

The importance of electrocardiographic findings in the diagnosis of atrial septal defect

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Abstract

Background: Atrial septal defect (ASD) is the most frequent heart defect observed in adulthood. Although it is usually non-symptomatic, it may result in heart failure, arrhythmic complications, and paradoxical embolism-related morbidity or mortality if the diagnosis is late.

Aim: This study was planned in order to investigate the importance of electrocardiographic findings in the diagnosis of ASD.

Methods: Sixty-one patients with a diagnosis of ASD and 66 healthy volunteers without cardiac disease were enrolled in the study. Electrocardiographs (ECG) were performed on all patients to investigate the presence of right bundle branch block (RBBB), incomplete RBBB, defective T wave (DTW), and notch finding in the R wave of inferior derivations (crochetage R wave). ASD types and diameters were determined via transthoracic and transoesophageal echocardiography.

Results: It was determined that incomplete RBBB (56% vs. 5%), DTW (48% vs. 3%), and R wave crochetage (57% vs. 8%) in inferior derivations were more frequent in ASD patients compared to the control group patients. The specificity of the defined ECG findings in the diagnosis of ASD were 95%, 97%, and 92%, respectively. No correlation was detected between the ASD diameter and incomplete RBBB, whereas significant correlation was observed between the ASD diameter and the presence of crochetage R wave (17.5 ± 4.0 mm in patients with crochetage R wave, and 20.9 ± 8.2 mm in patients without crochetage R wave, $p = 0.057$).

Conclusions: Detection of RBBB, DTW, and crochetage R wave in superficial ECG may contribute to early detection in patients with ASD.

Key words: atrial septal defect, electrocardiography, defective T wave, crochetage R wave

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INTRODUCTION

Atrial septal defect (ASD) is the most frequent heart defect in adults [1]. The detection of ASD in patients before thromboembolic and haemodynamic outcomes arise is important. Studies report more frequent incomplete right bundle branch block (RBBB) and crochetage R wave presence in inferior derivations in patients with ASD [2, 3]. However, the frequent presence of incomplete RBBB in the general population is a limiting factor for its diagnostic value. It has been reported in a recent study that co-existence of incomplete RBBB and defective T wave (DTW) has 87.1% sensitivity and 100% specificity for the diagnosis of ASD [4]. The aim of our study was to

investigate the diagnostic value of these electrocardiography (ECG) findings, which were reportedly related to ASD, and to examine the correlation with ASD diameter.

METHODS

Our study included 61 patients diagnosed with ASD between 2010 and 2013 and referred to our hospital for percutaneous or surgical closure, and 66 healthy individuals without cardiac disease. Patients with hypertension, diabetes mellitus, coronary artery disease, and congenital heart diseases, with the exception of ASD, were excluded. The presence of RBBB, incomplete RBBB, DTW, and crochetage R wave finding in

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Figure 1. Crochetage R wave in inferior leads

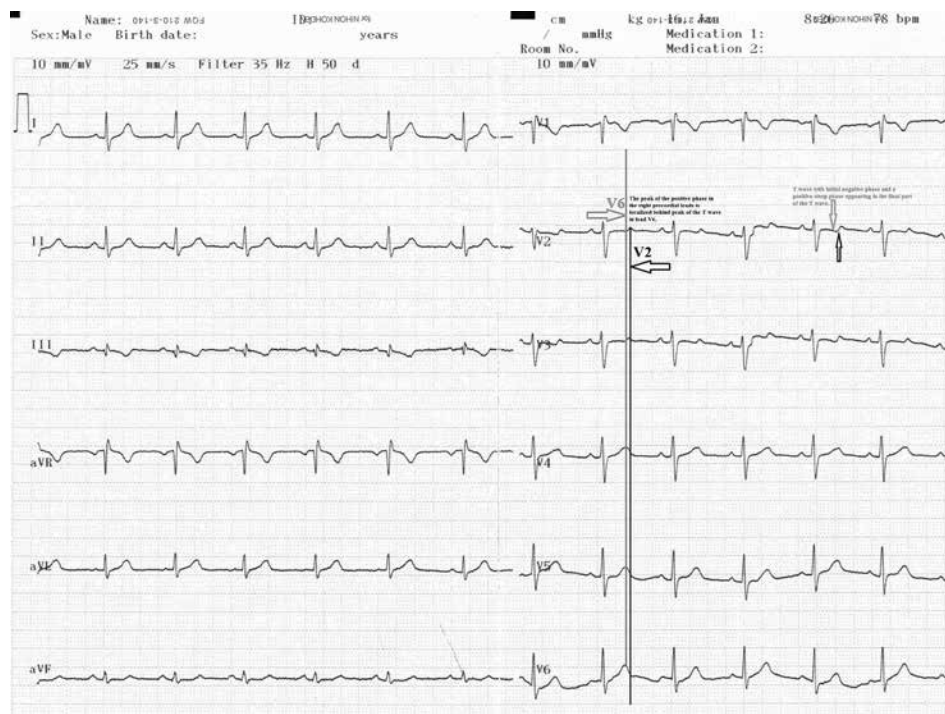


Figure 2. Defective T wave in V₂–V₆ leads

the R wave of inferior derivations (notch) were investigated using superficial ECG with 12 derivations (filtering interval: 0.15–100 Hz, AC filtering 60 Hz, 25 mm/s, and 10 mm/mV) by two separate cardiologists who were unaware of the

