Electronic stethoscope for early screening of congenital heart disease.

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Abstract

Background: Prevalence of congenital heart disease is measured universally by means of colour doppler echocardiography method. We still depend on stethoscope based cardiac murmur auscultation method for screening purpose. Using electronic stethoscope could be the potential to eliminate waiting time, travel and reduce cost associated with the assessment of cardiac murmurs in children. **Objective:** This study was aimed to evaluate its clinical correlation. **Methods:** This was a cross sectional study performed in the Department of Paediatric Cardiology, National Institute of Cardiovascular Diseases (NICVD) during the period July 2018 to December 2018. Following standard protocol of the Department of Paediatric Cardiology, NICVD, using electronic stethoscope auscultation done by paediatric cardiologist and heart sounds recorded for analysis. Echocardiography was also performed by paediatric cardiologist and diagnosis was compared with the analysis of heart sounds recorded by electronic stethoscope. **Results:** Out of 60 participants, normal heart sound was found in 17(28%) case and innocent murmur was found in 7 (12%) case. The pathological heart sound and murmur found in 36 participants. **Conclusion:** Electronic stethoscope may record and transmit heart sound efficiently for analysis and diagnosis of innocent or pathological murmur. It may also help to diagnose congenital heart disease (CHD). It has the potential for saving time and reducing inconvenience and cost which may incur if the patients are referred to a paediatric cardiologist without any judgment.

Key Words: Electronic Wireless Stethoscope, Congenital Heart Disease, murmur.

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Introduction

Congenital heart disease (CHD) is the most common cause of major congenital anomalies, representing a major global health problem. Twenty eight percent of all major congenital anomalies consist of heart defect[1]. Despite remarkable progress in clinical care for affected individuals, CHD remains the leading cause of infant mortality among birth defects[2]. Those who survive infancy, there is a high rate of comorbidities, both cardiac and extra cardiac, and expected lifespan is still limited[3].

UK database suggests around 1 in 4 cases of congenital heart disease in Great Britain are diagnosed later in childhood and net incidence in the UK is 6.9/1000 live birth. Most cases of CHD die in early infancy and some conditions do not manifest in the first few years of life, this emphasizing the need to establish diagnosis by any means[5]. People in the remote area suffer extremely due to lack of paediatric cardiologist and effective means. Some study suggested that a majority of CHD in children may remain undetected unless specific efforts are made

to diagnose them[2,3].

Evaluation of a heart murmur represents one of the most common reasons for referral to a paediatric cardiologist[4]. Studies have shown that following clinical examination by a paediatric cardiologist, the diagnosis of a murmur as innocent or pathological, is correct with a specificity of 95% and a sensitivity of 96%[5,6]. Further procedures, such as chest radiography, electrocardiography and echocardiography, are thus unlikely to alter a clinical diagnosis of an innocent murmur made by a paediatric cardiologist, based on auscultation[7]. Parents and referring physicians often expect a number of investigations to alleviate their concern, or to confirm or refute their suspicions[4,8,9]. Expensive investigations are therefore sometimes performed without any evident medical reason[10,11].

Canadian survey found that 96% of the children referred to tertiary hospitals had an innocent murmur and most cases diagnosed by clinical examination only[12].

Using electronic stethoscope could be the potential to eliminate waiting time, travel and reduce cost associated with the assessment of cardiac murmurs in children, specially with innocent murmurs. This study was aimed to evaluate its clinical correlation.

Methods

This was a cross sectional study performed in the Department of Paediatric Cardiology, National Institute of Cardiovascular Diseases (NICVD) during the period July 2018 to December 2018. Irrespective of sex, 60 patients from 01 month to 15 yrs of age were included. The attending parent or guardian of every participating child was informed of the purpose and procedure of the study and informed consent was taken in the prescribed format. For each child, detailed history was taken from the child/attendant, clinical examinations done and findings recorded in the prescribed data sheet.

Following standard protocol of the Department of Paediatric Cardiology, NICVD, without using any sedative, using the locally built electronic stethoscope (by research partner from the Department of Computer Science and Engineering, North Western University, Bangladesh) auscultation done by paediatric cardiologist and heart sounds recorded for analysis. Echocardiography using 'GE Vivid – S60' Cardiovascular Ultrasound System (echocardiography machine) was also performed by paediatric cardiologist and diagnosis was compared with the analysis of heart sounds recorded by electronic stethoscope. For every patient, heart sounds were recorded over the listening areas: aortic area (2nd right intercostal space), pulmonic area (2nd Lleft intercostal space), Tricuspid area (4th left intercostal space) and the mitral area (apex). For every participant phonocardiogram (PCG) was analysed.

Technologically, every heart sound recording and analysis was done in six steps. At first heart sound of children was recorded using electronic stethoscope. Then it was preprocessed for analysis by preprocessing steps. That preprocessed data

was de-noised. After de-noising, that data was processed using Mel-frequency Cepstral Coefficients (MFCCs- an algorhythm for sound processing Audio digital signal) signal processing algorithm. Then feature is extracted from proceeding data. Finally, SVM classification technique is applied to the extracted data to classify heart sound.

