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Original article

Phonocardiogram in adult patients with tetralogy of Fallot

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ABSTRACT

Background: Right ventricular outflow tract (RVOT) stenosis and pulmonary regurgitation (PR) are important residua and sequelae in adult tetralogy of Fallot (TOF) patients. Auscultation of the heart sound is a useful tool to detect and evaluate these lesions, but there was no previous report regarding heart sound in adult TOF.

Methods: We enrolled consecutive TOF outpatients from January 2013 to October 2013 in our adult congenital heart disease clinic. Phonocardiogram with phono-recording was performed with MES-1000 (Fukuda-Denshi Co., Tokyo, Japan), and compared heart sound with echocardiographic parameters.

Results: A total of 30 TOF patients were enrolled [age, 34.7 ± 12.8 years; 14 males (46.7%)]. In all 30 patients, phonocardiography was clearly recorded. Eighteen patients (60.0%) had the single second heart sound, which was more frequently observed before than after pulmonary valve reoperation (75.0% vs 11.1%). The single second heart sound was also associated with PR. In 18/30 (60%), diastolic murmur was associated with moderate PR ($p = 0.008$). In 14/30 (46.7%), systolic murmur was associated with moderate RVOT stenosis ($p = 0.012$).

Conclusion: Phonocardiogram was a useful tool to detect RVOT lesions. We should listen to heart sound carefully especially focusing on the second heart sound, systolic, and diastolic murmur.

Introduction

Tetralogy of Fallot (TOF) is one of the most common types of adult congenital heart diseases [1]. Recently, TOF management has led to dramatic improvements in early survival. But the management of TOF after repair is complicated due to arrhythmia, cardiac failure, sudden death, and reoperation [2]. Right ventricular outflow tract (RVOT) stenosis and pulmonary regurgitation (PR) are the most common complications in repaired TOF [3,4]. We should detect these abnormalities, but there is no consensus about how and when to detect them. Theoretically, auscultation of heart sound including second heart sound and heart murmur is clinically useful to detect these abnormalities, but there is no report about the usefulness and feasibility of these physical findings in adult patients with TOF.

We investigated whether phonocardiogram is a useful tool to detect RVOT abnormalities in adult TOF patients.

Methods

Patient selection

We enrolled all consecutive adult TOF patients at the outpatient clinic from January 2013 to October 2013 in our adult congenital heart disease clinic. We performed phono-recording and phonocardiogram in every patient.

Recording

Phonocardiogram with phono-recording was performed with MES-1000 (Fukuda-Denshi Co., Tokyo, Japan). Microphones were placed on the second left sternal border, second right sternal border, Erb area, and apex. Recording was performed in different frequency ranges with filters with nominal frequencies of 50, 100, 160, and 315 Hz. Recording was performed for 2 min in supine position with normal respiration after 5-min rest period.

Phonocardiogram analysis

Phonocardiogram was analyzed under 100 mm/s calibration. With auscultation sounds (phono-recording), we confirm that there were no significant artificial sounds. Single second heart sound is

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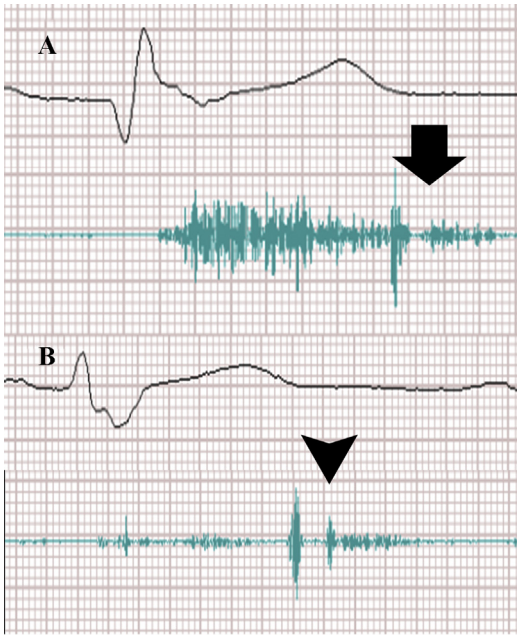

Fig. 1. Phonocardiogram at pulmonary area in 315 Hz band. (A) Patient no. 17. Systolic murmur and diastolic murmur without apparent pulmonary component of second heart sound (arrow). (B) Patient no. 16. Mild systolic and diastolic murmur with apparent pulmonary component of second heart sound (arrowhead).

defined as there is no apparent sharp pulmonary component at pulmonary area in 315 Hz band during each respiratory cycle [5] (Fig. 1). With the onset of the electrical depolarization (Q wave) as a constant point of reference, the time interval to the first component of the early systolic sound (Q-systolic time), and diastolic murmur duration was corrected for the heart rate as previously reported [6]. The third and fourth heart sounds were considered to be present whenever the characteristic low-frequency vibrations of more than 10% of the height of the second heart sound and the first heart sound, respectively, were recorded in the 50 Hz band [7].

