Percutaneous versus surgical closure of secundum atrial septal defect: Comparison of early results and complications

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Background Surgical closure of atrial septal defect (ASD) provides excellent results. Given the increasing popularity of percutaneous techniques, a comparison between the 2 methods is needed.

Methods Between December 1988 and June 2003, we performed 1284 procedures in 1268 consecutive patients with isolated secundum ASD. Five hundred and thirty-three patients underwent surgical repair of ostium secundum ASD (group A). Seven hundred and fifty-one consecutive patients underwent percutaneous ASD closure (group B). The following outcomes were studied: mortality, morbidity, hospital stay, and efficacy.

Results There were no postoperative deaths. The overall rate of complications was higher in group A than in group B: 44% (95% CI 39.8%-48.2%) versus 6.9 % (95% CI 5%-8.7%) ($P < .0001$). Major complications were also more frequent in group A: 16% (95% CI 13%-19%) versus 3.6% (95% CI 2.2%-5.0%) ($P = .002$). Multiple logistic regression analysis showed that surgery was independently strongly related to the occurrence of total complication (odds ratio [OR] 8.13, 95% CI 5.75-12.20) and of major complications (OR 4.03, 95% CI 2.38-7.35). The occurrence of minor complications was independently related to surgery (OR 7.33, 95% CI 4.75-11.02), childhood (OR 1.52, 95% CI 1.01-2.34), and presence of systemic hypertension (OR 1.35, 95% CI 1.01-4.41). Hospital stay was shorter in group B (3.2 $\pm$ 0.9 vs 8.0 $\pm$ 2.8 days, $P < .0001$).

Conclusions Percutaneous ASD closure provides, in experienced hands and in highly specialized centers, excellent results with a lower complication rate and requires a shorter stay in hospital. (Am Heart J 2006;151:228-34.)

Surgical closure of atrial septal defect (ASD) was performed for the first time in 1953.[1] This technique provides good early postoperative and long-term results.[2-5]

Surgical repair has been proven to be superior to medical treatment in middle-aged and elderly patients in a retrospective, nonrandomized study[6] and in a controlled, randomized trial.[7]

However, another therapeutic option has recently become available.[8] In fact, over the past decade, at least 6 different devices for transcatheter closure of secundum ASD[9-14] have been used in clinical trials, and several of them are fully approved for routine clinical application in different countries.

However, there are no single center reports of comparisons of early results, closure rates, mortality, morbidity, and complications between large series of patients treated with either transcatheter or surgical closure of secundum ASD.

We retrospectively compared early postoperative results and complications of these 2 techniques in a series of 1284 procedures in 1268 consecutive patients from a single center.

Patients and methods

Inclusion and exclusion criteria

We conducted a retrospective search of all eligible patients referred to our hospital for secundum ASD closure with echocardiographic signs of right ventricular overload. We excluded patients with (*a*) secundum ASD associated with complex congenital cardiac malformations, (*b*) angiographically confirmed acquired coronary artery disease, (*c*) severe mitral and/or tricuspid regurgitation, (*d*) ASD associated with partial anomalous pulmonary venous drainage, and (*e*) small ASD with a pulmonary-systemic (Qp/Qs) flow ratio of <1.5:1 and/or no signs of right ventricular volume overload.

Period of the study and patients

Between December 1988 and June 2003, 1268 consecutive patients with an echocardiographic diagnosis of secundum

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ASD were referred to our institution. There were 808 females and 460 males, with a mean age of 24.8 ± 18.0 years (range 9 months–81 years).

Data collection

We retrospectively collected the following information: age, age group (children/adults), type of repair (percutaneous/surgery), and sex (female/male); for medical history, the following variables were included: congestive heart failure, failure to thrive, transient ischemic attack (TIA)/stroke, systemic hypertension, diabetes, smoking, history of arrhythmias, obesity, chronic obstructive pulmonary disease (COPD), hemodynamic data when available (Q_P/Q_S, pulmonary vascular resistance [PVR]), ASD size, type of complication, length of hospital stay, and occurrence of a residual shunt.

Outcomes studied

The following outcomes were studied: (1) mortality, (2) morbidity (ie, complications), (3) length of hospital stay, and (4) efficacy (ie, residual shunt).

