

Original article

Value of the Electrocardiogram as a Predictor of Right Ventricular Dysfunction in Patients With Chronic Right Ventricular Volume Overload



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Article history:

Received 13 January 2014

Accepted 9 April 2014

Available online 7 October 2014

Keywords:

Pulmonary regurgitation

Tetralogy of Fallot

QRS

Fragmentation

ABSTRACT

Introduction and objectives: Pulmonary regurgitation is a common complication in patients with repaired tetralogy of Fallot or congenital pulmonary stenosis. Electrocardiographic variables have been correlated with parameters used to evaluate right ventricular function. We aimed to analyze the diagnostic value of the width and fragmentation of the electrocardiogram in the identification of patients with right ventricular dysfunction and/or dilation.

Methods: We selected 107 consecutive patients diagnosed with severe pulmonary insufficiency after repair of pulmonary stenosis or tetralogy of Fallot. The tests included electrocardiography, echocardiography, and magnetic resonance. Each electrocardiogram was analyzed manually to measure QRS duration. We defined QRS fragmentation as the presence of low-voltage waves in the terminal portion of the QRS complex in at least 2 contiguous leads.

Results: We found a significant negative correlation between QRS width and right ventricular function, as well as a positive correlation with right ventricular volume. The receiver operating characteristic curve indicated a cut-off point for QRS width of 140 ms, which showed good sensitivity for a diagnosis of right ventricular dilation (> 80%) and dysfunction (> 95%). In logistic regression models, a QRS duration > 140 ms was found to be the only independent predictor of right ventricular dilation and dysfunction.

Conclusions: Electrocardiography is a rapid, widely available, and reproducible tool. QRS width constitutes an independent predictor of the presence of right ventricular dilation and dysfunction. This study is the first to provide a cutoff value for QRS width to screen for right ventricle involvement.

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Valor del electrocardiograma como predictor de disfunción ventricular derecha en pacientes con sobrecarga crónica de volumen del ventrículo derecho

RESUMEN

Introducción y objetivos: La insuficiencia pulmonar es una complicación frecuente en pacientes con tetralogía de Fallot o estenosis pulmonar congénita reparada. Se han correlacionado variables electrocardiográficas con parámetros de función del ventrículo derecho. Proponemos analizar el valor diagnóstico de la anchura y la fragmentación del electrocardiograma en la identificación de pacientes con disfunción y/o dilatación del ventrículo derecho.

Métodos: Seleccionamos a 107 pacientes consecutivos diagnosticados de insuficiencia pulmonar grave tras reparación de estenosis pulmonar o tetralogía de Fallot. Se les realizó electrocardiograma, ecocardiograma y resonancia magnética. Cada electrocardiograma se analizó manualmente midiendo la duración del QRS. Definimos fragmentación del QRS como la presencia de ondas de bajo voltaje en la porción terminal del QRS en al menos dos derivaciones contiguas.

Resultados: Se obtuvo una correlación negativa y significativa entre anchura del QRS y función del ventrículo derecho, así como una correlación positiva con el volumen de este. De la curva ROC se obtuvo el punto de corte en 140 ms de anchura del QRS, que mostró buena sensibilidad para el diagnóstico de dilatación (> 80%) y disfunción (> 95%) del ventrículo derecho. En los modelos de regresión logística, QRSd > 140 ms se mostró como el único predictor independiente de dilatación y disfunción del ventrículo derecho.

Palabras clave:

Insuficiencia pulmonar

Tetralogía de Fallot

QRS

Fragmentación

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Conclusiones: El electrocardiograma es una herramienta rápida, disponible y reproducible. La anchura del QRS permite predecir de manera independiente la presencia de dilatación y disfunción del ventrículo derecho. Este es el primer estudio que propone un punto de corte en la anchura del QRS para el cribado de afección del ventrículo derecho.

