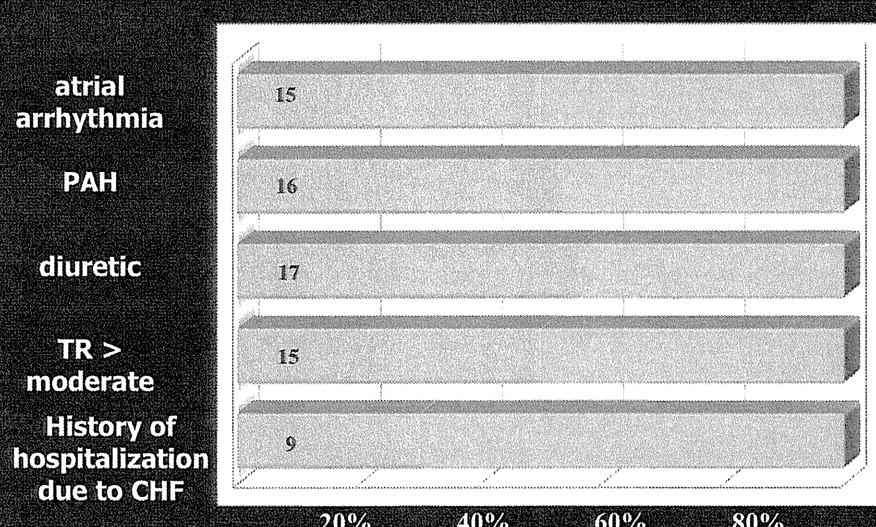
Japanese Society for Adult CHD

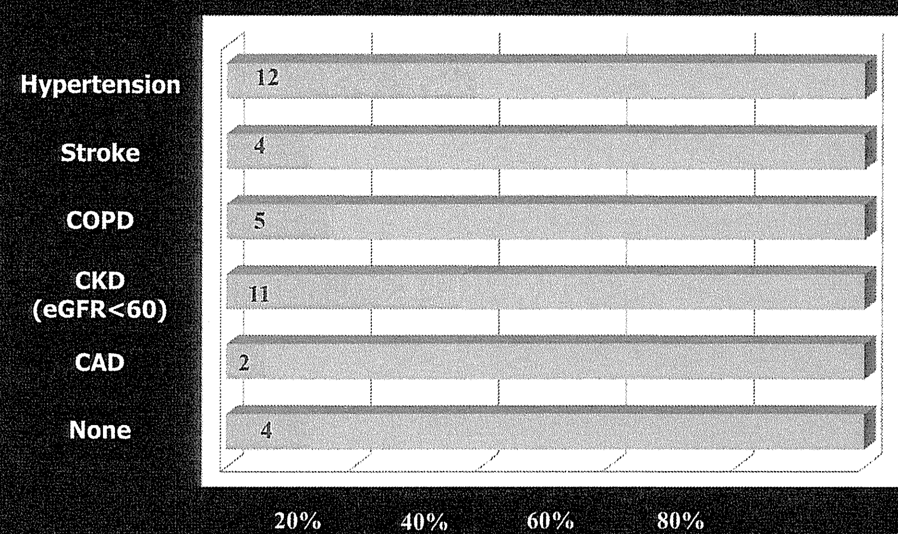
- Established in 1999
- Subgroup of Japanese Society for Pediatric Cardiology and Cardiac Surgery
- Active members: 200
  - 80% Pediatric Cardiologist
  - 10% Cardiac Surgeon
  - 5% Adult Cardiologist
  - 5% Obstetrician and Gynecologist