Patients

Group A. This group was formed of 533 subjects who underwent surgical closure of the secundum-type ASD during the period of the study. Their mean age at operation was 22.4 ± 18.9 (range 1-81) years and the female-male ratio was 393:124.

Of these 533 patients, some (group A1: 288 subjects, mean age 22 ± 19 [range 1-72] years) were treated when only the surgical procedure was available (December 1988–December 1996). Patients referred to our institution between December 1996 and June 2003 underwent ASD surgical closure if unsuitable for transcatheter closure (these surgically treated patients formed group A2: 245 patients, 20.5 ± 18.4 [range 1-81] years).

One hundred and sixty patients were referred to the surgeon without transesophageal echocardiography and/or cardiac catheterization for the following reasons: (*a*) single defect, too large for occlusion with the available devices; (*b*) multiple ASDs unsuitable for interventional closure; (*c*) multifenestrated ASDs within the interatrial septum unsuitable for percutaneous closure; and (*d*) a defect close to the superior vena cava, inferior vena cava, pulmonary veins, coronary sinus, or atrioventricular (AV) valves.

Sixty-nine patients were crossed over to the surgical group because, after evaluation by transesophageal echocardiography and cardiac catheterization with balloon stretching, the defect was considered unsuitable for percutaneous closure because of the previously reported reasons (*a*, *b*, *c*, *d*).

Finally, 16 subjects underwent surgery because of complications after percutaneous ASD treatment.

Group B. This group was formed of the 751 patients (336 males) who had a transcatheter implantation of one or more devices at a mean age of 29 ± 19.8 years (range 9 months-81 years).

Operative techniques

Group A. Patients were operated on under general anesthesia with the aid of cardiopulmonary bypass. Different techniques were used: midline sternotomy,[15] ministernotomy,[16] and right lateral thoracotomy.[17] All the surgical procedures were performed by members of the surgical team. The size of the secundum ASD was measured manually by the surgeon.

Group B. The procedure was performed under general anesthesia with fluoroscopy and transesophageal echocardiographic control.

Standard catheterization of the right side of the heart, Qp/Qs flow ratio, and pulmonary to systemic vascular resistance (Rp/Rs) ratio, and angiographic and stretched diameters of the defect were measured as previously described.[18]

Two different devices were used: the CardioSEAL/StarFLEX (CS/SF) (Nitinol Medical Technical Incorporated, Boston, Mass) and the Amplatzer Septal Occluder (ASO) (AGA Medical Corporation, Golden Valley, Minn).[12,14,19]

Definitions of complication

We included complications occurring within 2 weeks after the procedure or until discharge if hospitalization was longer.

Complications were classified as (1) minor, (2) major, and (3) death. Complications were calculated on an intention-to-treat basis.

1. Minor complications

   Group A: transient arrhythmias or arrhythmias interrupted by drugs, respiratory tract infections, pericardial effusion or pneumothorax not requiring mechanical drainage, mild anemia not requiring transfusion, others; we defined this as mild a complication that could be completely treated by drugs and gave no hemodynamic abnormalities;

   Group B: groin hematoma and all complications described for Group A.

2. Major complications

   a. Major transient complications

      Group A: heart failure, transient AV block needing a temporary pacemaker, severe bleeding requiring reoperation, cardiac tamponade, arrhythmias responsible for hemodynamic decompensation requiring immediate electrical cardioversion, surgical drainage of a pericardial or pleural effusion or of a pneumothorax, reoperation, severe anemia requiring blood transfusion, thrombus formation on the atriotomy treated by heparin;

      Group B: device embolization/malposition needing surgical retrieval and surgical closure of the ASD, thrombus formation on the device treated by heparin, vascular injury of the femoral vessels requiring vascular surgery repair, pericardial effusion with or without cardiac tamponade due to perforation of the left atrial and aortic wall by the device, all complications described for Group A.

Furthermore, we included complications after surgery in subjects who underwent a previous percutaneous attempt.

   b. Major complications with long-term sequelae

We included complications with neurologic sequelae and chronic cardiac failure.

3. Death

Hospital stay

This was defined as the period from admission until discharge from the hospital, including the admission day and the day of discharge.

Residual shunt

A residual shunt was considered to be present if color Doppler flow mapping on transthoracic echocardiography showed a left to right shunt across the interatrial septum.