Echocardiography

Echocardiography was performed with the patient in the left decubitus position using iE33 ultrasound system with an S5 transducer (Philips Medical Systems, Andover, MA, USA). The severity of valve disease was classified as mild, moderate, and severe according to previous reports [8,9]. Significant RVOT stenosis and PR were defined when the severity was moderate or severe.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation, and comparisons between the groups were made with Mann–Whitney *U*-test. Categorical data were compared between the groups with the χ^2 or Fisher's exact test. Box plots were used to show the median, minimum, and maximum values, and 25th to 75th percentiles of corrected diastolic murmur duration for the groups divided by pulmonary severity. Statistical significance was inferred when $p < 0.05$. All statistical testing and data analysis were performed with SPSS version 17 (SPSS Inc., Chicago, IL, USA).

Results

Patients

A total of 30 TOF patients were enrolled [age, 34.7 ± 12.8 years; 14 males (46.7%)]. We included 3 patients (10%) without intracardiac repair (ICR) and 11 patients (36.7%) were reoperated at age of 30.1 ± 12.9 years (Tables 1 and 2).

Phonocardiographic results

Eighteen patients (60.0%) had the single second heart sound. The single second heart sound was more frequent before than after reoperation of RVOT stenosis (75.0% vs 11.1%). The single second heart sound was not associated with RVOT stenosis, but with PR. QRS duration was not associated with single second heart sound (Table 3). The single second heart sound had a sensitivity of 62.5% and a specificity of 40.9% for the prediction of RVOT stenosis. For PR the sensitivity was 93.3% and the specificity was 73.3%.

Diastolic murmur was detected in 18 patients (60%). All diastolic murmurs were in early diastole and associated with PR (Table 4). Aortic regurgitation was only detected in six patients, and diastolic murmur could be heard in three patients with moderate aortic regurgitation. Diastolic murmur had a sensitivity of 86.7% and a specificity of 66.7% for the prediction of PR.

Systolic murmur was heard in 19 patients (63.3%, mid-systolic murmur, $n = 14$; pansystolic murmur, $n = 5$). Mid-systolic murmur was heard in seven of eight significant RVOT stenosis patients (87.5%). Mid-systolic murmur had a sensitivity of 87.5% and a specificity of 68.2% for the prediction of RVOT stenosis. Pansystolic murmur was heard in two of three residual ventricular septal defect (VSD) patients (66.7%), which was not statistically significant (Table 4).

There was no relationship between Q-systolic time and RVOT peak velocity by echocardiography ($r = -0.004$, $p = 0.998$) (Fig. 2A). A comparison of diastolic duration between each severity of pulmonary regurgitation showed severe pulmonary regurgitation had a tendency of shorter corrected diastolic duration (but not significant, $p = 0.423$) (Fig. 2B).

Discussion

Appropriate management of adult TOF is important. Among many late complications, residual anatomical and physiological abnormalities in RVOT are the most important. Various imaging modalities and physiologic assessments were developed and applied to repaired TOF patients, but there was no consensus about methods and optimal timing of performing these tests [4]. Auscultation and phonocardiogram were not new but inexpensive, repeatable, and less invasive objective tests. This is the first study on the usefulness of phonocardiogram in adult TOF patients.

Second heart sound

The second heart sound usually consists of aortic and pulmonary components. We can hear physiologically split second heart sound in normal healthy patients. In unrepaired TOF children, the second heart sound was always single due to dysplastic and/or stenotic pulmonary valve and relatively anterior aorta [5]. Pulmonary component could be audible in about 30% of unrepaired adult TOF patients [10]. In patients with repaired TOF with moderate-to-severe PR there might be a single second heart sound, but there were no previous reports on the clinical implication of single second heart sound in adult patients with repaired TOF [11,12]. In adult patients with repaired TOF, PR gradually increased due to deterioration of pulmonary valve function [13]. In our study, the single second heart sound was associated with severe PR, which helps understanding the pathophysiological cause of PR. The pulmonary valve dysfunction due to early calcification of handmade pulmonary valve during childhood might induce loss of pulmonary valve component of the second heart sound. After reoperation of RVOT with artificial