transthoracic echocardiography (TTE) results. The criteria of Wang et al. [4] were used for the diagnosis of DTW, and the criteria of Heller et al. [5] were used for the diagnosis of crochetage R wave presence in the inferior derivations (Figs. 1, 2).

Table 1. Demographic characteristics of patients

Variables	All (n = 127)	ASD- (n = 66)	ASD+ (n = 61)	P
Age [years]	33 ± 9	33 ± 9	33 ± 10	0.832
Male gender	40 (32%)	24 (36%)	16 (26%)	0.219
Ejection fraction [%]	64 (60–65)	62 (60–65)	65 (60–65)	0.319
RV [mm]	34 ± 9	28 ± 4	40 ± 9	< 0.001
LA [mm]	34 (32–37)	35 (32–38)	33 (32–37)	0.070
RA [mm]	48 (43–60)	44 (42–46)	60 (58–64)	< 0.001
LVEDD [mm]	43 (42–46)	45 (42–48)	43 (42–45)	0.017
LVESD [mm]	25 (23–28)	25 (23–28)	25 (23–29)	0.189

LA — left atrium; LVEDD — left ventricular end-diastolic diameter; LVESD — left ventricular end-systolic diameter; RA — right atrium; RV — right ventricle (which show a normal distribution mean ± standard deviation, and does not show a normal distribution median [25th vs. 75th percentile])

TTE and transoesophageal echocardiographic (TEE) examination were performed on all patients. ASD type and diameters were determined. The incidence of defined ECG findings in patients with ASD, and the correlation to the maximum measured diameter were investigated.

Statistical analysis

Data were analysed with SPSS software version 15.0 for Windows (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequency and percentage. The χ^2 test and Fisher's exact test were used to compare categorical variables. The Kolmogorov-Smirnov test was used to assess the distribution of continuous variables. Student's *t*-test was used for variables with normal distribution, and the values were presented as mean ± standard deviation. Continuous variables without normal distribution were analysed using Mann-Whitney U test, and the obtained values were presented as median (50th) values and interquartile ranges (25th and 75th). Correlation was investigated between two shunt values using Pearson's correlation analysis. Logistic regression analysis was used to evaluate the independent associates of the risk of ASD. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of ECG parameters were calculated. The odds ratios (OR) and 95% confidence intervals (CI) were calculated. A two-tailed *p*-value < 0.05 was considered statistically significant.

RESULTS

The demographic characteristics of the participants are shown in Table 1. Among those with ASD diagnosis, 95% had secundum, 1% had primum, and 2% had sinus venosus type ASD. It was observed that the right atrial and ventricular sizes of patients with ASD were wider than normal individuals, and the systolic pulmonary artery pressure measured over tricuspid insufficiency jet was higher. No difference was detected between groups regarding the left cardiac ventricles or the ejection fraction of the left ventricle (Table 1). The mean maximal defect diameter measured by TEE was 19.5 ± 6.9 mm among patients. The echocardiographically measured mean

Table 2. The relationship between the presence of atrial septal defect and electrocardiographic findings in logistic regression analysis

Variables	Odds ratio	95% CI	P
Defective T wave	29	7–129	< 0.001
Incomplete RBBB	26	7–94	< 0.001
Crochetage R wave	16	6–47	< 0.001
RBBB	2.3	0.7–8.2	0.184

CI — confidence interval; RBBB — right bundle branch block

Qp/Qs rate among patients with ASD was 2.1 (1.8–2.7). The treatment was percutaneous in 72%, surgical in 25%, and medical in 3% of the patients.

All participants had sinus rhythm. It was determined that the incomplete RBBB (56% vs. 5%), DTW (48% vs. 3%), and crochetage R wave in inferior derivations (57% vs. 8%) were more frequent among ASD patients compared to the control group patients. No significant difference was detected between groups regarding RBBB presence (13% vs. 6%). The specificity of the defined ECG findings in the diagnosis of ASD was 95%, 97%, and 92%, respectively.