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Abbreviations

CMR: cardiac magnetic resonance
 ECG: electrocardiogram
 PR: pulmonary regurgitation
 RV: right ventricle
 RVEF: right ventricular ejection fraction
 TOF: tetralogy of Fallot

INTRODUCTION

Pulmonary regurgitation (PR) is a common complication in patients who underwent surgery for tetralogy of Fallot (TOF) or for congenital pulmonary stenosis as children. It has been shown that surgical correction of TOF ameliorates the symptoms and prolongs survival.^{1,2} In pulmonary stenosis, the obstruction can be valvular, subvalvular (infundibular), or supra-ventricular. Valvular stenosis can be treated by means of percutaneous valvuloplasty, whereas supra-ventricular and subvalvular stenosis generally require conventional surgery, and the prognosis is less benign.³

The severe PR that usually develops after the intervention leads to dilation and progressive dysfunction of the right ventricle (RV), increasing the risk of arrhythmias and worsening the prognosis of these patients. Treatment is surgical, and involves replacement of the pulmonary valve with a prosthesis or homograft. When pulmonary valve replacement is carried out at the proper time, it is usually accompanied by a reduction in RV volume and, on occasion, by an improvement in the right ventricular ejection fraction (RVEF). However, when the intervention is indicated late after TOF repair, RV recovery is incomplete.⁴ The current indications for pulmonary valve replacement are not clearly defined, and the criteria are mainly based on the development of clinical events and/or excessive RV dilation.⁵ Thus, the proper timing of surgery is a challenge for clinicians as, in addition to the clinical variables, data from imaging studies must also be considered.

Cardiac magnetic resonance (CMR) is the gold standard for estimating RVEF and RV volumes. However, CMR is a very costly technique that is not available in all centers. Moreover, its use is controversial in patients with cardiac pacing devices or defibrillators, especially the latter, because of the risk of interferences and signal loss they induce.⁶ In this context, noninvasive complementary diagnostic methods, such as electrocardiography (ECG), become especially important as possible indirect markers of the progression of heart disease.

Surface ECG is a simple, affordable, and virtually noninvasive diagnostic test; different electrocardiographic variables have been correlated with parameters of RV function and with the onset of cardiovascular events.^{7,8} The relationship between QRS fragmentation and width and clinical parameters, including the development of arrhythmias, has been studied in TOF.⁹

The objective of this study was to analyze the diagnostic value of ECG parameters to identify those patients with RV dysfunction and/or dilation secondary to severe PR.

METHODS

Study Population

We carried out a retrospective selection of 107 patients diagnosed as having severe PR who were being followed up in the adult congenital heart disease unit of our center. All the patients had been diagnosed with TOF or pulmonary stenosis and had undergone surgical repair as children, resulting in significant PR as a sequel. We defined severe PR in accordance with the criteria previously established in the literature.¹⁰

The variables recorded included demographic and clinical data. Surface ECG, transthoracic echocardiography, and CMR were performed as part of the routine clinical evaluation. The interval between ECG and CMR was not longer than 15 days in any of the patients. We excluded patients with 1 or more of the following conditions: *a*) use of medication affecting QRS duration; *b*) pacemaker to stimulate cardiac rhythm; *c*) problems with the interpretation of CMR data due to the region of signal loss owing to the presence of an implanted cardioverter defibrillator; and *d*) presence of tricuspid atresia and/or RV hypoplasia.

Electrocardiographic Evaluation

A 12-lead resting ECG was performed in all the patients as part of their usual follow-up using a digital acquisition and storage system (filter band, 0.16 Hz to 100 Hz; 25 mm/s; 10 mm/mV; PageWriter TC70 cardiograph, Philips Medical Systems; Eindhoven, The Netherlands). To obtain the measurements, the size was augmented and a specific software package was employed (Cardio Calipers[®] 3.3, Iconico) with a resolution of 1 ms on the horizontal axis and 0.01 mV on the vertical axis.

Manual analysis of each ECG included measurement of the duration of the QRS complex in each of the precordial leads and calculation of the arithmetic mean. QRS duration was defined as the distance between the first deflection and the point of confluence of the final vector with the isoelectric line. We excluded measurement of atrial and ventricular premature beats. For the statistical analysis, we defined long QRS as that with a duration > 120 ms.

We analyzed QRS fragmentation (QRSf), defined as the presence of notches or low-voltage waves (R') in the terminal portion of the QRS complex or at the beginning of the ST segment in at least 2 contiguous leads (Figure 1A). In patients with prolonged QRS (> 120 ms), even with bundle branch block morphology, QRS fragmentation was defined as the presence of more than 2 R' in the R wave or in the nadir of the S wave in at least 2 contiguous leads (Figure 1B).

All of the ECG were analyzed by clinical cardiologists who were blind to the results of CMR imaging. Ten patients were randomly selected to repeat the analysis of the QRS complex, this time blinded, by the same operator and by a second operator to establish the interobserver and intraobserver variability.

Cardiac Magnetic Resonance

All the CMR images were acquired using a 1.5-T Magnetom scanner with Syngo MR 2004 V[®] software (Siemens Medical

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