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Percutaneous device closure of atrial septal defect results in very early and sustained changes of right and left heart function ☆

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ABSTRACT

Objectives: To investigate the echocardiographic effects of percutaneous closure of secundum atrial septal defect (ASD) in adults and assess which pre-closure parameters predict good response to closure.
Background: ASD is a common congenital heart disease often undiscovered until adulthood. ASD closure has been revolutionized by the use of percutaneous devices. The effects of these procedures on echocardiographic parameters are not well characterized.
Methods: Patients undergoing percutaneous device closure of ASD between June 2007 and June 2009 had 3 sequential echocardiograms reviewed: pre-procedure, immediate post-procedure (24 hours) and 6–8 weeks post-procedure. Significant changes from baseline were investigated using paired *t*-test/1-way ANOVA. Pearson correlation (2-tailed) tests were used to categorize patients as 'good responders' to closure in terms of selected parameters.
Results: 129 echocardiograms in 43 consecutive patients were included. Remodeling of both ventricles occurred immediately following ASD closure and was sustained. Right ventricular (RV) diameter in diastole decreased by 13.5% and 19.3% compared to baseline at 24 hours and 6–8 weeks post-closure, respectively ($p<0.05$); Left ventricular (LV) diameter in diastole increased by 8.5% and 15.6%, respectively ($p<0.05$). Functional parameters of the RV also demonstrated early and sustained decreases (TAPSE decreased by 8.3% and 17% compared to baseline at 24 hours and 6–8 weeks post-closure, respectively ($p<0.05$)). Smaller RV baseline diameter appeared to predict good response to closure.
Conclusions: Percutaneous ASD closure has immediate, sustained benefits on multiple echocardiographic parameters. Good responders have smaller RV at baseline, suggesting early closure is preferable.

1. Introduction

Atrial septal defects (ASD) are the commonest form of congenital heart disease diagnosed in adults, accounting overall for around 10% of all congenital heart defects [1]. The diagnosis and management of ASD in both paediatric and adult populations have benefited greatly from major advances over the last 10–15 years [2], including 3 dimensional and intracardiac echocardiography, as well as percutaneous device closure. Despite these advances, ASDs remain "the most underdiagnosed congenital heart disease in the adult age group", with age at diagnosis being clearly linked to subsequent complications including the late development of pulmonary hypertension and atrial dysrhythmias [2]. While many patients with ostium secundum ASDs may be initially free from overt symptoms, many become symptomatic later in life due to chronic volume overload of the right heart. Common presenting symptoms include effort dyspnoea, fatigue, or palpitations/dysrhythmia (usually due to age-related chronic atrial stretch predisposing the patient to electrophysiological remodeling and either atrial flutter or fibrillation) [3,4]. While surgical repair has excellent results in both the medium and long terms [5], percutaneous device closure has become the preferred method in the management of the majority of secundum ASDs, obviating the need for major cardiac surgery [6,7]. The beneficial effect of this intervention on quality of life is accepted [8]. Percutaneous closures are not associated with impaired post-procedural systolic or diastolic

Abbreviations: ASD, atrial septal defect; RV, right ventricle; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion; FrAC, fractional area change of the right ventricle; TR, tricuspid regurgitation; RVOT, right ventricular outflow tract; LV, left ventricle; RA, right atrium; LA, left atrium.

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cardiac dysfunction, unlike surgical ASD closures [9]. Currently, ostium primum and sinus venosus type ASDs continue to require full cardiothoracic surgical approaches for their definitive management, as do a proportion of secundum type defects which are anatomically unsuitable for device closure [10]. In experienced hands, percutaneous ASD closure is both safe (major complication rate less than 1%), clinically effective (greater than 95% success rate) and cost effective [11–13]. It can be expected that ASD closure would lead to reduced right heart volumes due to removal of left-to-right shunting. Indeed, previous authors have demonstrated that this does occur [14–19]. Whether this improves right ventricular (RV) performance [18] or simply prevents further deterioration [20] remains controversial. In addition, the effects of ASD closure on the atria and left side of the heart are poorly characterized. We set out to study the very early effects of percutaneous ASD closure on both the right and left sides of the heart and hypothesized that early cardiac remodeling would be represented by improvement in a variety of echocardiographic parameters of right and left heart functions that have not been previously studied. We also investigated which pre-procedural echocardiographic parameters may predict improved RV function following closure of the defect.

2. Methods

Transthoracic echocardiograms of 43 consecutive patients undergoing percutaneous closure of atrial septal defect at our institution over a 2-year period spanning June 2007 to June 2009 were retrospectively studied. Procedures were performed under general anaesthesia with transoesphageal echocardiographic and fluoroscopic guidance. The Amplatzer Septal Occluder (ASO – AGA Medical Corporation, Golden Valley, Minnesota, USA) was used in all cases. For study purposes, a series of 3 transthoracic echocardiograms were reviewed per patient, all of which had been performed as part of routine clinical care:

1. Echo 1 – performed in the 2 weeks leading up to the procedure
2. Echo 2 – performed the day after the procedure
3. Echo 3 – performed 6–8 weeks following the procedure

