Background—Percutaneous closure of atrial septal defects is well established in children and adults and has been found to improve symptoms and positively influence right-heart remodeling. The aim of this study was to evaluate the efficacy and long-term outcome in adult patients older than 60 years.

Methods and Results—The study population comprised 96 patients in the age group of 60 to 84 years. Percutaneous closure was performed effectively in all patients. Functional capacity according to New York Heart Association functional class and peak oxygen uptake (VO₂ max) in the cardiopulmonary exercise testing improved significantly after atrial septal defects closure, especially in patients with a pulmonary-to-systemic flow ratio >2. Echocardiographic measurements of the right ventricular end-diastolic diameter showed a significant decrease. No device-associated complications were observed, but in 16 patients, paroxysmal atrial fibrillation occurred after device implantation.

Conclusions—Percutaneous atrial septal defects closure can be performed safely and with minimal risk even in elderly patients. They profit in terms of symptom reduction, improvement of exercise capacity, and right-heart remodeling.

Atrial septal defects (ASDs) of secundum type are one of the most common congenital heart lesions in adults. Prevalence of ASDs in children is noted to be 11.4%¹ within the congenital heart defects. Spontaneous closure is unusual in adults, and most of them develop symptoms like fatigue, dyspnea, or paradoxical embolization in the course of time. The development of symptoms, echocardiographic signs of significant shunt volume or shunt-related pulmonary hypertension are widely accepted indications for closure of an ASD. Since the first percutaneous ASD closure performed by King and Mills², this minimally invasive method has become a well-established treatment for secundum-type ASD, with hemodynamically significant left-to-right shunt in children and adults. Several studies and our own experience have demonstrated clinical benefits and positive right-heart remodeling, with reduction of the right ventricular end-diastolic diameter.³–⁷ However, few studies were published considering patients older than 60 years.⁸–¹⁴ Although surgical and device closure can be performed safely in this age group, little data are published on functional results after device closure. The aim of this study, therefore, was to evaluate the efficacy and long-term outcome of percutaneous ASD closure in patients older than 60 years.

Methods

Patients

In this clinical study, 96 consecutive patients older than 60 years (69.9±5.3 years, 30 men) who underwent percutaneous ASD closure between October 1998 and June 2007 were investigated. Indications for closure were significant left-to-right shunt (right ventricular enlargement) detected by echocardiography, shunt-related symptoms, or pulmonary hypertension. Clinical examination with assessment of the functional capacity according to the New York Heart Association (NYHA) functional class and transthoracic echocardiography was performed in all patients before percutaneous closure. Right ventricular end-diastolic diameter (RVEDD), left ventricular end-diastolic diameter, and left atrial diameter (end-systolic) were assessed by conventional M-mode in parasternal long-axis view. Additionally, the right ventricular enlargement was semiquantitatively assessed in the apical 4-chamber view. Cardiopulmonary exercise testing (CPX), preinterventional and postinterventional, was available in a subgroup of 35 patients on an ergometer cycle. Starting with 25 W, the work rate was increased 10 W/minute. On patient exhaustion, the test was discontinued. Besides ECG and blood pressure, VO₂ max was registered according to a standardized protocol.¹⁵ All subjects gave written informed consent to the procedure.
follow-up after 3 and 12 months. The study was approved by the ethical committee of our institution.

Follow-Up
All patients were examined 3 months after percutaneous closure, including clinical and echocardiographic examination as well as a transesophageal contrast echocardiographic examination with valsalva maneuver for detection of residual shunt or thrombus formation on the device. The subgroup of 35 patients with CPX before ASD closure also underwent this examination.

Implantation Procedure
Percutaneous closure of the ASD was performed from the femoral vein under local anesthesia and analgesedation, and fluoroscopic and multiplane transesophageal echocardiographic guidance. In patients with risk factors for coronary heart disease or angina pectoris, a coronary angiogram was performed before device closure. Shunt volume was determined by stepwise oxymetric measurements of superior and inferior vena cava, and pulmonary artery blood sample using the Fick principle and expressed as percent of pulmonary blood flow (%). Before entering the left atrium, 100 IE/kg body weight intravenous heparin was injected. Native and balloon sizing diameters (“stop-flow technique”) of the ASD were measured in transesophageal echocardiographic examination and by fluoroscopy. Depending on the sizing diameter, the size of the device was chosen. A long sheath (9 to 12F) was positioned through the ASD in the left atrium near the left superior pulmonary vein. The device was introduced through this sheath and deployed under transesophageal echocardiographic guidance. After confirming a secure position by pull-and-push maneuver, the device was released from the delivery system, and the final position was documented by transesophageal echocardiography and fluoroscopy. Postinterventional treatment consisted of 100 mg acetylsalicylic acid once daily for 6 months and 75 mg clopidogrel once daily for 2 months. For peri-interventional prophylaxis, the patients were given a single dose of cefazolin (1.5 g IV) during the catheter procedure. Standard endocarditis prophylaxis was recommended for 1 year.