It was defined as trivial (color jet width <1 mm), small (color jet width 1-2 mm), moderate (color jet width 2-4 mm), or large (color jet width >4 mm). Presence of a residual shunt was checked at discharge.

Statistical analysis

Data are expressed as a frequency or percentage for the nominal variables, as the median for the ordinal variables, and as the mean (SD) for continuous variables; 95% CIs were calculated.

The comparability of surgical patients treated before and during the percutaneous era was examined before pooling the data for comparisons with patients in the device group (to avoid systematic differences between the 2 groups).

Nominal variables were compared using the χ^2 test or Fisher exact test as appropriate. Differences between groups were tested by a 2-tailed *t* test or Wilcoxon rank sum test as appropriate.

Multivariate analysis to test the role of risk factors in occurrence of total complications, minor complications, and major complications was performed using multiple logistic regression. The following independent variables were tested in the univariate analysis: age at surgery, age group (children/adults), type of repair (percutaneous/surgery), and sex (female/male); for medical history, the following variables were included in the model: congestive heart failure, TIA/stroke, hypertension, diabetes, smoking, history of arrhythmias, obesity, COPD, hemodynamic data when available (Q_P/Q_S, PVR), and ASD size. Variables associated with complications (total, minor, or severe) in the univariate analysis ($P < .01$) were entered into a multiple logistic regression analysis to estimate adjusted odds ratios (ORs) and 95% CI. Continuous variables were not dichotomized.

All tests were 2-sided. A *P* value of < .05 was considered statistically significant.

Results

Patients' characteristics

All subjects had a secundum ASD with right ventricular volume overload. Left ventricular size and function, evaluated echocardiographically, were normal. Table I shows the demographic and baseline clinical data of each group.

Patients in group B were older than those in group A (29 ± 19.8 vs 22.4 ± 18.9 years, $P = .02$). The mean ASD diameter was significantly larger in group A than in group B (2.9 ± 0.8 vs 2.3 ± 0.7 cm, $P = .03$).

Furthermore, patients in group B had a higher incidence of smoking habit and hypertension.

Table I. Demographic and baseline clinical data

	Group A (n = 533)	Group B (n = 735)	*P*
Age (y)			
Mean ± SD	22.4 ± 18.9	29 ± 19.8	.02
Median (range)	14 (1-82)	31 (0.6-81)	
Congestive heart failure	6 (1%)	4 (0.5%)	NS
COPD	0	4 (0.5%)	NS
TIA/stroke	6 (1%)	10 (1.3%)	NS
Systemic hypertension	40 (7.2%)	89 (12%)	.003
Diabetes	3 (0.5%)	7 (1%)	NS
Obesity	14 (2.5%)	11 (1.4%)	NS
History of previous atrial arrhythmias	28 (5%)	24 (3.2%)	NS
Smoking	26 (4.7%)	46 (6.3%)	.04
Q_P/Q_S*	2.4 ± 0.4	2.2 ± 0.8	NS
PVR (Wood unit)*	3.5 ± 1.4	3 ± 1.5	NS

NS, Not significant.
*The analyses of Q_P/Q_S and of PVR were made comparing 735 subjects who underwent fully successful percutaneous closure and 85 patients treated surgically who had cardiac catheterization before surgery.

Group A. Comparisons between the 2 surgical groups (A1 vs A2) showed no differences in age, ASD size, and in outcomes studied. Therefore, the data from both groups were pooled for analysis and comparisons with the percutaneous group.

The different surgical approaches used were median thoracotomy (458 patients), ministernotomy (45 patients), and right lateral thoracotomy (30 patients).

The last approach was used only in women when requested by the patient for cosmetic reasons. It was not used in female children in whom we have many concerns regarding the risk for breast maldevelopment and chest deformity.

The mean bypass time was 26.2 ± 10.2 (range 10-89) minutes and the mean aortic cross clamp time was 15 ± 6 (range 1-46) minutes.

The ASD was closed either by direct suture (340 patients) or by pericardial or Dacron patch (193 patients).

Group B. Two different devices were used: the CS/SF in 140 patients and the ASO in 595 patients. Thirty-one patients needed implantation of 2 devices to close multiple ASDs.

The mean procedure time and the mean fluoroscopy time were 67 ± 27 and 12.9 ± 11.8 minutes, respectively.