JSACHD

Comorbidities & Medication



Comorbidities



Catheter intervention

- 症例1

  VSD, PDA, Eisenmenger症候群

  ↓

  transcatheter ASD creation

- 症例2

  PA with VSD, APCA

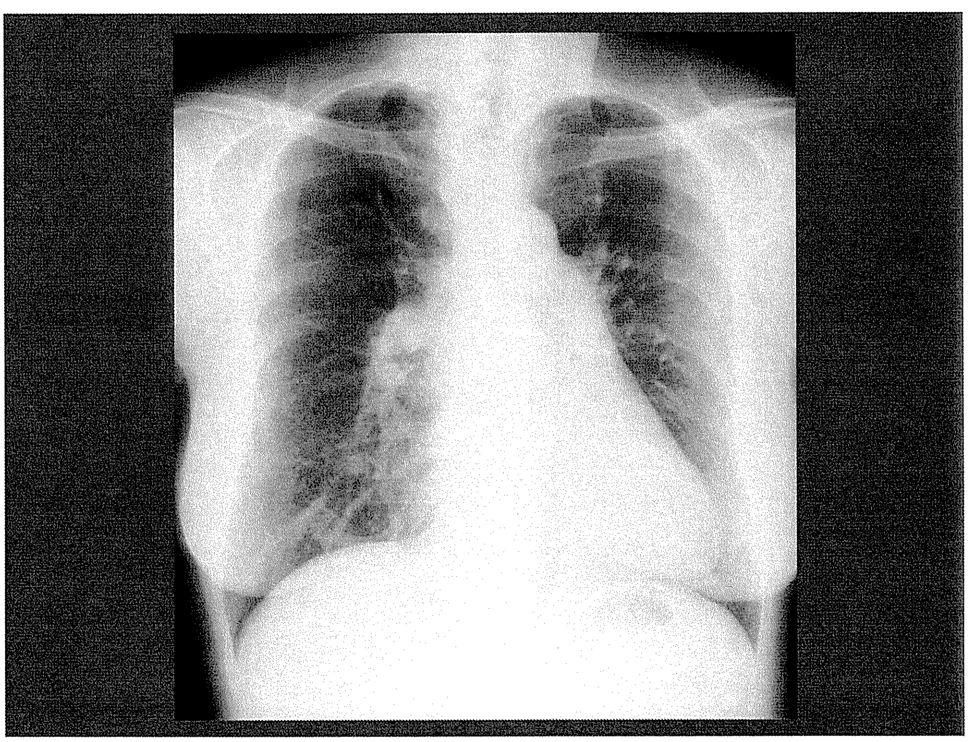
  ↓

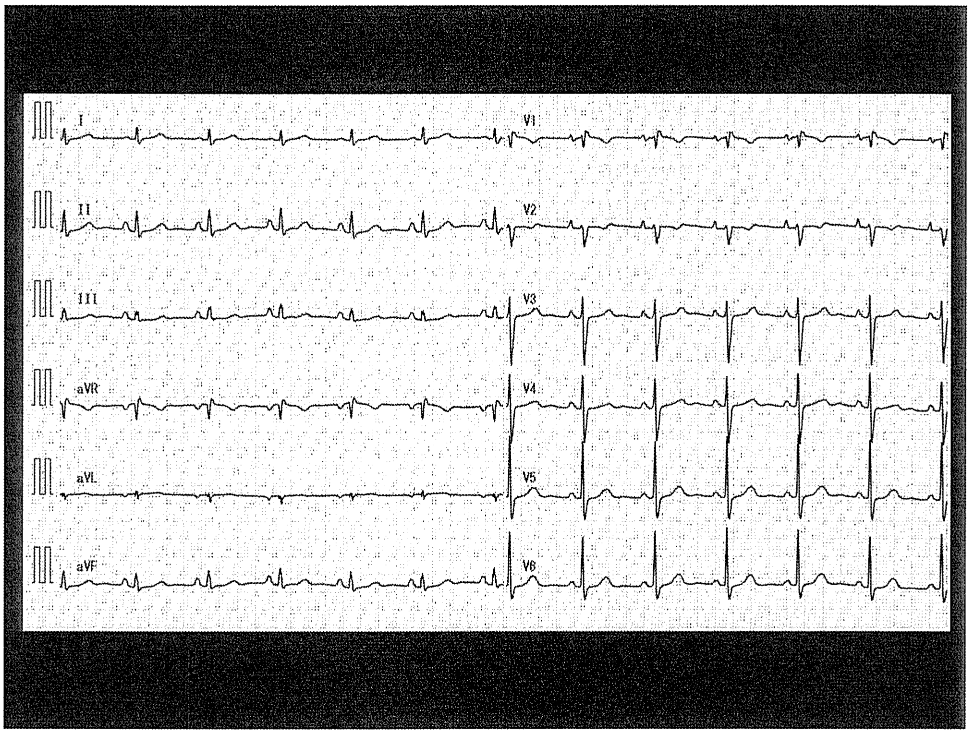
  transcatheter APCA occlusion

70 years female

- 10年ほど前の健康診断で胸部レントゲン異常を指摘され，心房中隔欠損症と診断された．手術を勧められたが，躊躇したまま経過をみられていた．

- 現在の処方
  amlodipine 5mg/day
  valsartan　80mg/day