Logistic regression analysis revealed significant correlation between ASD and the presence of DTW (OR 29; 95% CI 7–129, *p* < 0.001), incomplete RBBB (OR 26; 95% CI 7–94, *p* < 0.001), and crochetage R wave in inferior derivations (OR 16; 95% CI 6–47, *p* < 0.001) (Table 2). The sensitivity, specificity, PPV, and NPV of the ECG findings in the diagnosis of ASD are shown in Table 3. It was determined in our study that co-existence of DTW and incomplete RBBB had 100% specificity for the diagnosis of ASD.

No correlation was detected between ASD diameter and the presence of DTW or incomplete RBBB. Significant correlation was detected between ASD diameter and the presence of crochetage R wave in inferior derivations (17.5 ± 4.0 mm in patients with crochetage R wave, 20.9 ± 8.2 mm in patients without crochetage R wave, *p* = 0.057).

Table 3. Diagnostic test characteristics of defective T wave (DTW), incomplete right bundle branch block (RBBB), and crochetaje R wave in inferior limb leads in diagnosing atrial septal defect

	Sensitivity	Specificity	PPV	NPV
DTW	48%	97%	94%	67%
Incomplete RBBB	56%	95%	92%	70%
Crochetage R	57%	92%	88%	70%
DTW + incomplete RBBB	36%	100%	100%	63%

NPV — negative predictive value; PPV — positive predictive value

Statistically significant differences were detected in terms of Crochetage R wave presence for maximum ASD diameters between 1 and 1.25 cm and > 2.5 cm measured by TEE (47.9% vs. 90.9%, $p = 0.01$, respectively). There were no significant differences in terms of DTW, incomplete RBBB, and complete RBBB.

The averages of maximum ASD diameters measured by TEE, in patients who underwent percutaneous closure, was 18.2 ± 4.8 mm, 25.5 ± 7.1 mm were detected in those with surgical treatment ($p < 0.001$). In the case of patients who underwent percutaneous closure and surgery, there were no significant differences in terms of ECG findings.

DISCUSSION

The sensitivity and specificity of incomplete RBBB, defective T wave, and crochetaje R wave presence in at least one of the inferior leads among the ECG findings reported to be related to ASD in this study, were 56%, 48%, 57% and 95%, 97%, and 92%, respectively. Furthermore, the presence of crochetaje wave in inferior leads was found to be related to ASD diameter.

ASD patients may either be asymptomatic or may appear with non-specific symptoms such as arrhythmia, fatigue, or exercise intolerance. Many authors believe that ASD should be diagnosed and treated before adulthood due to potential complications [6, 7]. Therefore, several ECG findings have currently been defined for early diagnosis of the disease.

ECG may be normal in young and uncomplicated patients with ASD. However, the classical findings of significant ASD are prolonged PR interval, QRS time, and the presence of incomplete RBBB [8]. ECG findings may change according to the type of ASD. Ostium secundum ASDs are the most frequent and are related to right axis deviation and incomplete RBBB. Sinus venosus ASDs may show ectopic atrial pacemaker. Inverted P waves in the inferior leads suggest an absent or deficient sinus node, as may be seen in a sinus venosus defect [9, 10]. Ostium primum ASDs may show left axis deviation and transmission delay to the atrioventricular node [11]. Right ventricular hypertrophy findings may be observed with the development of pulmonary hypertension. Usually, sinus rhythm is observed in patients; however, atrial arrhythmias such as AF or supraventricular tachycardia may

be observed in the 3rd or 4th decades of life [12, 13]. In our study, all patients showed sinus rhythm; this may be because the mean age of our patient group was young.

The QRS complex is often slightly prolonged and has a characteristic rSr' or rsR' patterns that is thought to result from disproportionate thickening of the right ventricular outflow tract, which is the last portion of the ventricle to depolarise. This pattern is often described as incomplete RBBB. In an electrophysiology study by Sung et al. [2], no significant difference was observed in the H-RVA intervals between patients with ASD and healthy individuals. In this study, it was claimed that the rsR' or rSr' patterns observed in patients with ASD were related to a right ventricle overload rather than a real transmission delay. A difference was reported in the incomplete RBBB pattern between patients with ASD and healthy individuals. In the general population, sharp and narrow $r' < 5$ mV is detected with a 2.4% incidence. However, broader and somewhat slurred r' is observed in patients with ASD [14]. In a study including children with ASD, RSR' pattern in V₁ was reported to have 36.1% sensitivity, 80% specificity, 14.7% PPV, and 92.9% NPV for the diagnosis of ASD, which showed that it was a poor test for the detection of ASD [15]. In another study, incomplete RBBB was reported to be more frequent in older children and adult patients with ASD [16].

