AIM: To assess the relationship between cardiothoracic ratio (CTR) and ventricular and atrial volumes in patients with repaired tetralogy of Fallot (TOF).

MATERIALS AND METHODS: Patients with repaired TOF undergoing cardiac magnetic resonance (CMR) and chest radiography within 1 day were included ($n = 82$; median age: 24.7 years, interquartile range: 21.5–35.9). The CTR was obtained from upright posteroanterior chest roentgenograms. Analyses of CMR images and radiographs were performed in a blinded fashion.

RESULTS: There were 35.1% (13/37) of patients with normal CTR (<0.5) who had severe right ventricular (RV) dilatation. There were six patients (13.3%, 6/45) with high CTR with both normal RV and left-ventricular (LV) volumes. CTR did not correlate with either RV or LV volumes but showed a weak correlation with right- and left-atrial volumes ($r = 0.43$, $p = 0.0001$; $r = 0.27$, $p = 0.01$, respectively). CTR ≥0.5 showed poor ability in the identification of severe RV dilatation (sensitivity: 61.8%, specificity: 50%). The combination of CTR and signs of RV enlargement on lateral radiographs did not improve the diagnostic accuracy of any of those parameters alone.

CONCLUSION: CTR in patients with repaired TOF reflected atrial rather than ventricular dilatation. The use of CTR or lateral radiographs in patients with repaired TOF may lead to false conclusions concerning ventricular size.

Introduction

The cardiothoracic ratio (CTR) is commonly used as a simple, easily available, and highly reproducible marker of cardiac enlargement. CTR has been shown to be

* Guarantor and correspondent: M. Śpiewak, Magnetic Resonance Unit, Department of Radiology, Department of Coronary Artery Disease and Structural Heart Diseases, Institute of Cardiology, ul. Alpejska 42, 04-628 Warsaw, Poland. Tel.: +48 22 3434342; fax: +48 22 3434516.
E-mail address: mspiewak@ikard.pl (M. Śpiewak).

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independently associated with outcomes in various patients' populations including patients with congenital heart diseases.[1–4] Previous studies demonstrated an inconsistent association between roentgenographic parameters and left ventricular (LV) size, and the authors emphasized that CTR reflects right-sided rather than left-sided chamber enlargement.[5–9] Those studies, however, used echocardiography or angiography for estimating the size of cardiac chambers and all limitations associated with echocardiographic or angiographic measurements of LV and particularly right-ventricular (RV) size should be acknowledged.

RV dilatation often occurs in patients with repaired tetralogy of Fallot (TOF) and its identification is of particular importance for patients' treatment.[10] Additionally, LV size may be influenced by various factors such as residual ventricular septal defect, aortic regurgitation, or previous palliative shunts.[10] Therefore, haemodynamic abnormalities and their consequences may significantly affect the cardiac silhouette in this population. The CTR has been shown to be an independent risk factor of inducible sustained ventricular tachycardia and overall mortality in patients with repaired TOF.[1,11] Little is known, however, about the association between the CTR and the ventricular size after TOF repair.

It is believed that the CTR, which measures the transverse diameter of the heart does not reflect moderate RV dilatation, and it is postulated that the right ventricle becomes a factor influencing the cardiac silhouette on posteroanterior chest radiographs only when severe RV enlargement is present.[12] Lateral radiographs are believed to be better suited to assess RV size than posteroanterior ones. Cardiac magnetic resonance (CMR) enables accurate and reproducible measurements of cardiac chambers. The hypothesis of the present study was that CTR within a normal range does not exclude severe RV dilatation in patients with repaired TOF. The primary objective of the present study was to assess the relationship between CTR and ventricular and atrial volumes in patients with repaired TOF. An additional aim was to assess the diagnostic accuracy of lateral radiographs in the identification of RV enlargement.

Materials and methods

Patients

The local ethics committee approved the review medical records and patients databases. Each patient and/or their parents/guardians gave their written consent for CMR study. The Standards for Reporting of Diagnostic Accuracy were used to plan and conduct the study.[13]

A large cohort of consecutive patients with repaired TOF who had undergone a CMR study between June 2008 and end of December 2012 was screened and patients with a chest roentgenogram performed within 1 day from the CMR study were selected. Performing chest radiography within 1 day of the CMR virtually excludes any changes in ventricular size and function in clinically stable, conservatively treated patients. Between June and mid-September 2011, data were collected retrospectively, and from mid-September on, patients were included in a prospective manner.

Chest radiography

The CTR was measured in upright posteroanterior chest radiographs as the ratio of the maximal transverse diameter of the cardiac silhouette to the transverse thoracic diameter (the distance between the internal margins of the ribs at the level of the right hemidiaphragm).[1] Additionally, RV enlargement was determined on lateral chest radiographs when the retrosternal space was filled in more than one-third.[12] Retrosternal space was measured as the distance between the sternodiaphragmatic angle and the intersection of the trachea and the sternum.[12,14] A CTR of <0.5 was defined as normal and that of ≥ 0.5 as high. CTR measurements and the assessment of RV size on lateral views were performed by an experienced radiologist (MM, with 8 years of experience) blinded to the results of CMR study and the patients' histories.

CMR

All CMR studies were performed with the use of a 1.5 T system (Avanto; Siemens, Erlangen, Germany). Ventricular volumes and masses were measured as follows: (1) electrocardiography (ECG)-gated breath-hold balanced steady-state free precession (SSFP) stack of short axis images encompassing the entire ventricles was acquired (2.2–3.6 ms repetition time; 33–54 ms temporal resolution; 1.2 ms echo time; 64–79° flip angle; 8 mm section thickness; 1.6 mm gap); (2) manual delineation of epicardial and endocardial contours in end-diastole and end-systole was performed; (3) LV and RV end-diastolic volumes (LVEDV and RVEDV, respectively), LV and RV end-systolic volumes (LVESV and RVESV, respectively), and LV and RV masses (LVM and RVM, respectively) were calculated with the use of dedicated software (Mass 6.2.1; Medis, Leiden, the Netherlands).

Left atrium (LA) diameters were measured as previously described in balanced SSFP two-, four- and three-chamber views.[15] LA volume (LAV) was calculated according to the formula described by Maceira et al.[15] showing the best agreement with the measurements based on a stack of short axis images.[15] Right atrium (RA) diameters were measured in the four-chamber view and RA volume (RAV) was calculated with the use of the area–length method.[16] Total heart volume (THV) was calculated as a summation of RVEDV, LVEDV, RAV, and LAV. Volume parameters were indexed for body surface area (BSA).

Pulmonary flow was measured based on a flow-sensitive gradient-echo sequence (9.4 ms repetition time; 2 ms echo time; 30° flip angle; 5 mm section thickness) with the use of dedicated software (Argus; Siemens, Erlangen, Germany). A pulmonary regurgitation (PR) fraction (PRF) of $\geq 20\%$ was considered significant.[17]