I
II
III
aVR
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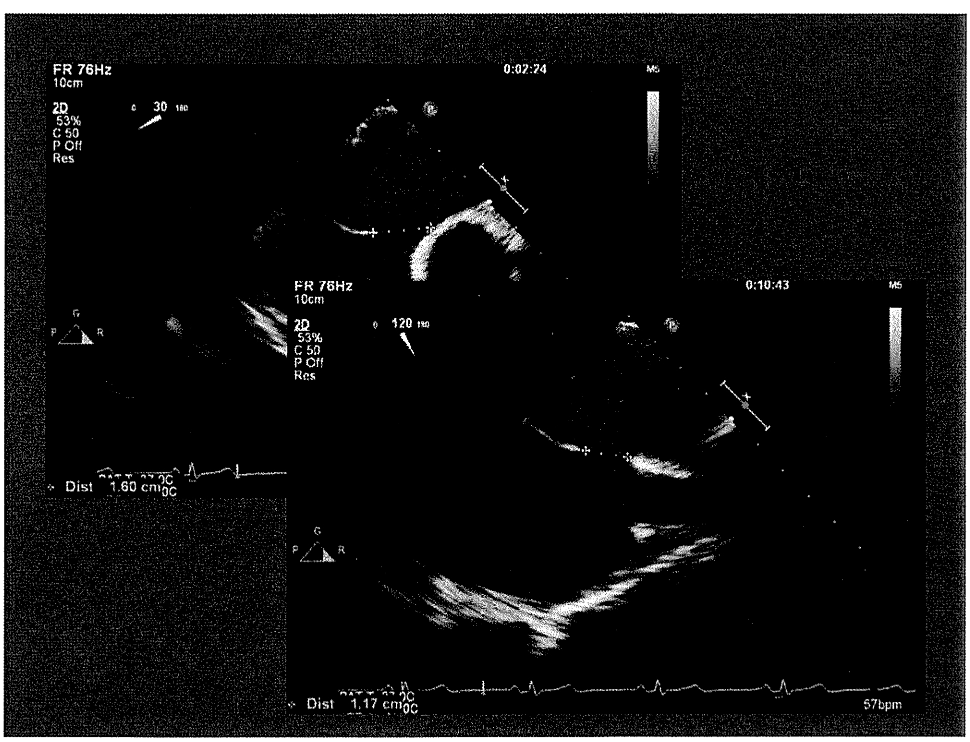
aVF
V1
V2
V3
V4
V5
V6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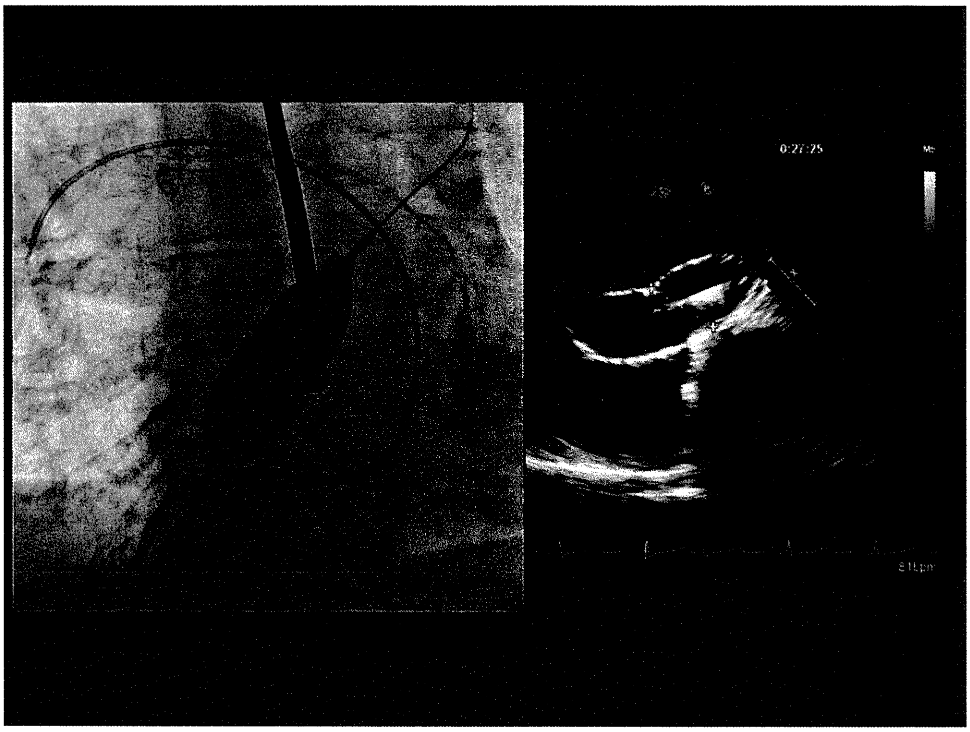
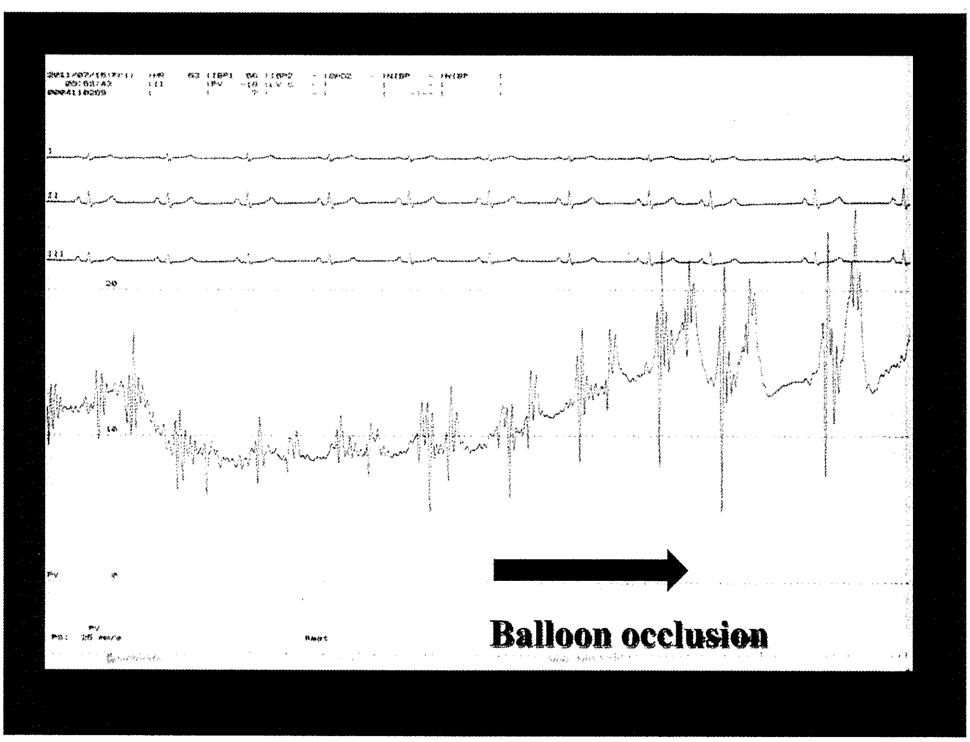
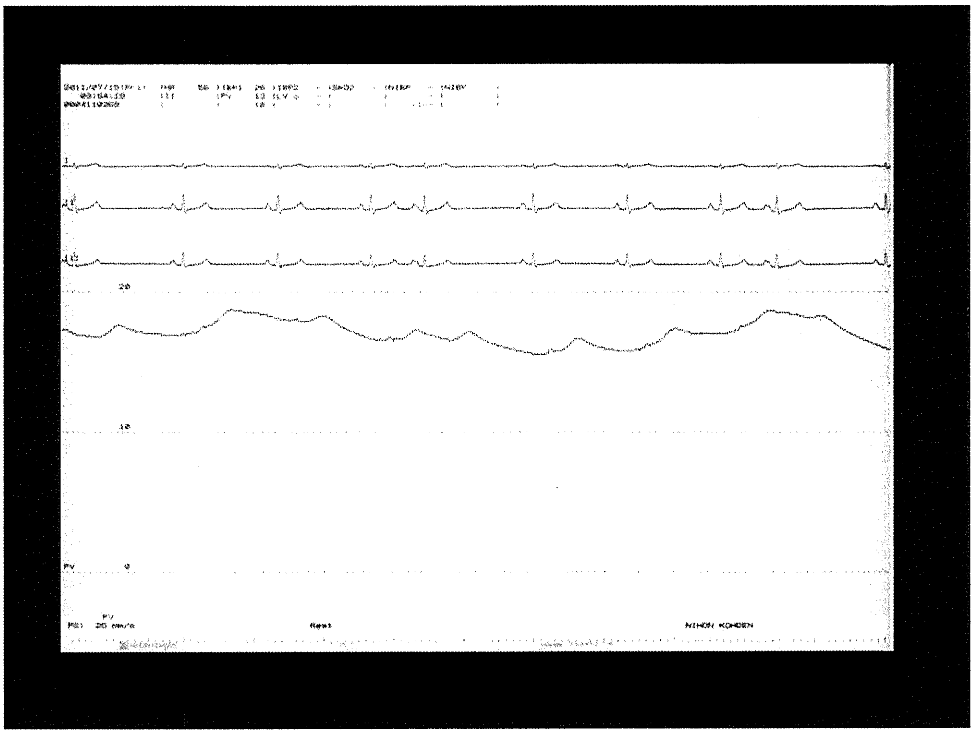
10cm
2D
53%
C 50
P Off
Res
0:02:24
30
Dist 1.60 cm
FR 76Hz
10cm
2D
53%
C 50
P Off
Res
0:10:43
120
Dist 1.17 cm
57bpm




