

# Transcatheter Closure of Atrial Septal Defect in Young Children

## Results and Follow-Up

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<b>OBJECTIVES</b>	This study sought to analyze the safety, efficacy, and follow-up results of percutaneous closure of secundum atrial septal defect (ASD) in young children.
<b>BACKGROUND</b>	Results of ASD transcatheter closure in adults are widely reported but there are no large published series concerning young children.
<b>METHODS</b>	Between December 1996 and February 2002, 48 of 553 patients percutaneously treated at our institution were children age $\leq 5$ years. Indications for closure were: elective closure in 32 patients; frequent respiratory infections in 8; failure to thrive in 2; liver transplantation in 5; and a fenestrated Fontan in 1. The procedure was carried out under general anesthesia with fluoroscopy and transesophageal control. Two different devices were used: 1) the CardioSEAL/StarFLEX (CS/SF) and 2) the Amplatzer septal occluder (ASO). Basal physical examinations and echocardiograms were performed prior to the procedure and at follow-ups (1, 6, and 12 months, and yearly thereafter).
<b>RESULTS</b>	The mean age at closure was $3.6 \pm 1.3$ years. A CS/SF was used in 10 subjects; an ASO was used in 38 patients. No deaths or immediate major complications occurred. The total occlusion rate was 87% at procedure, rising to 94% at discharge. The mean follow-up was $18 \pm 14$ months. No midterm major or minor complications occurred. The occlusion rate rose to 100% at 12 months of follow-up. Symptomatic patients improved significantly.
<b>CONCLUSIONS</b>	In the current era and in experienced hands, ASD closure can be performed safely and successfully, even in very young children. (J Am Coll Cardiol 2003;42:241-5) © 2003 by the American College of Cardiology Foundation

Secundum atrial septal defect (ASD) accounts for 6% to 10% of congenital heart disease at birth (1) and is the most common congenital heart defect in adulthood. It is generally agreed that an ASD associated with a large left-to-right shunt and either symptoms or significant cardiomegaly should be electively closed. Surgical repair of an ASD is a low-risk and widely accepted procedure (2); however, it is associated with morbidity (3,4), discomfort, and a thoracotomy scar. As an alternative to surgery, the first transcatheter closure of ASD was described in 1976 by King et al. (5) and, more recently, ASD transcatheter occlusion techniques have become an alternative to surgical procedures (6-8).

Previous studies have included predominantly adults (6-9). There are no published reports concerning large series of very young children.

Here, we report the results of ASD transcatheter closure in a pediatric population of 48 children age  $\leq 5$  years.

## PATIENTS AND METHODS

**Patients.** Between December 1996 and February 2002, 553 patients underwent percutaneous closure of ASD in our institution. Of these 553 subjects, 48 were children age  $\leq 5$

years. The age of these 48 subjects at intervention ranged from 8 months to 5 years.

Patients were assessed by a standard echocardiographic protocol. All underwent a transthoracic examination that was performed with a Vingmed 800 (Vingmed Sound, Horten, Norway) and a System Five Performance ultrasound system (Vingmed Sound) with a transducer appropriate to their size and body weight. The diameter of the ASD and the length of the interatrial septum were measured, as were its distances from the pulmonary veins, mitral valve, coronary sinus, superior vena cava, and inferior vena cava.

Parents gave their informed written consent to the procedure.

**Inclusion criteria.** Inclusion criteria for percutaneous ASD closure were the identification of an isolated secundum ASD with a pulmonary/systemic flow ( $Q_p/Q_s$ ) ratio  $>1.5:1$ , signs of right ventricular volume overload. Further, we closed interatrial communications in children as preventive treatment prior to liver transplantation. The patients selected for percutaneous closure were divided into two groups: group A patients were electively treated for "routine" closure of the ASD defect, and group B patients were those for whom the indications for closure were more pressing (symptomatic subjects [frequent respiratory infections, failure to thrive], closure of a fenestrated Fontan, and subjects requiring liver transplantation who had a patent

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**Abbreviations and Acronyms**

ASD	= atrial septal defect
ASO	= Amplatzer septal occluder
CS/SF	= CardioSEAL/StarFLEX
Qp/Qs	= pulmonary/systemic flow ratio
Rp/Rs	= pulmonary/systemic resistance ratio

foramen ovale or a small ASD). Frequent respiratory infections were defined as more than six events per year (10). Failure to thrive was defined according to Hamil et al. (11). Subjects requiring liver transplantation underwent closure because of the potential right-to-left shunt during the transplantation.

