

# Recent advances in closure of atrial septal defects and patent foramen ovale

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## Abstract

Transcatheter closure of secundum atrial septal defect (ASD) and patent foramen ovale (PFO) is now widely accepted as an alternative to surgical closure. With currently available devices and techniques, approximately 80-90% of secundum ASDs and all PFOs can be closed percutaneously. While many devices are available, the use of any particular device is dictated largely by individual defect anatomy, device availability, long-term considerations, approval status (US Food and Drug Administration approval versus CE mark), and physician preference.

## Introduction and context

Since the pioneering work of King and Mills in 1974 [1], numerous devices to close atrial septal defects (ASDs) have been developed and implanted. Several studies have shown that transcatheter closure of the vast majority of secundum ASDs and patent foramen ovaes (PFOs) is as safe and effective as the surgical approach. In the US, the Amplatzer septal occluder (ASO) (AGA Medical Corporation, Plymouth, MN, USA) and HELEX septal occluder (W.L. Gore & Associates, Inc., Flagstaff, AZ, USA) are the only ASD closure devices approved by the US Food and Drug Administration (FDA). A non-randomized trial in the US using the ASO [2] and the US multi-center pivotal trial [3] (using the HELEX septal occluder) both demonstrated transcatheter ASD closure to be equivalent to surgical ASD closure in terms of clinical efficacy and overall safety in patients with suitable anatomy. Though not approved in the US for ASD closure, many other transcatheter occluders are approved for human use throughout the world. In our practice and in other published series, only about 10-20% of patients with a secundum ASD cannot undergo successful transcatheter ASD closure because of anatomic factors such as deficiency of a portion of the rim of the defect or extremely large size of the defect [4].

There has been a growing trend toward closing PFO in patients who are at high risk for recurrent paradoxical

emboli, especially those with an embolic stroke and no other identifiable predisposing factor. We feel that current evidence indicates that PFO closure and medical management have relatively similar efficacy in reducing the risk of recurrent strokes in patients who have suffered an otherwise unexplained stroke. This sense of equipoise is the underlying principle allowing more detailed prospective randomized comparisons of the two strategies. Currently, in the US, no device has been approved by the FDA for PFO closure specifically as the first randomized prospective trials will not be completed until sometime in 2010. Devices approved for ASD or ventricular septal defect closure, however, are widely used off-label to close PFO in high-risk patients who, hopefully, have been appropriately counseled about the current state of evidence and the alternatives. While percutaneous ASD and PFO closures are safe and effective alternatives to surgery in the short and intermediate term, long-term data comparable to surgical closure are lacking, specifically regarding the effects on the heart of a permanent implant in the atrial septum.

## Recent advances

While device closure of PFOs and select ASDs has been shown to be safe and effective in the short term compared with surgical closure, the serious complication of cardiac perforation or erosion has been identified as a concern not seen in early studies. Though rare, this

complication can be sudden and potentially lethal. Erosions from the ASO, the most widely used ASD closure device worldwide, have been estimated at 0.1% or less. Factors predisposing to erosion are not well understood because of the rarity of the complication and limited available data. Device over-sizing was the first potential factor implicated with limited data and led to revised guidelines regarding sizing of ASO devices [5]. There remains, however, considerable controversy regarding the mechanisms of erosion. El-Said and Moore [6] recently concluded from a survey that the majority of the members of a large consortium of interventional cardiologists specializing in treatment of structural heart disease felt that 'motion' of the device was a primary factor in erosions rather than device over-sizing. Moreover, recent findings suggest that implantation of an ASD device may lead to more geometric changes in surrounding cardiac structures than previously had been thought [7].

We have personally been struck by the surprisingly dynamic nature of the atrial septum and the variability in ASD dimensions during the cardiac cycle. In fact, the size of an ASD has been found to change significantly during different phases of the cardiac cycle – by as much as an 86% change in area in some patients [8-10]. This contractility and motion of the atrial septum may be important in the interaction of septal closure devices with the atrial septum and adjacent structures. No case of cardiac perforation has been reported with the HELEX device (the other device approved in the US), but this device is used only in small- and medium-sized defects and the experience with this device is limited because it was only recently approved by the FDA. In addition, this device may develop one or more fractures of the supporting frame in a small percentage of cases. While these fractures are almost universally not associated with clinical consequences, there has been a single case of damage to the mitral valve [11]. Frame fractures of the HELEX septal occluder may be a related to atrial compressive forces as well [11,12].