Balloon occlusion

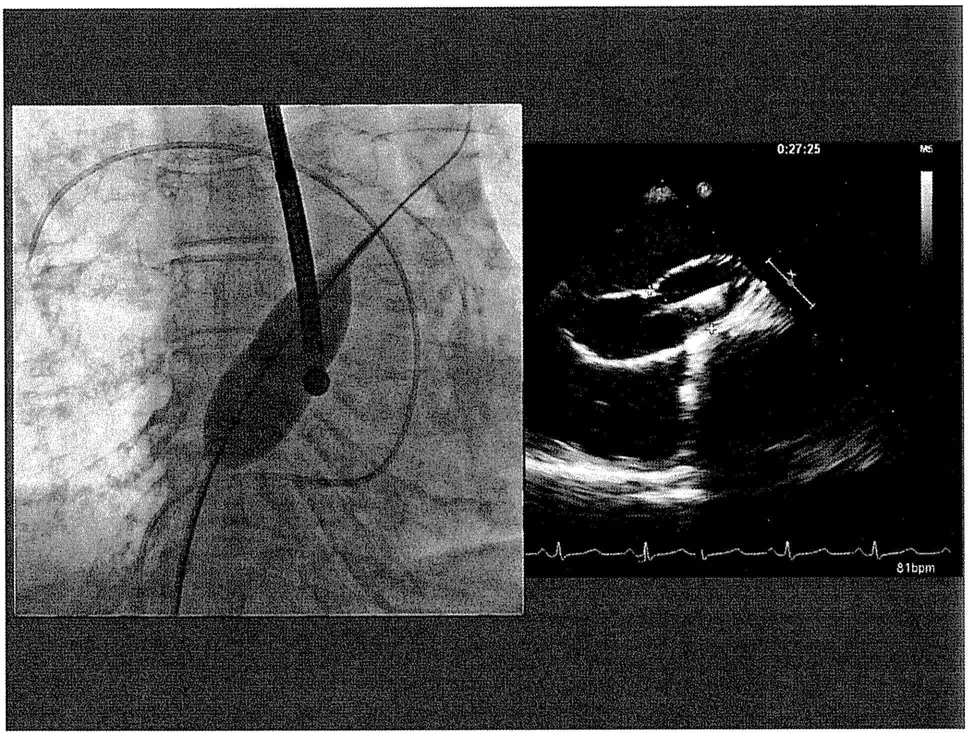


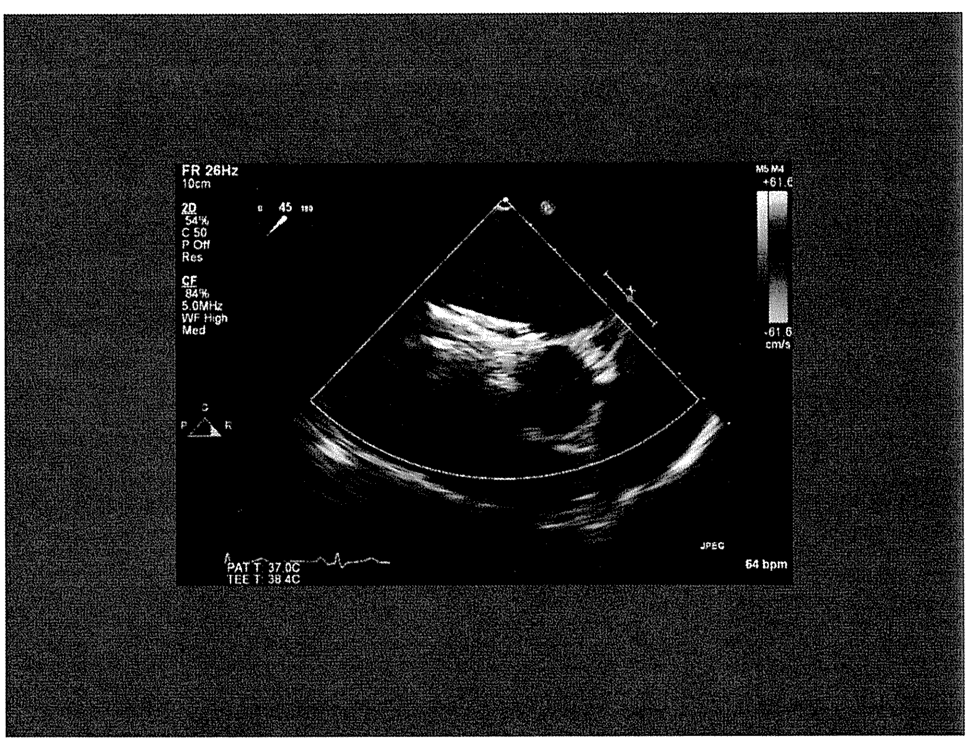
Masked Left Ventricular Restriction in Elderly Patients With Atrial Septal Defects: A Contraindication for Closure?

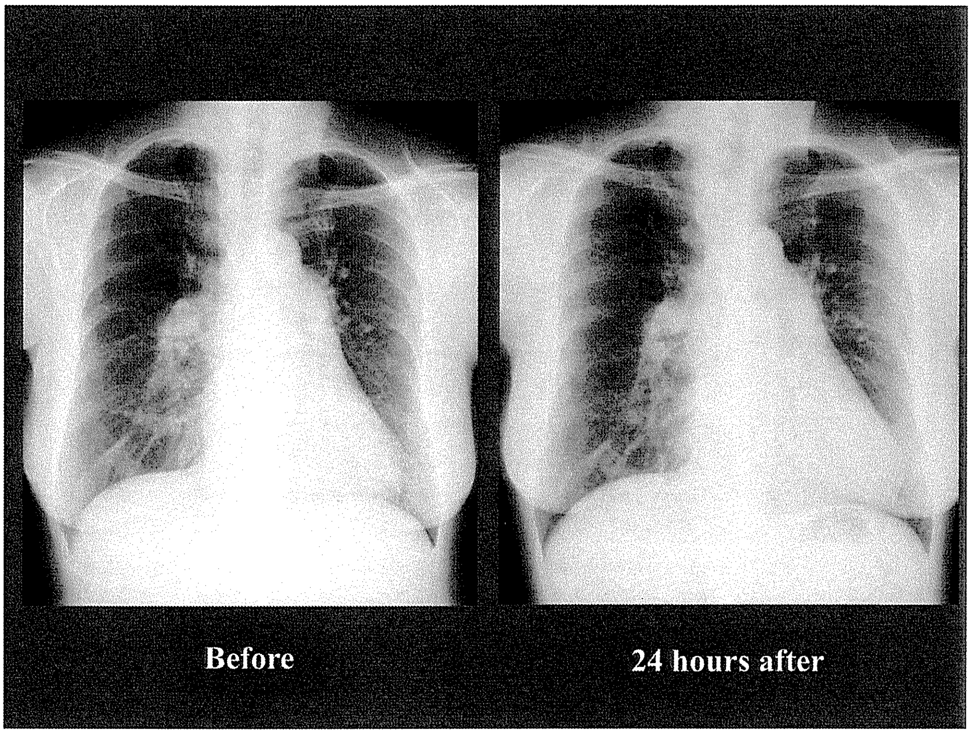
Peter Ewert,* MD, Felix Berger, MD, Nicole Nagdyman, MD, Oliver Kretschmar, MD, Sven Dittrich, MD, Hashim Abdul-Khaliq, MD, and Peter E. Lange, PhD

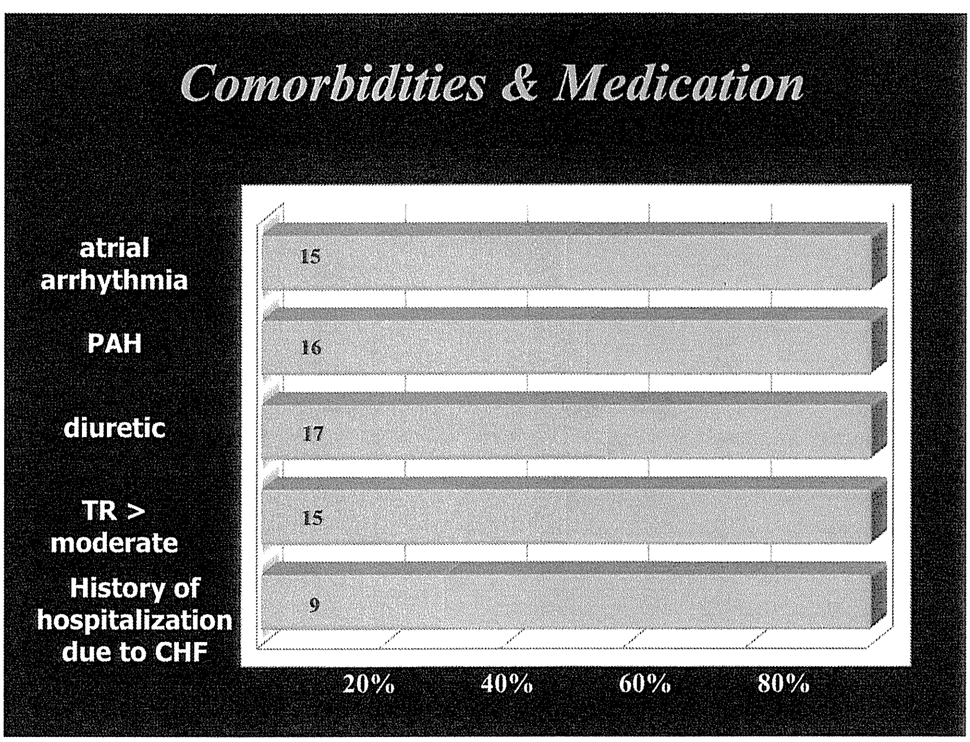
	Nonresponders (n = 11)	Responders (n = 7)	P
Age (median, years)	70	70	NS
Gender (f:m)	6:1	9:2	NS
Atrial flutter/fibrillation	4	4	NS
Systemic hypertension	5	3	NS
Coronary heart disease	0	1	NS
Defect diameter (mm)	24	25	NS
Shunt (Qp/Qs)	1.6	1.8	NS
Mean arterial pressure (mm Hg) before/during occlusion	94/95	94/93	NS
LA pressure (mean, mm Hg) before/during occlusion[a]			
a-wave	7/7	18/26	0.02
v-wave	6/7	24/41	< 0.001
Mean	3/4	14/23	< 0.001