Hemodynamic data

There were no differences in the Qp/Qs ratio and in the Rp/Rs ratio between the 735 patients in group B and the 85 patients who underwent cardiac catheterization before surgery (Table I).

Mortality

There were no deaths in the postoperative period in either group.

Table II. Minor transient complications

	Group A (533 patients)	Group B (751 patients)
Mild anemia	46 (8.6)	0
Mild pneumothorax	4 (0.8)	0
Dysphonia	2 (0.2)	0
Subcutaneous emphysema	5 (0.9)	0
Transient ST-segment elevation	9 (1.7)	0
Respiratory tract infections	12 (2.2)	0
Mild pericardial effusion	21 (3.9)	1
Bedsores	1 (0.2)	0
Unexplained prolonged fever	9 (1.7)	0
Arrhythmias		
Atrial fibrillation	26 (4.9)	7 (0.9)
Supraventricular paroxysmal Tachycardia	7 (1.3)	3 (0.4)
Mild pleural effusion	7 (1.3)	0
Transient AV block	0	1 (0.1)
Retropharyngeal bleeding	0	1 (0.1)
Groin hematoma	0	1 (0.1)
Technical problems		
Malposition/embolization of the device retrieved percutaneously	0	11 (1.5)
Sizing balloon rupture	0	1 (0.1)
Total	149 (27.9)	25 (3.3)

Values are presented as n (%).

Table III. Severe transient complications

	Group A (533 patients)	Group B (751 patients)
Severe anemia—blood transfusion	33 (6.1)	/
Pneumothorax requiring surgical drainage	6 (1.1)	/
Pleural effusion requiring surgical drainage	5 (1)	/
Pericardial effusion requiring surgical drainage	13 (2.4)	1 (0.2)
Transient heart failure	1 (0.2)	/
Transient AV block requiring pacemaker	3 (0.6)	/
Reoperation		
Severe bleeding	2 (0.4)	/
Patch detachment	1 (0.2)	/
Arrhythmias		
Atrial fibrillation—DC shock	10 (1.8)	4 (0.5)
Ventricular fibrillation	1 (0.2)	/
Thrombus formation on the left side of the device	/	3 (0.4)
Malposition/embolization needing surgery and surgical ASD closure	/	14 (1.9)
Vascular injury of the femoral vessels	/	4 (0.5)
Surgery due to left atrium free wall and aortic perforation with pericardial effusion with or without cardiac tamponade	/	2 (0.2)
Seizures	1 (0.2)	/
Systemic thromboembolism with stroke	1 (0.2)	/
Cardiac failure	1 (0.2)	/
Thrombus on the atriotomy treated with anticoagulant	8 (1.4)	/
Total	86 (16)	27 (3.6)

Values are presented as n (%). *DC*, Direct current.

Complications

There were no significant differences in complication rate between the 2 surgical groups (A1 vs A2).(total complications 47% vs 40%, major complications 17% vs 12%).

The rate of total complications was significantly higher in group A patients (group A 44% [95% CI 39.8%-48.2%] vs group B 6.9% [95% CI 5%-8.7%], $P < .0001$).

Also, major complications were more frequent in group A (group A 16% [95% CI 13%-19%] vs group B 3.6% [95% CI 2.2%-5.0%], $P = .002$).

Group A. Minor and major transient complications are reported in detail in Tables II and III. Major complications with long-term sequelae occurred in 3 patients (0.56%, 95% CI 0%-1.5%). Two patients had neurologic sequelae. One had hemiplegia because of an embolic event. A thrombus formed 3 days postoperatively on the left side of the interatrial patch and embolized on the fourth postoperative day causing an ischemic stroke. The second patient developed seizures in the postoperative period, and these persisted in the follow-up. The third patient manifested cardiac failure in the immediate postoperative period and had residual chronic heart failure that persisted in the follow-up.

Reoperation was needed in 3 patients: in 2, because of severe bleeding; and in the third, because of detachment of the patch on the fourth postoperative day.

Group B. The most frequent complication was device malposition or embolization needing surgical retrieval and surgical closure of the ASD. This complication occurred in 14 subjects. Surgical closure in these patients was uneventful.