The focus of much of the recent work on ASD and PFO device development has been driven by the hypothesis that leaving a foreign implant behind might not be the ideal way to close these defects. The BioSTAR septal repair implant (NMT Medical, Inc., Boston, MA, USA) is a bioabsorbable device, the bulk of which is made of acellular porcine intestinal collagen cellular matrix. This material has been shown to be absorbed and replaced with native tissue within 2 years. The phase 1 clinical trial of the BioSTAR Evaluation Study [13] showed excellent closure rates for PFOs and ASDs, and the investigators hypothesize that the advantages to such a device are less

potential for thrombus formation, erosion, and arrhythmias and better accessibility to the left atrium if needed in the future. Another modality currently being evaluated is closure of PFOs without implants. The Paradigm 1 clinical study by Sievert *et al.* [14] used the PFX closure system (Cierra, Inc., Redwood City, CA, USA), which delivers radiofrequency energy to 'weld' the two sides of the atrial septum together. Although the study demonstrated feasibility and safety of the technique, closure rates were far less than those reported with current alternative PFO closure devices.

Understanding of the anatomy of the atrial septum and its relationship to important adjacent structures is a pivotal part of ASD and PFO closure. In recent years, imaging during the procedure with intracardiac echocardiography (ICE) has proven to be a safe and effective alternative to transesophageal echocardiography (TEE) in select patients. ICE has been shown to decrease procedure times while avoiding the need for general anesthesia in many patients [15]. This is our preferred adjunct imaging modality (in addition to fluoroscopy) in appropriate-sized patients. Moreover, it may be used in addition to TEE to guide closure of defects with difficult anatomy. Despite advances in imaging modalities (i.e., ICE), we feel that fluoroscopy remains an important part of the procedure and allows the operator to assess the anatomy of the defect (by angiography and balloon occlusion) and the configuration of the device in various imaging planes.

### Implications for clinical practice

Percutaneous device closure of ASD and PFO has proven to be an excellent alternative to surgical closure in the majority of affected patients. The percutaneous approach is clearly preferred by nearly all patients since it is an outpatient procedure that is much less painful and does not result in a lifelong visible scar. In centers with qualified interventionalists, over 80% of affected patients are treated with the percutaneous approach. However, operator and center experience are important considerations as increased short-term risks in adults do seem to correlate with the relatively lower number of procedures performed at centers annually [16]. While percutaneous device closure of secundum ASD and PFO provides overall excellent clinical results in short- to medium-term studies, there are few data on long-term outcomes and possible complications. FDA-mandated post-market surveillance studies, which are currently under way, may help to better characterize long-term risks. Although transcatheter ASD closure devices from only two manufacturers have been approved in the US, there are many other designs in various stages of development and use around the world. For any given

device, there are distinct advantages and disadvantages related to technical aspects, device profile, and retrievability. Though still experimental, newer technologies aimed at leaving little or no foreign material behind remain promising alternatives for the future.

### Abbreviations

ASD, atrial septal defect; ASO, Amplatzer septal occluder; FDA, US Food and Drug Administration; ICE, intracardiac echocardiography; PFO, patent foramen ovale; TEE, transesophageal echocardiography.

### Competing interests

LAL receives grant support and is a consultant at the 'less than significant' level for W.L. Gore & Associates, Inc. AMQ declares that he has no competing interests.