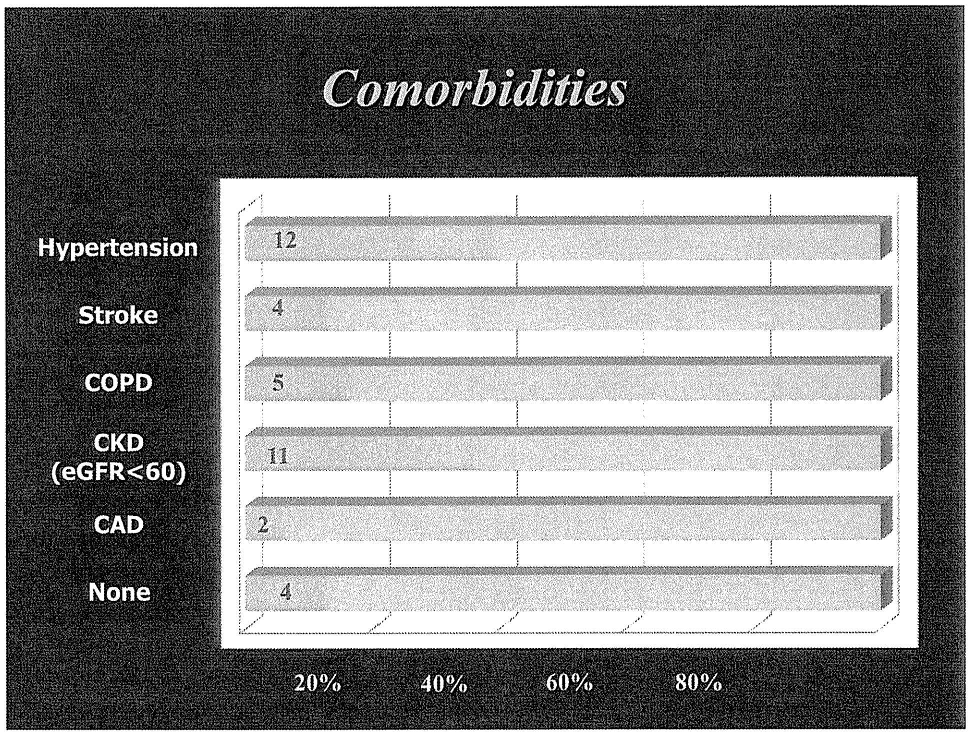
Catheterization and Cardiovascular Interventions 52:177–180 (2001)

