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Impact of right ventricular size on ECG after percutaneous closure of atrial septal defect with Amplatzer Septal Occluder

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Summary

Objectives: To assess ECG changes after percutaneous atrial septal defect (ASD) closure in children with significant left-to-right shunt.

Methods: Analysis of data of 36 consecutive children with an ASD who had successful percutaneous ASD closure with an Amplatzer Septal Occluder. Assessment comprised echocardiography and ECG the day before and after the procedure and at 1, 6 and 12 months follow-up.

Results: The median age (interquartile range) of children was 7.3 (5.3) years. On the day after the procedure the end diastolic diameter of the right ventricle showed already a diminution (34 (12) mm/m^2 before intervention vs. 32 (12) mm/m^2). ECG changes were first observed at 1 month follow-up (PR interval before intervention 139 (20) ms vs. 132 (20) ms; QRS duration 88 (18) ms vs. 82 (19) ms) and at 6 months follow-up (QRS axis 77° (33) before intervention vs. 72° (53)). With the exception of the QRS duration, ECG intervals and axis were in a normal range in all patients before the procedure. Median QRS duration normalised at 1 year follow-up (83 (8) ms).

Conclusion: After transcatheter ASD closure, decrease in right ventricular size began rapidly and was followed by reduction of the QRS duration and PR interval within weeks. Shifting to the left of the QRS axis was observed within 6 months follow-up. This study showed that ECG changes due to right ventricular volume overload can regress and normalise after percutaneous ASD closure in children.

Key words: Amplatzer Septal Occluder; ECG changes; atrial septal defect; ASD closure

Introduction

Atrial septal defects (ASD) account for 10% of all congenital heart defects [1]. Haemodynamic consequences of an ASD are dilatation of the right atrium and right ventricle (RV) because of the volume overload due to the left-to-right shunt through the ASD. Classical ECG findings for a significant ASD are prolongation of the PR interval, prolongation of the QRS duration and right axis deviation of the QRS [2]. If not closed such an ASD can be associated, in adult patients, with complications such as congestive heart failure, atrial arrhythmias, impaired aerobic capacity and pulmonary hypertension [3, 4]. Therefore, many authors suggest ASD closure before adulthood [5, 6]. Percutaneous and surgical ASD closure have been proven to be safe and efficient in abolishing the left-to-right shunt [6–8], thus preventing progression of right heart dilatation and consecutive RV dysfunction. Percutaneous ASD closure has the advantage of reducing the length of hospital stay, of avoiding surgical incisions on the heart and cardiopulmonary bypass. It is less invasive and has been proven to be as effective and safe as surgery with less morbidity [9–13]. All these benefits are associated with social and economical advantages [12–14].

Percutaneous ASD closure is an ideal situation to study changes of RV dimensions and their impact on ECG as interferences from cardiopulmonary bypass, cardiac incisions and sutures on the right atrium and on the interatrial septum are excluded. The focus of this study was to describe electrocardiography (ECG) changes after ASD device closure in a paediatric population and to delineate that with the abolition of the right heart chambers overload the PR interval and the QRS duration may shortened.

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Methods

Between January 2000 and July 2002, 36 consecutive children underwent secundum ASD device closure with an Amplatzer Septal Occluder (AGA Medical, Golden Valley, Minnesota) at our institution. All patients underwent 2-D and Doppler echocardiography (Sonos 5000, Philips Netherlands) and 12 leads ECG (Marquette MacVu 7, Marquette USA) the day before and the day after the procedure. Clinical, echocardiography and ECG follow-up were obtained at 1, 6 and 12 months respectively. ECG registration was standardised (speed: 25 mm/s, voltage: 10 mm/mV) and have been performed by two technicians. A single investigator made all the echocardiographic measurements and the retrieval of computerized ECG measurements.

ECG and echocardiography data were reviewed and analysed retrospectively. A four-chamber view was obtained to measure the maximal right and left ventricular inlet diameter at end diastole, the measure was then normalised with the body surface area. The measurements were made at the tip of the atrio-ventricular valve (figure 1) as described and used for evaluation of the RV dimension by others authors [15–17]. Residual shunts were defined as present or absent and then classified as none, small (<1 mm), medium (1–2 mm) or large (>2 mm). Off-line measurements were performed using the same ultrasound machine. Twelve-lead surface ECGs were obtained and computerized values controlled for the mean frontal plane P, QRS and T axis. The duration of the interval PR in lead II (measured from the initial deflection of the P wave to the initial deflection of the QRS complex), the width of the QRS duration (measured from the initial deflection of the QRS complex to where the terminal deflection crosses the baseline, taken in any chest lead where the deflection was acute enough to permit accurate determination) were also controlled and the QTc duration calculated using Bazzett's formula. The ECG normal values were retrieved from the Davignon et al., publication [18], where data from 2400 infants, children and adolescents were obtained. The echocardiographic normal values were retrieved from other previous publications cumulating data of 160 normal children and adolescents [15–16].