**Exclusion criteria.** We excluded patients with: (1) secundum ASD associated with complex congenital cardiac malformations; (2) ASD associated with partial anomalous pulmonary venous drainage; (3) patent foramen ovale or small ASD with Qp/Qs <1.5:1 or with no signs of right ventricular volume overload. The only exception was that of infants requiring liver transplantation; (4) a single defect too large for occlusion; (5) multiple ASDs unsuitable for percutaneous closure; (6) multifenestrated ASDs within the interatrial septum unsuitable for percutaneous closure; and (7) a defect too close to the superior vena cava, inferior vena cava, pulmonary veins, atrioventricular valves, or coronary sinus. A rim of <7 mm between the defect and these structures was considered a contraindication to percutaneous closure.

A defect was considered too large for percutaneous closure in the following cases. (1) When we considered using an Amplatzer septal occluder (ASO) (AGA Medical Corp.), we added 12 to 14 mm to the echocardiographically measured defect diameter (12 to 14 mm is the diameter of the rim around the central retention skirt of the ASO—12 mm in devices up to 20 mm and 14 mm in larger devices). When the value obtained was more than the interatrial septal length measured in the four-chamber view on transthoracic or transesophageal echocardiography, we addressed the patient to surgery. (2) When we considered using a CardioSEAL/StarFLEX (CS/SF) (Nithinol Medical Technical Inc., Boston, Massachusetts), a device-to-defect ratio of 1:8 was used. Therefore, when this value was more than the interatrial septum length, the infant was addressed to surgery.

**Device and procedure.** The procedure was carried out under general anesthesia with fluoroscopy and transesophageal echocardiographic control with a multiplane transesophageal probe interfaced with Vingmed 800 (Vingmed Sound). In subjects who needed liver transplantation, the procedure was undertaken under heavy sedation with fluoroscopy control and transthoracic echocardiography (Vingmed 800 and System Five performance; Vingmed Sound) using a 5-mHz ultrasound probe.

Standard catheterization of the right heart was performed: the Qp/Qs ratio, the pulmonary-to-systemic vas-

**Table 1.** Patients' Demographic Characteristics and Indications for Atrial Septal Defect Closure

N	48
Age (yrs)	3.6 ± 1.3
Gender (F/M)	30/18
Weight (kg)	15 ± 4 (range 8-20)
Indications for closure	
Group A: elective closure	31
Group B: other indications	
Frequent respiratory infections	8
Failure to thrive	2
Liver transplantation	6
Fenestrated fontan	1

cular resistance ratio (Rp/Rs), and angiographically demonstrated and stretched diameters of the defect were measured as previously described (12).

Two different devices were used: the CS/SF (Nithinol Medical Technical Inc.) and the ASO (AGA Medical Corp.) (6,7,9). The techniques of delivering these two devices have been described elsewhere (6,7,9).

**Residual shunt.** A residual shunt was considered to be present if color Doppler flow mapping showed a left-to-right shunt across the interatrial septum. It was defined as trivial (<1 mm color jet width), small (1 to 2 mm color jet width), moderate (2 to 4 mm color jet width), or large (>4 mm color jet width).

**Follow-up protocol.** All patients underwent clinical examination, electrocardiography, chest X-rays, and transthoracic echocardiography before discharge and at 1, 6, and 12 months after the procedure, and yearly thereafter. Antiaggregation therapy with aspirin, 5 mg/kg/day PO was prescribed for six months.

**Statistical analysis.** Data are expressed as a frequency or percentage for nominal variables and as the mean ± SD for continuous variables.

Differences among outcomes with various devices were analyzed by unpaired *t* tests. If the distribution of the variable was not normal according to the Wilk-Shapiro test, or if the Bartlett test for the homogeneity of the variance yielded a significant result, the Mann-Whitney *U* test was used. All tests were two-sided. A value of *p* < 0.05 was considered to be statistically significant.