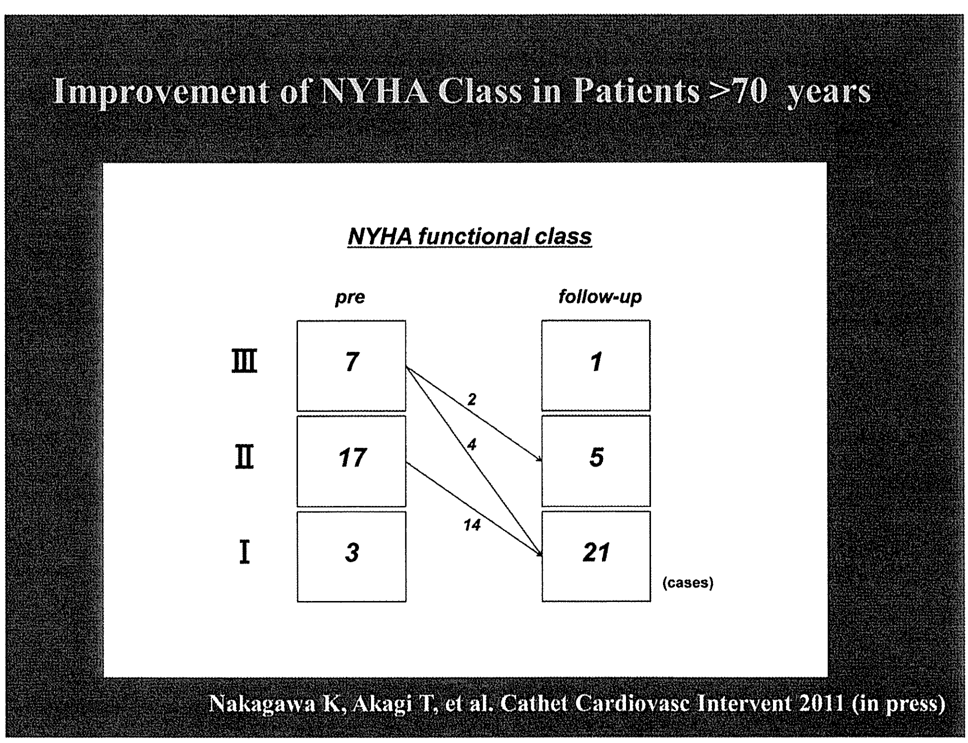

0:27:25
81bpm

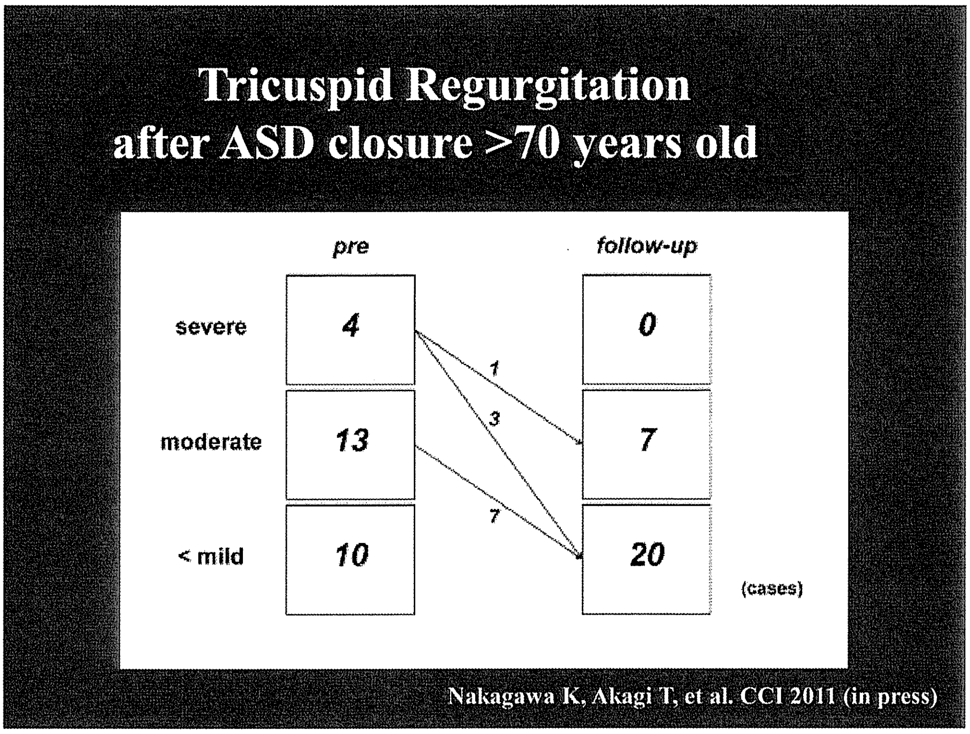

FR 26Hz
10cm
2D
54%
C 50
P Off
Res
CF
84%
5.0MHz
WF High
Med
45
+61.6
-61.6
cm/s
JPEG
64 bpm
PAT T: 37.0C
TEE T: 38.4C


Before
24 hours after


Comorbidities & Medication
atrial arrhythmia
PAH
diuretic
TR > moderate
History of hospitalization due to CHF
15
16
17
15
9
20%
40%
60%
80%


Comorbidities
Hypertension
Stroke
COPD
CKD
(eGFR<60)
CAD
None
12
4
5
11
2
4
20%
40%
60%
80%


Improvement of NYHA Class in Patients >70 years
NYHA functional class
pre
follow-up
Ⅲ
Ⅱ
Ⅰ
7
17
3
1
5
21
2
4
14
(cases)
Nakagawa K, Akagi T, et al. Cathet Cardiovasc Intervent 2011 (in press)


Tricuspid Regurgitation
after ASD closure >70 years old
pre
follow-up
severe
moderate
< mild
4
13
10
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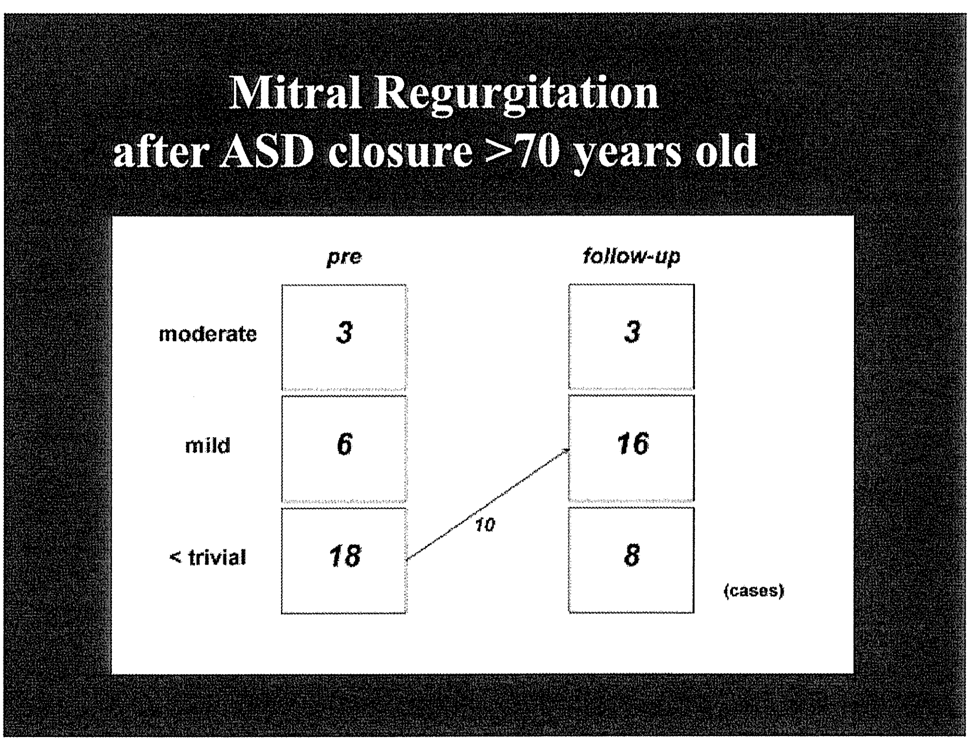
(cases)
Nakagawa K, Akagi T, et al. CCI 2011 (in press)


Mitral Regurgitation
after ASD closure >70 years old
pre
follow-up
moderate
mild
< trivial
3
6
18
3
16
8
10
(cases)


To establishment for optimal management system
for ACHD patients
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Cardiology in the Young 2011; Page 1 of 4
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Brief Report

Catheter closure of coronary sinus atrial septal defect using Amplatzer Septal Occluder

Yasufumi Kijima,[1] Manabu Taniguchi,[2] Teiji Akagi[2]

[1]*Department of Cardiovascular Medicine, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences;* [2]*Division of Cardiac Intensive Care Unit, Okayama University Hospital, Okayama, Japan*

Abstract Coronary sinus defect is a rare type of atrial septal defect. We report two patients who had a coronary sinus atrial septal defect without persistent left superior caval vein, where the orifice of the coronary sinus was closed using the Amplatzer Septal Occluder. The procedure was successful, without any complications including conduction disturbance.

Keywords: Adult congenital cardiac disease; catheter intervention; atrial septal defect

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CORONARY SINUS DEFECT IS A RARE TYPE OF ATRIAL septal defect in which communication occurs between the coronary sinus and left atrium as a consequence of a partial or complete absence of the coronary sinus septum, and it comprises less than 1% of atrial septal defects.[1] Coronary sinus defect can be considered as a type of unroofed coronary sinus syndrome. Unroofed coronary sinus syndrome is frequently associated with persistent left superior caval vein and other cardiac anomalies. Therefore, surgical repair is the standard treatment for patients with unroofed coronary sinus.[2–4] Closure of the coronary sinus orifice, resulting in coronary sinus flow draining into left atrium, is one of the operative options in patients who have unroofed coronary sinus without persistent left superior caval vein.

We report two adult patients who had coronary sinus defect without persistent left superior caval vein, and the orifice of the coronary sinus was closed using the Amplatzer Septal Occluder (AGA Medical Corporation, Plymouth, Minnesota, United States of America).

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Case 1

A 67-year-old man with exertional dyspnoea was referred to our institution for catheter closure of the atrial septal defect. The transthoracic echocardiography showed left-to-right shunt across the atrial septal defect, which was difficult to distinguish from the coronary sinus orifice. The transoesophageal echocardiogram showed unroofed coronary sinus, and the maximum diameter of the atrial septal defect was 8 millimetres, with an adequate rim around the defect, except for the deficient posterior rim. Cardiac contrast-enhanced computed tomography showed normal pulmonary venous return and the absence of the persistent left superior caval vein.