The Amplatzer Septal Occluder was used in all children. Device details and implantation procedure have been previously described elsewhere [7, 19].

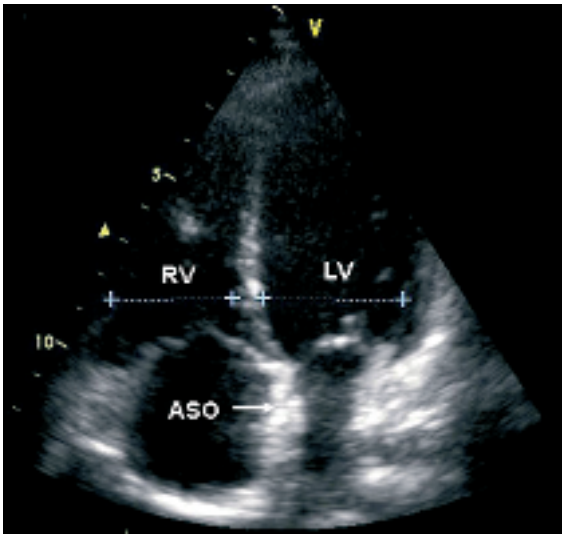

Figure 1

Echocardiography after atrial septal defect closure with an Amplatzer Septal Occluder (ASO): a four-chamber is obtained to measure the maximal right (RV) and left ventricular (LV) inlet diameter at end diastole. The measurements were made at the tip of the atrio-ventricular valve.

Statistical analysis

Data are presented as median value (interquartile range [IQR]) in the text and box plot with median and IQR in figures for normally distributed data obtained before the procedure and at 1 day, and 1, 6 and 12 months after the procedure. Variables obtained from echocardiography and ECGs at each follow-up period were compared with pre-procedural values; categorical data are presented as a proportion of the total number of patients who had data available during the follow-up period. The descriptive statistics were obtained using Statview® 5.0 (SAS Institute Inc.)

Results

Thirty-seven devices were successfully implanted in 36 children without complication. Their ages ranged from 15 months to 15 years (7.3 [5.3]). The Amplatzer Septal Occluder size ranged from 8 to 26 mm in diameter (mean 16 mm). The mean pulmonary pressure was normal in all patients. The median left-to-right shunt was 1.8:1 (range 1.6–3.0:1). Data analysis was complete in all patients at day one, in 36 patients at 1 month, in 28 patients (drop-out 22%) at 6 months and in 20 patients (drop-out 44%) at 1 year follow-up. If median age and median left-to-right shunt at 6 months and one year follow-up are compared with the median value of the whole group before intervention, there are some changes: 7.3 (5.3) years vs. 8.2 (6.6) years and 8.8 (6.2) years respectively, median left-to-right shunt was 1.8:1 (0.7) vs. 2.0:1 (0.8) and 2.1:1 (0.5) respectively.

A residual shunt was detected in 12 patients (12/36) by transoesophageal echocardiography immediately after Amplatzer Septal Occluder placement. At follow-up transthoracic echocardiography revealed a small residual shunt in only 3 patients (3/36) after 1 month, in 2 patients (2/28) after 6 months, and in 1 patient (1/20) after one year. The residual shunt was graded as haemodynamically non significant in every patient.

Echocardiography showed that end diastolic four-chamber RV size had already decreased the day after the intervention. Before the intervention the median RV size was 34 (12) mm/m^2, it had decreased to 32 (12) mm/m^2 the day after; and it reached 30 (13) mm/m^2 at one year (figure 2a). The median four-chamber ratio RV size to LV size was 0.97 (0.16) before intervention vs. 0.86 (0.13) the day after the ASD closure, reaching 0.78 (0.17) at one year.

ECG analysis revealed a rapid decrease in the PR interval (139 (20) ms vs. 132 (16) ms after one month, the median PR interval reaching the value

of 130 (16) ms at one year (figure 2b). The QRS duration analysis showed a shortening at 1 month (88 (18) ms vs. 82 (19) ms) with a value at one year of 82 (8) ms (figure 2c). Two patients showed a persistent prolongation of the QRS duration after one year follow-up. They were two of the oldest patients with respectively 13.5 and 14.7 years of age, the QRS durations at one year follow-up in these two patients were respectively 103 ms and 113 ms. The median frontal plane QRS axis declined gradually from 77° (33) to 72° (38) at one month, reaching 64° (37) at 1 year (figure 2d).

