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Journal of Electrocardiology 47 (2014) 175 – 182

JOURNAL OF Electrocardiology

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Electrocardiographic detection of right ventricular pressure overload in patients with suspected pulmonary hypertension

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Abstract

Background and Purpose: Early, preferably noninvasive, detection of pulmonary hypertension improves prognosis. Our study evaluated the diagnostic accuracy of the electrocardiographically derived Butler–Leggett (BL) score and ventricular gradient (VG) to estimate mean pulmonary artery pressure (PAP).

Methods: In 63 patients with suspected pulmonary hypertension, BL score and VG were calculated. The VG was projected on a direction optimized for detection of right ventricular pressure overload (VG-RVPO). BL score and VG-RVPO were entered in multiple linear regression analysis and the diagnostic performance to detect PH (invasively measured mean PAP ≥ 25 mmHg) was assessed with receiver operating characteristic analysis.

Results: Both BL score and VG-RVPO correlated significantly with mean PAP (r = 0.45 and r = 0.61, respectively; $P < 0.001$). Combining BL score and VG-RVPO increased the correlation to 0.67 ($P < 0.001$). The diagnostic performance of this combination for the detection of PH was good with an area under the curve of 0.79 ($P < 0.001$).

Conclusion: Combination of the BL score and VG-RVPO allows for accurate detection of increased PAP.

Keywords: Electrocardiogram; Ventricular gradient; Pulmonary hypertension; Right ventricular pressure overload

Introduction

Pulmonary hypertension (PH) is a serious condition with an unfavorable prognosis [1]. PH causes pressure overload of the right ventricle (RV) with an increase in RV wall tension and RV hypertrophy and dilatation [2]. Commonly, there is a delay in diagnosis of PH, partly due to the often mild and nonspecific symptoms of the disease and the absence of overt signs of RV dysfunction in the early stage of the disease. Early detection of PH is crucial in order to improve the prognosis [3–5]. Therefore, simple and widely available diagnostic tests to detect PH are needed, especially in patient groups at risk for the development of PH, such as patients with connective tissue disease or portal hypertension. The electrocardiogram (ECG) may provide such a test. However, the standard 12-lead ECG has only limited value to detect PH. The vectorcardiogram (VCG), synthesized from the standard 12-lead ECG, has been recognized as a novel and easy applicable method to detect RV pressure overload (RVPO) due to PH [6–9]. Several applications of the VCG have been described in the evaluation of RVPO in patients with PH, including the Butler Leggett (BL) [6] QRS amplitude criteria and the ventricular gradient (VG), a 3-dimensional measure of ventricular action potential duration (APD) heterogeneity [8]. Both methods were able to distinguish patients with PH from patients without. In addition, the VG was also associated with mortality in a heterogeneous group of PH patients [9]. These studies demonstrated that the VCG could be a valuable tool in the screening of patients with suspected PH.

However, it remains unknown if the combination of the ECG-derived BL score and VG would improve detection of PH. Therefore, the aims of the current study were to determine the separate diagnostic accuracies of the ECG-derived BL score and VCG-based VG for estimating mean pulmonary artery pressure (PAP), and to assess the value of

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http://dx.doi.org/10.1016/j.jelectrocard.2013.10.010

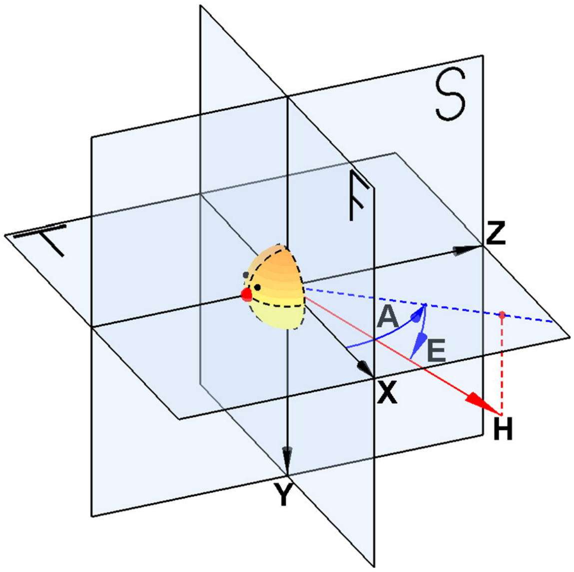

Fig. 1. AHA vectorcardiographic conventions. Pictorial representation of the vectorcardiographic conventions as published by the American Heart Association [15]. A = azimuth; E = elevation; H = heart vector; T = transverse plane; F = frontal plane; S = sagittal plane; X, Y, Z=x, y, z axes.

combining these two methods to diagnose RVPO in patients with suspected PH.