**RESULTS**

**General characteristics.** The patients' demographic data and indications for ASD closure are reported in Table 1. During the period of the study we examined 99 subjects with isolated secundum ASD age ≤5 years. Of these 99 patients, 43 (43.4%) underwent surgery based only on transthoracic echocardiographic findings because the defect was considered unsuitable for percutaneous closure. Eight subjects (8.1%) were taken to the catheterization laboratory but were excluded after transesophageal echocardiography and balloon sizing of the defect because the defect was too large and/or had deficient rims. Percutaneous closure was,

**Table 2.** Procedure and Device Data

Fluoroscopy time (min)	17 ± 10 (range 3-50)
Procedure time (min)	72 ± 30 (range 40-180)
Qp/Qs	2.2 ± 0.6
Systolic pulmonary artery pressure (mm Hg)	20 ± 7
Mean pulmonary artery pressure (mm Hg)	13 ± 3
Stretch diameter (mm)	16 ± 4.4 (range 5-25)
Sizes of devices used	
ASO (mm)	5-26
CS/SF (mm)	17-33
Hospital stay (days)	3.1 ± 0.1 (range 3-5)

ASO = Amplatzer septal occluder; CS/SF = CardioSEAL/StarFLEX; Qp/Qs = pulmonary/systemic flow ratio.

therefore, planned for 48 patients (48.5%) and was successfully achieved in all of them.

Six of seven patients age <2 years were treated before liver transplantation. The seventh subject, age 18 months, was treated because of a failure to thrive. We treated three patients age 2 to 3 years: one because of failure to thrive and the other two because of frequent respiratory infections. Most patients older than 3 years were treated electively.

**Procedure: results.** Data regarding the procedure, devices used, and hospital stay are reported in Table 2.

Two different devices were used to close a secundum ASD: 1) a CS/SF in 10 patients, and 2) an ASO in 38 patients.

Five patients with multiple ASDs had successful transcatheter closure; a single device was used in three patients (ASO in two cases, CS/SF in one case), and simultaneous placement of two devices was needed in two subjects (one with ASO and one with CS/CF).

Immediately after the closure, transesophageal echocardiographic examination showed that all the devices were in good positions.

**Procedure: complications.** No deaths or major complications occurred. There were, however, technical problems in two subjects. In the first subject, age 8 months, who underwent ASD closure before liver transplantation, a 7-mm ASO was retrieved because the device obstructed the superior vena cava flow; a 5-mm ASO was used instead and there were no further problems. The second subject was an 18-month-old boy with two ASDs and aneurysm of the interatrial septum. A 15-mm ASO was used but a satisfactory closure of the two holes was not achieved; therefore, the device was retrieved and two CS/SF devices were successfully implanted (23 and 28 mm, respectively). Finally, one subject (a 4.8-year-old boy) experienced mild retropharyngeal bleeding due to orotracheal intubation.

**Residual shunt.** Of all the percutaneously treated patients, 41 (87%) achieved total occlusion at implantation, as assessed by transesophageal echocardiography. At discharge, the total occlusion rate had risen to 94%, as evidenced by transthoracic echocardiography. In all other subjects the residual shunt was defined as being small to trivial. Echocardiography at 1 and 6 months' follow-up showed total

occlusion in 47 of 48 patients (98%) and at 12 and 24 months' follow-up in 100% of patients.

**Comparison between CS/SF and ASO.** No significant difference was observed between the ASO and CS/SF groups concerning age, gender ratio, or Qp/Qs. Both average fluoroscopy time (15 ± 11 min vs. 26 ± 5 min;  $p < 0.004$ ) and procedure time (60 ± 20 min vs. 85 ± 35 min;  $p < 0.004$ ) were lower in the ASO group.

Atrial septal defect closure with ASO was successful in 34 of 38 (89%) patients immediately after implantation; in almost all patients (37 of 38; 97%) at discharge; and in all patients 1 month after the procedure. CardioSEAL/StarFLEX ASD closure was successful in 7 of 10 patients (70%) at implantation and at discharge and in 2 additional patients at 1 month (90%). The rate of complete closure had risen to 100% by the time of the 12-month follow-up. Residual shunting was more common in the CS/SF group immediately after the procedure ( $p < 0.03$ ) and at discharge ( $p < 0.03$ ), but not after one month of follow-up.