Catheter closure was performed under general anaesthesia. Pulmonary-to-systemic flow ratio was 1.57. Balloon-sizing with stop-flow technique resulted in a stretched diameter of 9 millimetres. A 9-millimetre device was deployed in a stable and proper position without any complications. The transoesophageal echocardiogram images clearly showed the unroofed portion of the septum between the coronary sinus and left atrium (Fig 1a and b). Systemic oxygen saturation before the procedure was 98% and did not change after the atrial septal

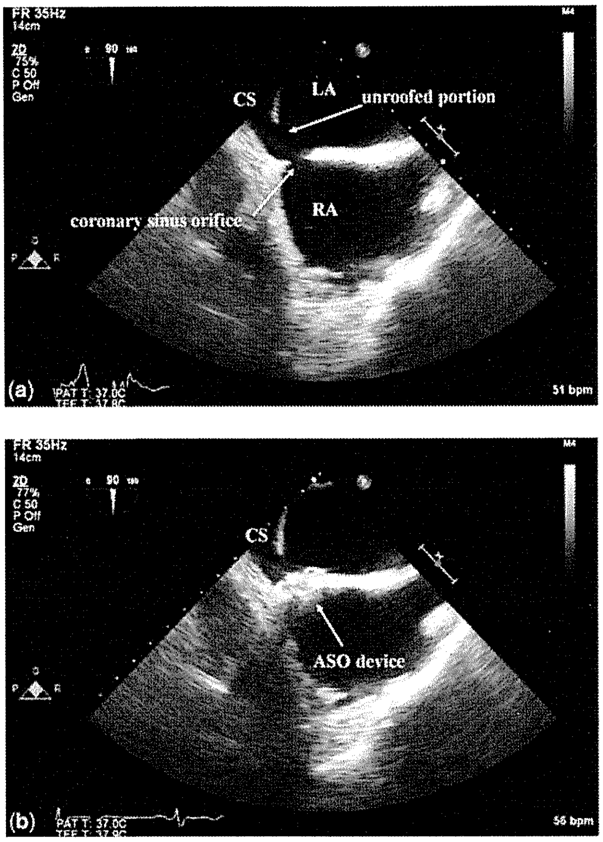

Figure 1.
(a) The transoesophageal echocardiogram shows the CS opening into both the LA and the RA. (b) The device is deployed in the interatrial septum with the unroofed portion of the CS remaining open (CS = coronary sinus; LA = left atrium; RA = right atrium; ASO = Amplatzer Septal Occluder).

defect closure (98%). At 24 months after the procedure, there were no complications, including atrioventricular blocks, and the patient had normal systemic oxygen saturation (98%).

Case 2

A 68-year-old man with exertional dyspnoea and a history of syncope was referred to our institution for catheter closure of the atrial septal defect. The transoesophageal echocardiogram showed unroofed coronary sinus, and the maximum diameter of the defect was 7 millimetres with adequate septal rim. The contrast echocardiography from the left arm did not reveal a flow of persistent left superior caval vein.

Catheter closure was performed under general anaesthesia. Pulmonary-to-systemic flow ratio was 1.69. A 9-millimetre device was selected by balloon-sizing and the device was deployed in a stable and proper position without any complications (Fig 2a and b). The transthoracic echocardiography after the procedure showed a considerably large unroofed portion of the coronary sinus with the device deployed in a stable position closing the interatrial left-to-right shunt (Fig 2c). Systemic oxygen saturation was 98% before the catheter closure and remained at the same level at discharge (98%). Desaturation was not observed around the catheter closure. At 19 months after the procedure, there were no complications, including atrioventricular blocks, and the patient had normal systemic oxygen saturation (98%).

Discussion

To our knowledge, this is the first case report of closing the orifice of the coronary sinus using an Amplatzer Septal Occluder device in patients who had unroofed coronary sinus without persistent left superior caval vein. There are four previous case reports of catheter treatment in cases with unroofed coronary sinus.[5–8] Of the four case reports, one showed catheter closure of the coronary sinus defect with persistent left superior caval vein using the Amplatzer Septal Occluder device. In this case, the unroofed portion of coronary sinus was closed and persistent left superior caval vein was draining into the right atrium after the closure.[5] Two reports showed catheter treatment for a persistent left superior caval vein using a caval vein filter and coil,[6] as well as a vascular occlusion device.[7] Another report showed catheter treatment for the unroofed portion of the coronary sinus using a covered stent.[8] All these reported cases were complicated with persistent left superior caval vein; however, our cases were not.

Previous reports have classified the morphology of unroofed coronary sinus into four types.[1] Diagnosis of the coexistence of persistent left superior caval vein is important because it may cause systemic embolisation and/or generalised cyanosis due to right-to-left shunt and it may also alter the strategy for treatment, including the method of anatomical reparation in the surgical procedure.[4,9] Both of our cases had developed partially unroofed portion of the coronary sinus without persistent left superior caval vein, and therefore our cases belonged to partially unroofed terminal portion of the coronary sinus type of Kirklin and Barratt-Boyes classification.

In cases with partially unroofed terminal portion of coronary sinus, the coronary sinus orifice opens into the left atrium rather than the right atrium and the localised aperture of the unroofed portion is just before the orifice of the coronary sinus. In this type of unroofed coronary sinus, standard surgery involves closure of the unroofed portion or allowing the coronary sinus to open into the left atrium by closure of the orifice of coronary sinus. Our cases were not complicated with persistent left superior

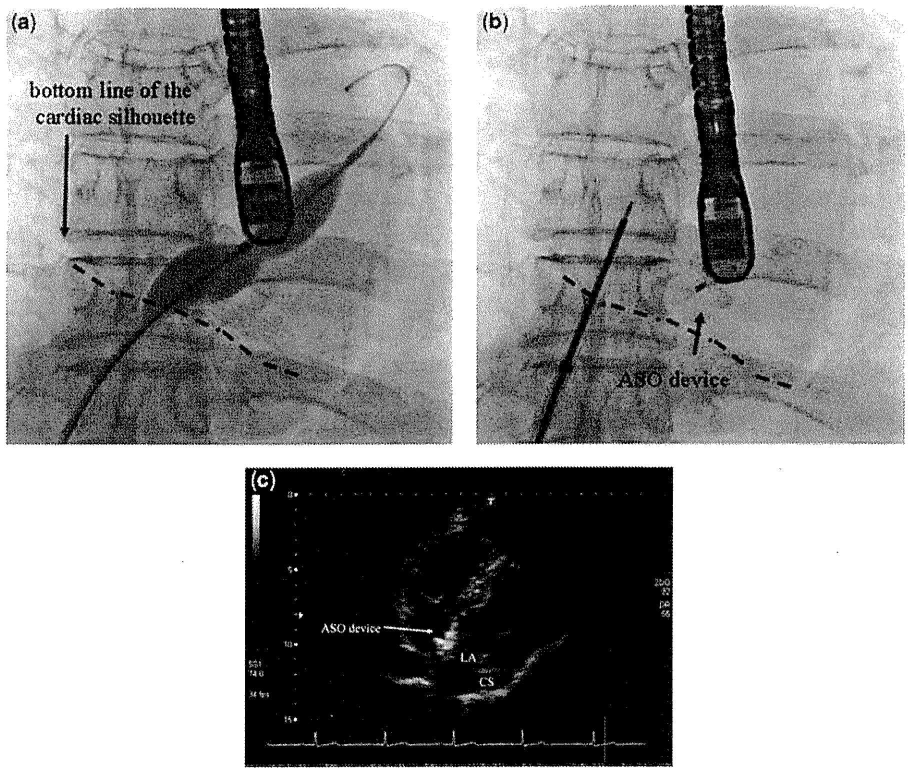

Figure 2.
(a) The cineangiographic image of balloon-sizing in the anteroposterior projection shows that the waist of the balloon is positioned lower than usual for secundum-type atrial septal defect. (b) The device is deployed with stability in the same position as the waist of the balloon. (c) The transthoracic echocardiogram shows a large unroofed portion of the CS with the device deployed in the interatrial septum (ASO = Amplatzer Septal Occluder; CS = coronary sinus; LA = left atrium).