Discussion

This study evaluated ECG changes after transcatheter closure of ASD using the Amplatzer Septal Occluder in children. Our point of interest was not ECG changes in term of arrhythmias, this subject having already been investigated by others [20, 21]. The scope of this study was to correlate ECG changes to the acute changes on RV volume after ASD closure. There is in the follow-up a certain number of drop-outs. All patients could be analysed at 1 day and 1 month after the intervention, but the follow-up performed for patients in others clinics did not always supply ECGs or echocardiography, thus forbidding accurate measurement. As described in the Results section the patients where the data had been obtained are older than the initial group and with a greater left-to-right shunt, this could have introduced a certain bias in selecting the patients that would probably have the major changes in their ECG and echocardiography at follow-up. On the other hand these are the patients that are interesting for the purpose of the study.

Classic ECG changes secondary to significant left-to-right shunt through an ASD with consecutive dilatation of right atrium and right ventricle are PR interval prolongation, QRS duration prolongation and right axis deviation of the QRS [15, 22]. These changes are principally noted in adult patients or in the presence of very large left-to-right shunts, and they are probably are the sub-

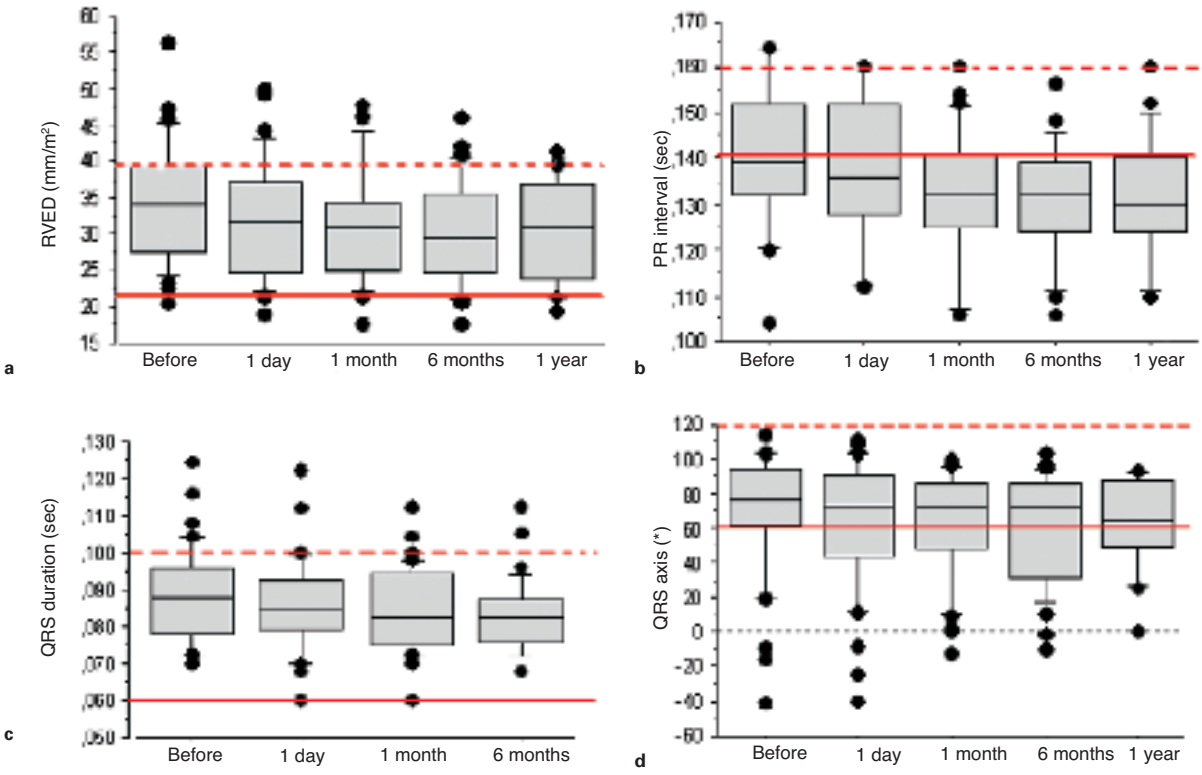

Figure 2

a. Box plot (median, IQR) demonstrating the evolution of the dimension of the end-diastolic diameter of the right ventricle indexed to the body surface area between before intervention and measures after intervention. Continuous line: mean normal value for the population, dashed line: 2SD of the normal value. Normal value retrieved from two publications [15–16] that have analysed a total of 160 normal children and adolescents.
b. Box plot (median, IQR) demonstrating the evolution of the PR interval between before intervention and measures after intervention. Continuous line: mean normal value for the population, dashed line: 2SD of the normal value. Normal value retrieved from the publication of Davignon et al., that have analysed 2400 normal infants, children and adolescents [18].
c. Box plot (median, IQR) demonstrating the evolution of the QRS duration between before intervention and measures after intervention. Continuous line: mean normal value for the population, dashed line: 2SD of the normal value. Normal value retrieved from the publication of Davignon et al., that have analysed 2400 normal infants, children and adolescents [18].
d. Box plot (median, IQR) demonstrating the evolution of the QRS axis between before intervention and measures after intervention. Continuous line: mean normal value for the population, dashed line: 2SD of the normal value. Normal value retrieved from publication of Davignon et al., that have analysed 2400 normal infants, children and adolescents [18].

strate for late arrhythmias [23]. Our data show that, in the paediatric aged group with a haemodynamically significant left-to-right shunt, preclosure ECGs are in the normal range with the exception of the median value of the QRS duration being at the upper limit of normal [18]. For the same magnitude of left-to-right shunt as in our paediatric group, the adult patients group studied by Veldtman et al., shows a clearly prolonged preclosure QRS duration [24].