Echocardiograms for patients with atrial septal defects were performed in a structured manner according to a defined protocol in our institution (shown in Appendix 1). All echocardiograms were performed on a GE Vivid 7 machine (GE Healthcare, Milwaukee, WI, USA). Standard parasternal, apical and subcostal echocardiographic imaging planes were acquired with the use of 2D and M-mode imaging, alongside pulsed and continuous wave Doppler. Colour tissue Doppler imaging was performed for measurement of systolic myocardial velocities at the mitral and tricuspid annuli, and frame rates were maximised prior to acquisition. Cardiac cycles were saved as digital loops and stored for later offline analysis. Analysis was performed using a GE Echopac workstation. Chamber quantification was performed according to current guidelines. Myocardial velocites were analysed using the Q-analysis feature of GE Echopac. Systolic velocities were recorded from the lateral and septal aspects of the mitral annulus, the tricuspid annulus and the mid-right ventricular free wall. Diastolic velocities were recorded from the septal and lateral aspect of the mitral annulus, and E:E' ratio calculated using both the septal and lateral values, and the mean of the two. The echocardiograms of study participants were extensively reviewed and analysed for the purposes of this research by a single member of the research team (ML) who had not been directly involved in the care of the patients. The reviewer was blinded to both the identity of the patient and also which echo it was, within the series of 3. The data generated were interpreted by calculation of means, standard errors, paired *t*-tests between Echos 1 and 2, and one-way ANOVAs, with a p-value of <0.05 being considered as statistically significant. Individual baseline parameters were investigated using a Pearson correlation (2-tailed) test to investigate whether any of them could predict a significant (1 standard deviation, 1 SD) improvement in subsequent echocardiographic parameters following ASD closure. We split patients undergoing ASD closure into good responders ($\geq$1 SD improvement) or poor responders ($<$1 SD improvement) to percutaneous ASD closure.

3. Results

A total of 43 patients were included in the trial, each of whom underwent 3 serial transthoracic echocardiograms according to the defined schedule above, giving a total of 129 echocardiograms for analysis. Demographic data of the enrolled patients is given in Table 1. Table 2 illustrates in detail the mean results from study group of patients.

The RV demonstrated a variety of changes in response to percutaneous ASD closure. There was a statistically significant decrease in RV diameter both immediately following ASD closure and carrying on through to Echo 3 at 6–8 weeks (Fig. 1B). RV area in diastole showed statistically significant decreases when pre-procedure echo was compared to post-procedure echo and echo at 6–8 weeks and also when immediate post-procedure echo was compared to echo at 6–8 weeks (28.24 cm^2 at Echo 1 vs 26.05 cm^2 at Echo 2 ($p<0.05$ vs Echo 1) vs 20.46 cm^2 ($p<0.05$ vs Echo 1 and Echo 2) at Echo 3; Table 2). RV area in systole demonstrated a statistically significant decrease at 6–8 weeks only when compared to the immediate post-procedure echo (16.88 cm^2 at Echo 1 vs 17.34 cm^2 at Echo 2 vs 14.12 cm^2 ($p<0.05$ vs Echo 2)). TAPSE (tricuspid annular plane systolic excursion – Fig. 1C) decreased significantly immediately post-procedure (2.78 cm at Echo 1 vs 2.55 cm at Echo 2 ($p<0.05$ vs Echo 1) vs 2.3 cm at Echo 3 ($p<0.05$ vs Echo 1)), and RV systolic basal velocities decreased significantly at 6–8 weeks compared to pre-procedure (RV TDi (basal) 10.71 at Echo 1 vs 10.08 at Echo 2 vs 9.09 at Echo 3 ($p<0.05$ vs Echo 1)). RV fractional area change (FrAC) also demonstrated statistically significant decreases both immediately and at 6–8 weeks (Fig. 1D). Tricuspid regurgitation (TR) velocity and hence estimation of pulmonary artery pressure demonstrated significant reductions at 6–8 weeks (PAP 34.98 mmHg at Echo 1 vs 29.24 mmHg at Echo 3 ($p<0.05$)). Right ventricular outflow tract (RVOT) diameter also decreased in size significantly when the 6–8 week echo was compared to that done pre-procedure. No significant change was demonstrated in RV myocardial performance index. Good responders in terms of change in RV diameter following ASD closure were significantly more likely at baseline to demonstrate smaller RV diameters and lower TAPSE.

The left ventricle (LV) demonstrated apparent early and late responses to percutaneous ASD closure. There was a significant increase in LV diastolic diameter (Fig. 2A) the day after ASD closure. This significant trend continued through to Echo 3. Systolic LV diameters also demonstrated a trend towards increasing following ASD closure but were not statistically significant. Fractional shortening of the LV increased significantly the day after ASD closure (Fig. 2B), a trend that continued at Echo 3. LV posterior wall thickness increased significantly between Echo 1 and Echo 3. LV ejection time also increased significantly immediately following closure of ASD and continued at 6–8 weeks (286.05 ms at Echo 1 vs 303.92 ms at Echo 2 ($p<0.05$ vs Echo 1) vs 300.58 ms at Echo 3 ($p<0.05$ vs Echo 1)). There were significant reductions in septal (Fig. 2C) and lateral systolic velocities of the LV immediately post-procedure and at 6–8 weeks, and there was likewise a significant decrease in septal mitral annular diastolic (E) velocity. All E' measures demonstrated a trend towards decreasing, with concomitant increases in E:E' ratios (statistically significant in terms of septal E:E' and mean E:E' (Fig. 2D)). There were no significant changes noted in LV outflow tract diameter, though septal

Table 1
Demographics of patients enrolled in study.

	Total	Males	Females
Number of patients enrolled in study	43	11 (26% of total)	32 (74% of total)
Mean size of device (mm)	25.6 (range 10–40)	23.6 (range 10–32)	26.1 (range 10–40)
Mean age at procedure (years)	48 (range 18–82)	44 (range 18–74)	49 (range 21–82)
Number of patients requiring second device	2 (4.7%)	1 (9.1% of male procedures)	1 (3.1% of female procedures)