In 2 patients, surgery was required for a life-threatening complication. In the first subject (a 33-year-old woman), cardiac tamponade occurred 11 hours after the implantation of a 26-mm ASO device. In the second patient (a 23-year-old woman), a large pericardial effusion was seen during transthoracic echocardiography 20 hours after the implantation of a 26-mm ASO device. These 2 women underwent surgery, and perforations of the anterior left atrial free wall and of the posterior wall of the aorta were found in both. Surgical closure and postoperative course were uneventful, and the patients had no sequelae.

Arrhythmias occurred in 14 subjects (atrial fibrillation in 11, paroxysmal supraventricular tachycardia in 3).

Four subjects required immediate direct current shock to interrupt the arrhythmia.

Four patients had injury to the femoral vessels that required vascular surgery. Thrombus formation on the left side of the device occurred in 3 patients soon after implantation of an ASO. One patient was a 62-year-old female with hypertensive cardiomyopathy and spontaneous echocardiographic contrast. The 3 patients were treated with heparin and did not develop any further complications.

One patient with pericardial effusion had a perforation because of the guidewire and needed surgical drainage of the effusion in the catheterization laboratory.

Multivariate analysis

The only variable independently related to the occurrence of total complication was the type of repair, with an 8-fold increase of risk for patients undergoing surgical repair (OR 8.13, 95% CI 5.75-12.20, $P < .0001$). The same result was obtained for major complications (OR 4.03, 95% CI 2.38-7.35, $P < .001$).

The occurrence of minor complications was independently related to surgery (OR 7.33, 95% CI 4.75-11.02, $P = .001$), childhood (OR 1.52, 95% CI 1.01-2.34, $P = .03$), and presence of systemic hypertension (OR 1.35, 95% CI 1.01-4.41, $P = .04$).

Hospital stay

Group B patients spent a significantly shorter time in hospital than did group A patients (3.2 ± 0.9 vs 8 ± 2.8 days, $P = .0001$).

Residual shunt

A small to trivial residual shunt was more frequently shown in patients in group B (8.5% vs 2.8%, $P = .01$). In Group A, 1 subject required reoperation for a partial patch detachment and significant residual shunt. In Group B, the frequency of a residual shunt was lower in patients in whom an ASO was placed than in those in whom a CS/SF was used (4.8% vs 21%).

Discussion

Atrial septal defect accounts for about 10% of congenital heart diseases.[20] Although surgery remains the standard therapy, several devices for transcatheter closure have been developed in recent years.

However, as reported by Brickner et al,[21] the "safety and efficacy of percutaneous closure is unknown." Indeed, it is still unclear whether device implantation can adequately replace conventional surgery as the first choice treatment of ASD in suitable patients.

Morbidity

The main finding of our study is that the overall rate of complications was significantly higher in the surgical group. Also, when considering only severe complications, the difference was still relevant.

Different results were obtained in 2 previous studies.

Berger et al[22] compared the outcomes of 61 patients undergoing surgical closure with those of 61 subjects who were treated percutaneously with an ASO device. They found no differences in complication rates between the 2 methods.

Formigari et al[23] studied 171 patients: 51 had a device implanted, 72 underwent minimally invasive surgical operations, and 50 had conventional sternotomy operations. The number of complications was higher in the surgical groups (12.6% vs 3.8% for transcatheter closure). However, stratifying complications by pure clinical impact score, conventional surgery was the safest technique (0% vs 2.8% for the minimally invasive surgery vs 3.8% for the interventional therapy).

These studies were carried out during a short period (1-2.5 years), and with a small series, it is probable that the complication rate of surgery could have been underestimated. In fact, although exceedingly rare, severe complications, including perioperative mortality, may occur.[2,4,15]

In our series there were no early deaths, but major complications occurred in 86 cases (16%).

Similar results were reported recently by the Amplatzer investigators group.[24] These authors compared, in a large multicenter, nonrandomized trial, the safety, efficacy, and clinical utility of the ASO with surgical closure of secundum ASD. They showed that the complication rate was 7.2% in the device-treated group and 24% in the surgically managed group ($P < .001$). However, this was a multicenter study, and only one of the currently available devices was used.