Statement of Responsibility
The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Statistics
Statistical analysis was performed with the SPSS statistical package (version 15.0, SPSS Inc, Chicago, Ill). In the following sections, continuous variables are expressed as mean and standard deviation after checking for normality of distribution. Differences between baseline and follow-up were analyzed by the paired sample t test. A P value <0.05 was considered statistically significant. Correlation between changes in right and left ventricular diameter was analyzed with Pearson bivariate correlation.

Results
Patient characteristics, and clinical and hemodynamic data are listed in Table 1. Fourteen patients did not report any adverse symptoms despite significant left-to-right shunt and were classified as NYHA I, 48 patients were classified as NYHA II, and 27 as NYHA III. Two of the patients (2.1%) had an ischemic stroke as an indication for interventional closure, the others a hemodynamic indication. Chronic atrial fibrillation (AF) was present in 21 patients of which all received oral anticoagulation therapy. Elevated lipoproteins were found in 44 patients, and 54 patients were treated medically for arterial hypertension. Fifty-one patients underwent a coronary angiogram just before the device implantation, of which 21 patients had a coronary artery disease. Three of them had significant coronary artery stenosis and were treated by percutaneous coronary intervention in the same procedure.

Implantation Procedure
The atrial septal defect was multifenestrated in 8 patients. The mean defect diameter measured by transesophageal echocardiography was 14.8±5.8 mm, and the sizing diameter was 20.8±5.8 mm. The mean shunt volume was 48.7±12.6%. Mean pulmonary arterial pressure was 25.1±7.8 mm Hg and mean pulmonary vascular resistance was 174±103 dyne/s per cm.⁵ Percutaneous ASD closure was performed successfully in all patients using an Amplatzer septal occluder device (AGA Medical Corp, Golden Valley, Minn) in 95 patients and Cardia-Star device in 1 patient. Median device size was 21.9±5.7 mm (range, 11 to 38 mm). In 1 patient, the septum secundum tear during the balloon sizing, wherein a larger device was subsequently necessary for closure. One patient who underwent coronary angiography in the same procedure required surgical vascular repair due to groin hematoma at the puncture site. Two patients developed mild symptoms of pulmonary congestion directly after implantation. Both improved shortly after diuretic treatment.

Follow-Up
Seven patients were lost to clinical follow-up. The 3-month follow-up after device closure (108±53 days), including transesophageal contrast echocardiography, demonstrated a tiny residual shunt through the device in 15 patients (16.9%).
In the long-term follow-up (median, 33.6\,\text{months}; range, 2.8 to 100.1 months), no device-associated complications, such as thrombus formation on the device, or device embolization or malposition were observed. NYHA functional class improved in 62 patients (69.7%). Three patients reported clinical worsening, and 24 patients reported no change in their functional capacity (Figure 1). Despite gender (21 women, 6 men), there were no other obvious differences between responders and nonresponders regarding age, shunt, PA pressures, or preinterventional VO$_2$max. Seven (7.3%) patients reported of paroxysmal atrial fibrillation before device closure and were treated by oral anticoagulation. New paroxysmal AF occurred in 16 (17.9%) patients after device closure. Ten of them received new oral anticoagulation therapy; the remaining 6 had only a single short episode of AF within the first 3 months after ASD closure and no further recurrence and hence were not treated with phenprocoumon. Within the subgroup of the patients with paroxysmal AF, 3 reported deterioration and 8 no change in their NYHA functional class. Residual shunting did not influence the functional outcome; 11 patients improved in their NYHA functional class, 2 remained unchanged, and 2 worsened.

VO$_2$max increased overall by 10% (17.1±5.5 versus 18.8±5.4 \text{mL/kg per min}, P<0.05; Figure 2). A larger increase of VO$_2$max could be measured in patients with a pulmonary-to-systemic flow ratio (Q$_p$:Q$_s$) >2 than in those with a Q$_p$:Q$_s$<2. Eighteen patients with CPX met the criteria of Q$_p$:Q$_s$>2 (Figure 3). The increase of VO$_2$max was significant in this group (17.1±5.7 versus 19.8±5.9 \text{mL/kg per min}, P<0.05). The other 17 patients with CPX had a Q$_p$:Q$_s$<2 and showed a slight increase in their VO$_2$max after ASD closure, which was statistically not significant (17.1±5.5 versus 17.7±4.8 \text{mL/kg per min}, P=NS).