**Hospital stay.** All patients stayed in the hospital for three days, except for three subjects who had transient fever, for whom the hospital stay was prolonged to five days. Only paracetamol was given.

**Follow-up.** The mean duration of follow-up was 18 ± 14 months (range 12 to 52 months). There were no deaths, no endocarditis and no rhythm disturbances or other complications during the whole follow-up period.

Patients with failure to thrive had complete recovery of growth (from <5th percentile up to the 25th to 50th percentile after 1 year of follow-up). Subjects with frequent respiratory infections had no significant recurrences.

One subject, treated with a 33-mm CS/SF, showed the fracture of an arm of the device at the six-month follow-up. However, as reported in the data, this had no practical consequences (6).

## DISCUSSION

Atrial septal defects as large as 5 to 8 mm may close spontaneously in a significant portion of subjects as old as 2 to 3 years of age (13,14), so we treated children age <3 years old only if liver transplantation was planned (6 patients) or when symptoms were present (4 patients). Furthermore, in these latter subjects, the defects were always 10 mm or larger. Most of our patients were treated electively when older than 3 years. Surgery for ASD closure is usually performed electively at 4 to 5 years of age (15,16). Therefore, we decided to use the same timing for percutaneous closure in our patients.

Percutaneous ASD closure is now routinely performed in adults. Various devices are currently available for transcatheter closure of ASD (6,7,9,17). There are reports of many series in older patients (6-9,17), but no large reports about the safety, feasibility, and efficacy of percutaneous ASD closure in very young children.

Rastegari et al. (18) reported a series of 20 subjects age

between 6 months and 20 years who underwent ASD closure with an Amplatzer device. They reported no complications, and successful closure was achieved in all subjects. Vogel et al. (19) studied 12 consecutive symptomatic children age <2 years: 6 had failure to thrive, 5 suffered from frequent chest infections, and 1 had heart failure. Ten patients underwent successful closure; in two subjects, surgery was needed because of device malposition. Finally, one subject experienced a transient neurologic complication.

In our series of 48 patients age  $\leq 5$  years, successful closure was achieved in all. Technical problems occurred in two subjects, but these problems were managed percutaneously. Although no major complications occurred in our series, complications are, of course, possible. In a previous article (7), we reported the occurrence of malposition or embolization that required surgical retrieval in 10 of 417 percutaneously treated adult patients (2.4%). There are maneuvers and techniques to retrieve percutaneously introduced devices for ASD closure. However, relatively large, long sheaths (up to 13F) are needed, limiting the role of these approaches in the case of embolization or malposition in very young children. Immediately after the procedure there was a trivial shunt in 13% of the subjects; however, this rate fell to 0 at the 1-year follow-up.

Finally, there were no complications during the follow-up; patients with frequent respiratory infections had no significant recurrences; and subjects with failure to thrive showed significantly better development.

**Clinical implications.** The demonstration of the safety and efficacy of ASD percutaneous closure in young and very young children has some clinical implications. The first important advantage of percutaneous techniques is related to their lesser psychological impact. In fact, the absence of skin scars, the shorter hospitalization, and the avoidance of admission to an intensive care unit are widely appreciated by patients and parents.

There may also be some advantages during the follow-up. First, the absence of a scar on atrial myocardium may reduce the incidence of incisional arrhythmias. Second, bypass surgery is complicated by a late decline in cognitive function, as shown by Newman et al. (20) in patients undergoing coronary artery bypass graft. Even in pediatric patients, there is some evidence that bypass surgery may be related to a slightly poorer neuropsychological outcome at follow-up (21). Probably, the brain is less compromised when using percutaneous procedures. Third, from our study it appears that in the current era, percutaneous ASD closure provides a valuable alternative to surgery, even in very young children.

**Study limitations.** Obviously not all ASDs can be treated by percutaneous techniques. In fact, 48 of 99 children age  $\leq 5$  years who were assessed for ASD repair underwent percutaneous closure. Although the techniques of percutaneous closure appear to be safe, we do not know whether the devices are safe in the very long term. In contrast, the

long-term safety and efficacy of surgery have been well established (2,3,15,16,22,23).

## CONCLUSIONS

Percutaneous ASD closure can be performed safely and successfully in selected young and very young children. Cardiologists and pediatricians should bear in mind that a valuable alternative to surgery now exists for ASD closure.

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