### References

- King TD, Mills NL: **Nonoperative closure of atrial septal defects.** *Surgery* 1974, **75**:383-8.
- Du ZD, Hijazi ZM, Kleinman CS, Silverman NH, Larntz K; Amplatzer Investigators: **Comparison between transcatheter and surgical closure of secundum atrial septal defect in children and adults: results of a multicenter nonrandomized trial.** *J Am Coll Cardiol* 2002, **39**:1836-44.
- Jones TK, Latson LA, Zahn E, Fleishman CE, Jacobson J, Vincent R, Kanter K; Multicenter Pivotal Study of the HELEX Septal Occluder Investigators: **Results of the U.S. multicenter pivotal study of the HELEX septal occluder for percutaneous closure of secundum atrial septal defects.** *J Am Coll Cardiol* 2007, **49**:2215-21.
- Butera G, Romagnoli E, Carminati M, Chessa M, Piazza L, Negura D, Giamberti A, Abella R, Pome G, Condoluci C, Frigiola A: **Treatment of isolated secundum atrial septal defects: impact of age and defect morphology in 1,013 consecutive patients.** *Am Heart J* 2008, **156**:706-12.
- Amin Z, Hijazi ZM, Bass JL, Cheatham JP, Hellenbrand WE, Kleinman CS: **Erosion of Amplatzer septal occluder device after closure of secundum atrial septal defects: review of registry of complications and recommendations to minimize future risk.** *Catheter Cardiovasc Interv* 2004, **63**:496-502.
- El-Said HG, Moore JW: **Erosion by the Amplatzer septal occluder: experienced operator opinions at odds with manufacturer recommendations.** *Catheter Cardiovasc Interv* 2009, **73**:925-30.
- Schoen SP, Boscheri A, Lange S A, Braun M U, Fuhrmann J, Kappert U, Strasser RH: **Incidence of aortic valve regurgitation and outcome after percutaneous closure of atrial septal defects and patent foramen ovale.** *Heart* 2008, **94**:844-7.

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- Handke M, Schafer DM, Muller G, Schochlin A, Magosaki E, Geibel A: **Dynamic changes of atrial septal defect area: new insights by three-dimensional volume-rendered echocardiography with high temporal resolution.** *Eur J Echocardiogr* 2001, **2**:46-51.
- Linguraru MG, Kabla A, Marx GR, del Nido PJ, Howe RD: **Real-time tracking and shape analysis of atrial septal defects in 3D echocardiography.** *Acad Radiol* 2007, **14**:1298-309.
- Maeno YV, Benson LN, McLaughlin PR, Boutin C: **Dynamic morphology of the secundum atrial septal defect evaluated by three dimensional transoesophageal echocardiography.** *Heart* 2000, **83**:673-7.
- Qureshi AM, Mumtaz MA, Latson LA: **Partial prolapse of a HELEX device associated with early frame fracture and mitral valve perforation.** *Catheter Cardiovasc Interv* 2009, **74**:777-82.
- Fagan T, Dreher D, Cutright W, Jacobson J, Latson L; GORE HELEX Septal Occluder Working Group: **Fracture of the GORE HELEX septal occluder: associated factors and clinical outcomes.** *Catheter Cardiovasc Interv* 2009, **73**:941-8.
- Mullen MJ, Hildick-Smith D, De Giovanni JV, Duke C, Hillis WS, Morrison WL, Jux C: **BioSTAR Evaluation STUDY (BEST): a prospective, multicenter, phase I clinical trial to evaluate the feasibility, efficacy, and safety of the BioSTAR bioabsorbable septal repair implant for the closure of atrial-level shunts.** *Circulation* 2006, **114**:1962-7.
- Sievert H, Fischer E, Heinisch C, Majunke N, Roemer A, Wunderlich N: **Transcatheter closure of patent foramen ovale without an implant: initial clinical experience.** *Circulation* 2007, **116**:1701-6.
- Boccalandro F, Baptista E, Muench A, Carter C, Smalling RW: **Comparison of intracardiac echocardiography versus transesophageal echocardiography guidance for percutaneous transcatheter closure of atrial septal defect.** *Am J Cardiol* 2004, **93**:437-40.
- Opotowsky AR, Landzberg MJ, Kimmel SE, Webb GD: **Percutaneous closure of patent foramen ovale and atrial septal defect in adults: the impact of clinical variables and hospital procedure volume on in-hospital adverse events.** *Am Heart J* 2009, **157**:867-74.