Right ventricular enlargement (RVEDD >30 mm) was present in 77 of 96 patients; 19 patients showed no significant enlargement of the right ventricle. After ASD closure, a significant reduction of the RVEDD (38.9±8.7 versus 32.3±8.6 mm, P=0.05) could be measured in the echocardiographic assessment. Of 77 patients with RVEDD enlargement, 23 (29.9%) reached normal RVEDD (<30 mm) after 3 months. The left ventricular end-diastolic diameter increased significantly (46.2±6.8 versus 50.5±6.9 mm, P<0.05), and the left atrial diameter did not change (49.3±9.4 versus 48.1±9.6 mm, P=NS; Figure 4). A significant correlation between decrease in RVEDD and increase in left ventricular end-diastolic diameter could be detected (r=0.505, P<0.01; Figure 5).

**Discussion**

Percutaneous device closure is nowadays a routine treatment of hemodynamically significant ASD in children and adults. Symptom reduction, improved exercise capacity, and right-heart remodeling were demonstrated in the past. The aim of this study was to evaluate the efficacy and long-term outcome of percutaneous ASD closure in patients older than 60 years. Because only 4 patients of 96 showed complications due to the procedure, it can be concluded that this intervention can be performed safely and at low risk also in elderly patients. Decrease or even normalization of right ventricular size could be observed in the majority of patients within the first 3 months after ASD closure. Cardiac remodeling is an early postinterventional effect and appears during the first months after ASD closure.\textsuperscript{16,17} Significant improvement of NYHA functional class and exercise capacity in the
The majority of patients could be proved in this study. Especially patients with a Qp:Qs > 2 seem to profit by this treatment. Minimal residual shunting after 3 months does not influence their outcome because further endothelialization with complete elimination of residual shunt can be expected in long term. However, the outcome was influenced if the patient developed paroxysmal AF. A significantly higher percentage of patients with paroxysmal AF after device closure reported of unchanged or deteriorated functional capacity. Although patients with chronic AF before ASD closure showed an improvement of the NYHA functional class after device closure, 68.7% of patients with new paroxysmal AF showed no change or even worsening of their NYHA functional class. The majority of the patients were symptomatic and improved in their functional capacity after ASD closure. Even in asymptomatic elderly patients, a device closure may induce positive right ventricular remodeling and hence should be performed in this age group as well.

ASD closure with abolishment of left-to-right shunt leads to augmented left ventricular filling by increased left ventricular preload and therefore to improved left ventricular stroke volume. The rise in left ventricular stroke volume may explain the increase in VO2max and increase of functional capacity. Especially in this age group in which impaired diastolic function is common, this may explain the functional improvement.

Potential risk of transient pulmonary congestion was described especially in elderly patients with impaired diastolic function after ASD closure. Pathophysiologically, this phenomenon can be explained with augmented left atrial pressure after abolishment of left-to-right shunting by ASD closure. In our series, 2 patients developed mild symptoms of pulmonary congestion directly after implantation. Both improved shortly after diuretic treatment and presented with stable functional status in long-term follow-up.

In general, the results of this study confirm other published clinical observations, with few patients undergoing surgical repair or smaller study groups after device closure. In comparison to surgical ASD treatment, patients’ functional recovery was faster in the interventional group, probably because of the effects of thoracotomy and heart lung machine. Especially, older patients were at a higher risk during surgery and often have delayed recovery.

Hence, interventional closure of secundum-type atrial defects with moderate or severe left-to-right shunt can be recommended in patients older than 60 years, with good functional results in the majority of patients.

**Study Limitations**

Potential limitation may occur by missing CPX data during follow-up in some patients and lacking comparison with surgically treated patients.

**Conclusion**

Percutaneous closure of ASD can be performed safely and at minimal risk in patients older than 60 years. They benefit by symptom reduction, improvement functional exercise capacity, and positive right-heart remodeling.

**Disclosures**

None.

**References**


**CLINICAL PERSPECTIVE**

This clinical study on interventional closure of atrial septal defects in patients older than 60 years could demonstrate relief of symptoms, improvement of functional capacity, and positive right-heart remodeling in the echocardiographic analysis. Especially in patients with high shunt volume, the exercise capacity improved significantly. This procedure can be performed with minimal acute and long-term risk, and the authors recommend interventional atrial septal defects closure in this age group.
Percutaneous Closure of Atrial Septal Defects: Echocardiographic and Functional Results in Patients Older Than 60 Years
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