Heart sound recording and analysis

Heart sound recording done as shown in Fig 1.

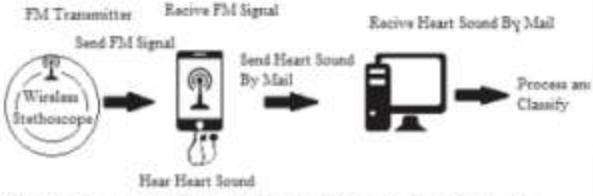

Figure 1. Flowchart of heart sound recording

At first, heart sound recorded using the electronic stethoscope (Fig 2a, 2b & 3). That device amplified the heart sound and transmitted the sound using the device's FM transmitter. Then a smartphone was used to record the heart sound by receiving the sound through FM module. Finally, recorded sound was sent to a PC and analysed.

Electronic Stethoscope

The electronic stethoscope was locally built by the research partners from the Department of Computer Science and Engineering, North Western University, Bangladesh. To build electronic stethoscope, with the chest piece of standard clinical stethoscope, along with the required hardware, Condenser microphone, Microphone amplifier (MAX4466), FM transmitter were used. After assembling the portions, the prototype of the electronic stethoscope was like Fig. 2a & 2b.

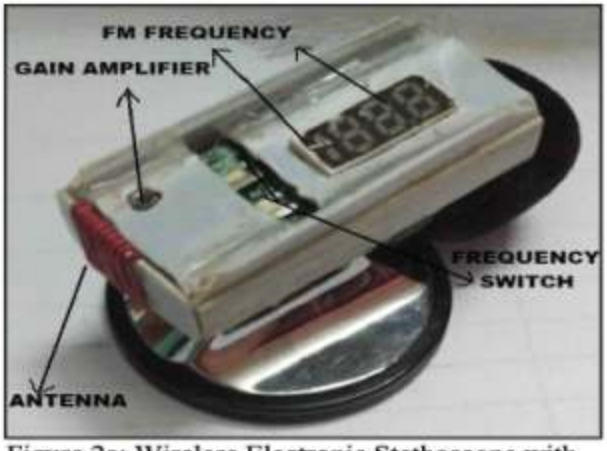

Figure 2a: Wireless Electronic Stethoscope with different parts

Figure 2b: Wireless Electronic Stethoscope with different parts

Figure 3: Photograph of doctors recording heart sound

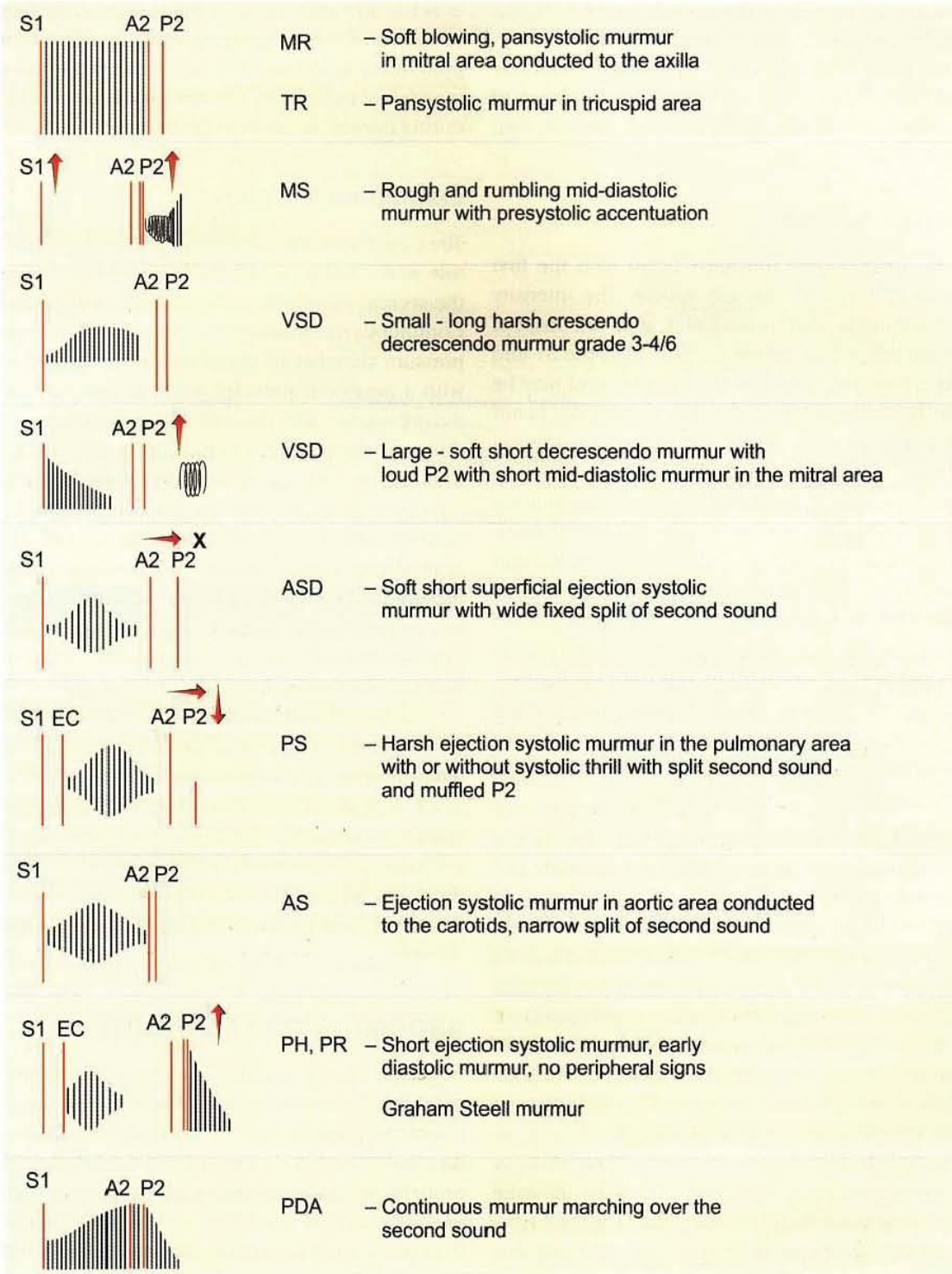

Figure 4: Schematic diagrams (PCG, phonocardiogram) of various murmurs in different congenital heart disease[16]. (A2, aortic component of second heart sound; AS, aortic stenosis; ASD, atrial septal defect; EC, ejection click; MR, mitral regurgitation; MS, mitral stenosis; P2, pulmonary component of second heart sound; PDA, patent ductus arteriosus; PH, pulmonary hypertension; PR, pulmonary regurgitation; PS, pulmonary stenosis; S1, first heart sound; TR, tricuspid refurgitation; VSD, ventricular septal defect).

Results

Out of 60 participants, normal heart sound was found in 17(28%) case and innocent murmur was found in 7 (12%) case. The pathological heart sound and murmur found in 36 participants and diagnosed as shown in the Figure 5. Nature of all murmurs and heart sound recorded in electronic stethoscope were same as found in traditional stethoscope and Echo.

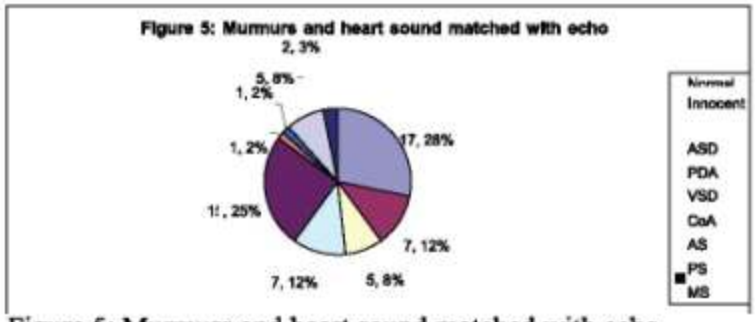

Figure 5: Murmurs and heart sound matched with echo

DISCUSSION