Methods

A total of 63 patients who were evaluated with right heart catheterization for suspected PH were included in the current study. According to the current recommendations, patients with mean PAP ≥ 25 mmHg were considered to have PH [10]. All patients were screened according to the institutional protocol based on the current guidelines [10] prior to right heart catheterization including a conventional 10-second 12-lead ECG and 2-dimensional transthoracic echocardiography. In addition, the underlying etiology of PH was determined according to the Dana Point classification [10]. All data for the current study were prospectively collected in the departmental Cardiology Information System (EPD-Vision®, Leiden University Medical Center, the Netherlands) and were retrospectively analyzed. Patients were included if an ECG was available within 40 days of the right heart catheterization. Exclusion criteria were the presence of atrial fibrillation, pacemaker rhythm, prior myocardial infarction, and complex congenital heart disease. Additionally, to reduce the possibility that abnormal electrical activity of the left ventricle (LV) would influence the ECG, patients with increased LV mass index (>95 g/m^2 and >115 g/m^2 for female and male patients, respectively) or increased relative wall thickness (>0.42) measured with echocardiography were excluded [11].

Standard 10-s 12-lead ECGs were recorded in the supine position and were processed with the ECG Analysis Program of the University of Glasgow [12]. All ECGs were also processed with the Leiden University interactive research-oriented MATLAB (The MathWorks, Natick, MA) program LEADS (Leiden University Medical Center, Leiden, the Netherlands) [13] that performed the VCG analysis needed for the VG calculation. The VCG was synthesized by multiplying the 8 independent ECG leads I, II and V1–V6 by the Kors ECG-to-VCG transformation matrix [14]. Fig. 1 shows the American Heart Association VCG standard [15], which we adopted for the directions of the X-, Y- and Z-axes and the spatial vector orientation (azimuth, elevation). The magnitude of the ventricular gradient is computed as the vectorial sum of its X-, Y- and Z-components (QRST integrals in the X-, Y-, and Z-leads; Fig. 2).

In the current study the projection of the VG on the X-axis (VG-X) [8,9,16] was used as the predictor variable, as well

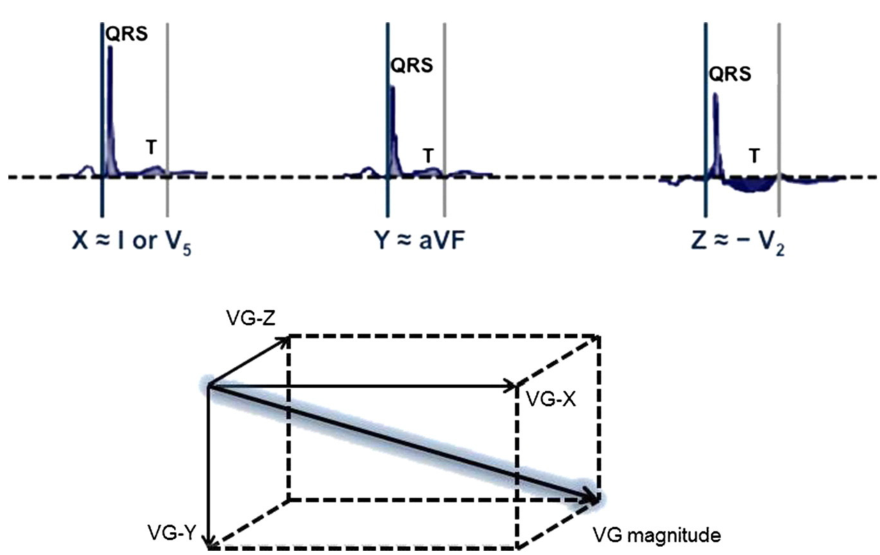

Fig. 2. Calculation of the ventricular gradient.The ventricular gradient is computed as the vectorial sum of its X-, Y- and Z-components (QRST integrals in the X-, Y-, and Z-leads). The X-component points in the positive X-direction (from left to right), the Y-component points in the positive Y-direction (craniocaudal direction). The Z-component is almost zero, due to the fact that the (negative) T-wave almost completely compensates for the positive QRS area. As it is just positive, it points in the positive Z-direction (backward). For reasons of clarity, the magnitude of the VG-Z vector in the picture is larger than its actual value.