Right ventricular dilatation is a cornerstone of chronic left-to-right shunt through an ASD. Many studies analyse the recovery of the RV after surgical or percutaneous ASD closure. In all the studies there is a degree of reduction of the RV size with each mode of closure [24–28]. The speed of reduction of the RV seems to be related to the age of the patient and the degree of the left-to-right shunt as demonstrated by Du et al., [27]. In our group the RV decrease was rapid and already noted at echocardiography the day after intervention, although the RV size was only estimated with the measure of the end diastolic diameter in four-chamber view. Berger et al., also demonstrated a reduction in end diastolic RV volume on echocardiogram early after device or surgical closure [25]. Du et al., showed that RV volume overload decreased dramatically within 24 hours after transcatheter closure of the ASD [27]. Interestingly, in adult groups, some ventricles with prolonged volume overload did not completely return to normal dimensions, with as much as 25–30% of patients having a persistent RV enlargement one year after ASD closure [24]. Du et al., confirm these data and conclude that the rapid change in RV size after ASD transcatheter closure is inversely related to preclosure, RV dimension and age of the patient [27].

Although RV dimension decreased rapidly after the intervention, ECG analysis showed in our paediatric population, that PR interval and QRS duration decreased in a slower way, and at the same time there was a leftward shift of the QRS axis. Reduction of these parameters was observed between 1 to 6 months after device closure. Veldtman et al., also demonstrated the same findings in their adult population [24]. At one-year follow-up the median PR interval and QRS duration were within a normal range, only two paediatric patients showed a prolonged QRS in our study. At one-year follow-up, the PR interval was in the normal range for the group of Veldtman et al., but the mean value of the QRS duration was always prolonged. These findings could probably be related to the percentage of adult patients demonstrating persistence of RV enlargement at one-year follow-up [24].

The delay between changes in the diameter of the RV and changes of the ECG, according to the knowledge acquired from animal and human studies, is probably due to the time for cardioreparation [29–31]. Volume overload induces cardiac remodelling with myocyte hypertrophy and excessive accumulation of collagen in the heart [32–35]. Abolition of the left-to-right shunt allows for a rapid decrease in the RV volume and in the echocardiographic dimension of the RV. The myocardium necessitates more time to decrease and normalise. The ECG is a measure of the electrical conduction in the heart musculature and then could reflect the time needed for normalisation of the myocardium after suppression of the left-to-right shunt.

Study limitations

Only transthoracic cross-sectional echocardiography was used for RV assessment which is known as being less accurate than magnetic resonance or three-dimensional echocardiography for this purpose [36]. For this retrospective study, the four-chamber end diastolic diameter of the RV was used to surrogate the end diastolic RV volume. As patients served as own controls we submit that a simple diameter assessment was adequate for the aim of the study.

This is a retrospective study with a small cohort of patients with variable age and a short follow-up period. The drop out rate at 6 months and particularly at 1 year follow-up is relatively high, with changes in the principal characteristics of the population (age and magnitude of left-to-right through the ASD). This selection has to be taken into consideration and may have implications in the results observed in this study as already discussed. Larger multicenter studies, addressing both adults and children may permit a more detailed assessment of RV dimension and subsequent electrophysiologic changes.

Conclusion

Nevertheless, our study showed that after ASD closure in children the rapid abolition of volume overload permits normalisation of RV size with a delayed reduction and normalisation of ECG abnormalities.

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