The present study shows that this electronic stethoscope allows digitalised heart sounds to be e-mailed easily, with maintained sound quality. It further indicates that telemedicine is a safe and convenient method for referral of heart murmurs in children for evaluation by paediatric cardiologists[12].

In our study the prevalence of cases with pathological heart sounds was 60%. This is a higher prevalence than what most referral hospitals experience. There is no true prevalence of pathology among the referrals, as this may vary as a function of referring doctors' profiles of referrals.

In a prospective series of 161 patients, with innocent or pathological heart murmurs being clinically examined by paediatric cardiologists, Smythe et al. showed that the clinical examination alone has a sensitivity of 96% and a specificity of 95%[5]. Rajakumar and coworkers reported a clinical evaluation of 128 heart murmurs by paediatric cardiologists and general paediatricians[17]. They found no difference in sensitivity between the two groups (85% *v* 79%, p = 0.53). Paediatric cardiologists, however, had a higher specificity than the general paediatricians (76% *v* 55%, p = 0.001). In a study of the accuracy of clinical assessment of heart murmurs by general paediatricians, the mean sensitivity and specificity were 82% and 72%, respectively[18]. Dahl LB et al concluded that referring the heart sounds with a brief clinical history as e-mail attachments is a safe and accurate method of assessing children presenting with heart murmurs at their primary care doctor[12]. Our observation is similar.

The main difference for the cardiologist, between a real clinical versus a recorded heart sound or murmur consultation, is the fact that in the latter, the cardiologist has to rely on the sounds selected and recorded by somebody else, perhaps with far less experience. This is the weak point in any "store and forward" electronic referral system. In spite of this, the accuracy of the method was very good in our study.

The present study indicates that electronic stethoscope may record and transmit heart sound efficiently for analysis and diagnosis of innocent or pathological murmur. It may also help to diagnose congenital heart disease (CHD). It has the potential for saving time and reducing inconvenience and cost which may incur if the patients are referred to a paediatric cardiologist without any judgment.

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