Another ECG finding that is reportedly related to ASD is the presence of an R wave with a notch close to the apex in inferior derivations (crochetaje R wave). In a study by Heller et al. [5], the ECG findings of 532 patients with ASD were compared to the those of healthy individuals in the control group, and since the crochetaje R wave was present in only one of the inferior limb leads, the sensitivity and specificity for the diagnosis of ASD was reported to be 73.1% and 92.6%, respectively. It was also reported that when it was present in three leads, the specificity reached 100%. This finding was reported to be correlated to the size of the defect and the amount of the shunt, which disappeared despite the presence of incomplete RBBB post-operatively [5]. In a recent study, it was reported that patent foramen ovale (PFO) is more frequent in patients who have a crochetaje R wave in the inferior limb leads, among patients with cryptogenic stroke (36% vs. 9%). It was reported in the same study that larger infarctions were observed in the brains of patients with

crochetage R wave than in those without crochetage R wave, among patients with PFO [17]. In our study, crochetage R wave presence was investigated in inferior limb leads and was found to have 57% sensitivity and 92% specificity for the diagnosis of ASD. We observed that the defect size was larger in patients with crochetage R wave compared to those without crochetage R wave, among patients with ASD. No correlation was detected between incomplete RBBB or defective T wave and ASD diameter.

Ava et al. [18] reported 'dart T wave' presence defined as 'double peaked T wave with a prominent second summit' in right precordial leads among children with ASD. In a recent study by Wang et al. [4], the ECGs of 132 patients with ASD were investigated, and co-existence of incomplete RBBB and defective T wave was reported to have 100% specificity and 87.1% sensitivity for the diagnosis of ASD. In the same study, the defective T wave was defined as 'horizontal or inverted displacement of the proximal T wave limb in the right precordial leads'. It was also reported that defective T wave presence, independent of incomplete RBBB, had 87.1% sensitivity and 97.0% specificity for the diagnosis of ASD. In our study, the presence of DTW was found to have 48% sensitivity and 97% specificity for the diagnosis of ASD. Furthermore, co-existence of incomplete RBBB and DTW was found to have 100% specificity for the diagnosis of ASD.

Limitations of the study

In our study, the presence of the ECG findings such as complete RBBB, incomplete RBBB, crochetage R wave, and defective T wave values at diagnosis were investigated, all of which have been reported to be associated with ASD in previous research. Comparatively few sensitive parameters, such as expanded P wave, have been evaluated. In addition, the study population was reported smaller, the effect of defined ECG findings, could not be evaluated for the prognosis.

CONCLUSIONS

Since disease prognosis is good with early diagnosis and treatment of ASD, ASD detection in patients before the development of complications is important. Therefore, a careful examination of ECG findings may give important clues for the diagnosis of ASD.

Conflict of interest: none declared

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Znaczenie wyników elektrokardiografii w diagnozowaniu ubytku przegrody międzyprzedsionkowej

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Streszczenie

Wstęp: Ubytek przegrody międzyprzedsionkowej (ASD) jest najczęstszą wadą serca występującą u osób dorosłych. Zwykle nie powoduje ona objawów, lecz jeśli nie zostanie wcześniej rozpoznana, może być przyczyną niewydolności serca, zaburzeń rytmu i zatorów paradoksalnych oraz związanych z tym śmiertelności i chorobowości.

Cel: Celem pracy była ocena znaczenia parametrów elektrokardiograficznych (EKG) w diagnozowaniu ASD.

Metody: Do badania włączono 61 chorych z ASD i 66 osób zdrowych (bez chorób serca). U wszystkich pacjentów wykonano badanie EKG w celu sprawdzenia, czy występują: blok prawej odnogi pęczka Hisa (RBBB), niepełny RBBB, nieprawidłowy załamek T (DTW) i wcięcia w załamku R w odprowadzeniach II, III i aVF (zazębiony załamek R). Typy i wymiary ASD określono za pomocą echokardiografii przezklatkowej i przezprzełykowej.

Wyniki: Ustalono, że niepełny RBBB (56% vs. 5%), DTW (48% vs. 3%) i zazębiony załamek R (57% vs. 8%) w odprowadzeniach II, III i aVF występowały częściej u chorych z ASD niż u osób z grupy kontrolnej. Swoistość określonych cech w EKG w stosunku do rozpoznania ASD wynosiła odpowiednio 95%, 97% i 92%. Nie wykazano żadnych korelacji między średnicą ASD a niepełnym RBBB, stwierdzono natomiast istotne zależności między średnicą ASD a obecnością zazębianego załamka R ($17,5 \pm 4,0$ mm u chorych z zazębianym załamkiem R i $20,9 \pm 8,2$ mm u pacjentów bez zazębiania załamka R; $p = 0,057$).

Wnioski: Stwierdzenie RBBB, DTW i zazębianego załamka R w zapisie powierzchniowego EKG może się przyczynić do wczesnego wykrycia ASD.

Słowa kluczowe: ubytek przegrody międzyprzedsionkowej, elektrokardiografia, nieprawidłowy załamek T, zazębiony załamek R

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