Regarding medium- and long-term results, our study did not address these issues. However, in literature, there are some data. Regarding percutaneous closure at a midterm follow-up, risks for atrial arrhythmias and thrombus formation are reported.[19,25] Concerning surgery, incisional atrial arrhythmias, pericardial effusion, and tamponade, systemic thromboembolism are the most frequent complications encountered in these patients.[3,15]

Efficacy

As widely reported in literature,[2-5,14,15,19,22,23] successful closure of the defect was obtained in most patients in both groups. In literature, the incidence of residual shunting after surgical closure varies from 2% to 7.9% in the long-term follow-up data.[5,15]

In our series, a tiny residual shunt at discharge was more frequent in subjects treated percutaneously. However, as reported in literature,[12,14] endothelialization process takes several weeks, so residual shunt reduces significantly during the follow-up.

Hospital stay

In our series, the surgical procedure required a significantly longer period in hospital than did percutaneous closure. Other groups[23] have indicated that shorter hospitalization periods can be achieved in patients treated with midline sternotomy or minimally invasive approaches who do not develop complications. However, we remove pleural drains on the second postoperative day, and then, patients need at least 2 to 3 days for complete mobilization. Patients were discharged home on the sixth or seventh postoperative day. Many of our patients came from far away, so we preferred to prolong the hospitalization.

Clinical implications

In our study, percutaneous closure of ASD appears to be safer than surgical closure; furthermore, in our analysis this technique needs a shorter time spent in hospital. It is also possible to speculate that the shorter postoperative convalescence after transcatheter ASD closure could lessen the social impact (ie, work absence).

Another important advantage is related to the lesser psychological impact of percutaneous techniques. In fact, the absence of skin scars, shorter hospitalization, and avoidance of admission to the 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 arrhythmias. Secondly, bypass surgery is complicated by a late decline in cognitive function as shown by Selnes et al[26] in patients undergoing CABG. Even in pediatric patients, there is some evidence that bypass surgery could be related to a slightly poorer neuropsychological outcome in the follow-up.[27] Thirdly, from our study, it appears that, in the current era, most ASD are suitable for transcatheter closure.

Limitations of the study

Our study has several limitations. First, it was a retrospective study. Secondly, patients were not treated in the same period; more than half of the subjects treated surgically had their ASD repaired before the interventional methods had been developed. Furthermore, when both techniques were available, patients treated surgically were those with larger or more complex defects. This could impact on the occurrence of complications. Thirdly, we performed a single-center study, so results are limited to our own experience. Furthermore, we included in our study only complications occurring during the first 2 weeks after the procedure or until discharge if hospitalization was longer than 2 weeks. During a period of longer follow-up, the rate of complication could be different from the one found in our study.

Finally, we could not perform a randomized study, which limits the possibility of comparing the 2 strategies. However, true randomization of these 2 management strategies is not easily feasible; in an era in which in Western countries' patients and parents of children are very aware of therapeutic options, a randomized trial about ASD closure would be hard if not impossible to accept. Nevertheless, Benson and Hartz[28] found little evidence that estimates of treatment effects in observational studies (including retrospective studies) are different from those obtained in randomized controlled trials. Therefore, the true superiority of randomized over well-designed observational studies has recently been questioned.[28,29]

We do not know the Qp/Qs ratio and the Rp/Rs ratio in all patients treated surgically because most of them did not undergo diagnostic catheterization. However, we found no differences in the Qp/Qs ratios and the Rp/Rs ratios between patients treated percutaneously and subjects undergoing cardiac catheterization before surgical ASD closure. Furthermore, we compared surgical patients treated in the 2 periods, and we found no differences in age, ASD size, and outcomes studied.

In our series, hospitalization was longer in surgical patients. This was partly due to postoperative complications but also to our policy to admit these patients for 6 to 7 days because many of our patients came from far away. Some groups have suggested shorter stays in hospital (up to 3-4 days) and an early follow-up (7 days postoperatively) in the outpatient clinic.

Finally, although the technique of percutaneous closure appears to be safer, we do not know whether the devices are safe during a long follow-up, and although very rare in our experience, life-threatening complications may occur. In contrast, the long-term safety and efficacy of surgery are well known.[2-5,15]

Moreover, transcatheter ASD closure has to be performed in highly specialized centers. In fact, a surgical backup is mandatory.

Conclusions

We conclude that, in experienced hands and highly specialized centers, transcatheter ASD closure provides excellent results and fewer complications, and the patients spend a shorter time in hospital. Longer follow-up studies are necessary to show that percutaneous closure is the treatment of choice in patients with secundum ASD.

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