caval vein, and therefore there was clinical validity for the closure of the atrial septal defect, which corresponded to the orifice of the coronary sinus. Catheter closure of the atrial septal defect is an accepted procedure worldwide, even in adults.[10] In patients with partially unroofed terminal portion of the coronary sinus-type unroofed coronary sinus, surgical closure of the coronary sinus orifice or aperture of the unroofed portion of the coronary sinus is generally selected. In surgical procedures, conduction disturbances, including complete atrioventricular blocks, can lead to operative complications and caution is required during the procedure to avoid these complications.

In our cases, there were no additional conduction disturbances during the procedures and during the follow-up period. In addition, even though the coronary venous flow drained into the left atrium, there was no change in systemic oxygen saturation when observed immediately after occlusion, as well as during our follow-up period. Long-term follow-up is important for the evaluation of systemic desaturation due to drainage of coronary venous flow into the left atrium. The findings from our cases suggest that catheter closure might be not disadvantageous for conduction disturbance compared with standard and conventional surgical reparation in the acute or mid-term period after the procedure. Because the compact atrioventricular node, conduction tract and the branching bundle lie beneath the transitional cells or the atrial overlay cells,[11] mild compression from the surface by device might not damage the conduction tract.

In conclusion, our experiences suggested that catheter closure of coronary sinus atrial septal defect is a simple and novel approach. A precise diagnosis of the unroofed coronary sinus and information about the presence of persistent left superior caval vein is mandatory for indication of this procedure.

Acknowledgment

The authors thank Dr Koji Nakagawa for supporting their procedure as an assistant operator, and Dr Shunji Takemoto for providing them the patients' information of case 2. This study was not supported by any funding. The authors have no conflict of interest to declare.

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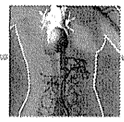

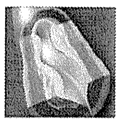

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Real-time imaging for transcatheter closure of atrial septal defects

Nowadays transcatheter closure has become the standard treatment for an atrial septal defect (ASD). Since morphologic variation of ASD is common, imaging modalities with high diagnostic ability continue to be required. Meanwhile, experts are required to visualize high-quality images with advanced imaging modalities. Echocardiography plays a pivotal role in patient selection for treatment, recently introduced 3D echocardiography is a promising modality to provide comprehensible *en face* images of ASD, especially in patients with a complex-shaped ASD. In addition, cardiac MRI and computed tomography can provide complementary information. Transesophageal echocardiography and intracardiac echocardiography can provide images of excellent quality for guidance of the procedure. In this review, we discuss the role of imaging for transcatheter ASD closure, focusing on echocardiography.

KEYWORDS: 3D atrial septal defect imaging modality intracardiac echocardiography transcatheter closure transesophageal echocardiography

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tmnb@md.okayama-u.ac.jp

More than half a century has passed since the first surgical closure of an atrial septal defect (ASD) was performed with cardiopulmonary bypass [1], and it has been the standard treatment for all types of ASDs. Ever since the first transcatheter closure of an ASD was reported in 1976 [2]. With further development and improvement of the transcatheter technique and devices, these transcatheter techniques have become an alternative to surgical closure in most patients with secundum type of ASDs [3–5]. Various devices have been developed, however some of them are no longer used. The Amplatzer® Septal Occluder (ASO) (AGA Medical, MN, USA) is one of the most frequently used devices. More than 200,000 devices have been implanted worldwide since 1996, and excellent outcome with the use of the device including cardiac remodeling and exercise capacity for both pediatric and adult patients, has been reported in short- and long-term follow-up [5–8].

Remarkable progress has recently been made in noninvasive imaging modalities including echocardiography, computed tomography (CT) and cardiac magnetic resonance (CMR) imaging, and they have been absolutely essential for structural heart intervention in such situations as selection of patients, guiding the procedure and post-procedural assessment. Although visualization of high-quality images with these advanced imaging modalities is often hard to learn, images obtained by expert hand can facilitate an understanding of the complex morphology of structural heart disease and can contribute to procedural success. Therefore, interventionalists performing structural heart interventions should be familiar with these imaging modalities.

Morphologic variation of ASDs is common [9] and the shape of ASDs change dynamically during the cardiac cycle [10]. Thus, imaging modalities for evaluating ASDs are required to have sufficient temporal and spatial resolutions. Device portability and real-time imaging capability are also indispensable for guiding the procedure in the catheterization laboratory. From these standpoints, echocardiography has a central role in imaging for this treatment [11]. Therefore, in this article we discuss the role of imaging for transcatheter ASD closure using ASO, focusing on echocardiography.

Patient selection for transcatheter ASD closure

Candidates for ASD closure have a hemodynamically significant atrial shunt or the presence of right ventricular volume overload and/or clinical symptoms of dyspnea, reduced exercise capacity or paradoxical embolism [12]. Pulmonary vascular resistance <5 wood units/m^2 and peak pulmonary artery pressure ≤70% of systemic blood pressure are also important conditions for ASD closure [13]. In general, an ASD of more than 10 mm in diameter is considered to account for a significant left-to-right shunt, although ASD can enlarge with time, independent of age at diagnosis and body surface area [14]. In addition

future medicine part of fsg

to these indications, ASD morphology should be suited for transcatheter closure.

Morphological indication

It is well known that morphological variations of ASD are frequent and that appropriate patient selection for transcatheter ASD closure is crucial for a successful procedure [4,9,15]. ASDs are grouped into four major categories: ostium primum, ostium secundum, sinus venosus and coronary sinus septal defect (Figure 1). Ostium secundum is the most common type of ASD, in which the defect involves the region of the fossa ovalis, and this type is indicated for transcatheter ASD closure. Coronary sinus septal defect is a rare type, in which a communication occurs between the coronary sinus and the left atrium as a result of an unroofed coronary sinus. Ostium primum and sinus venosus are indicated for surgical repair. Although surgical repair is the standard treatment for a coronary sinus septal defect, there are some case reports in which transcatheter closure was successful [16,17].

In patients with ostium secundum, two crucial parameters – the maximal ASD diameter in order to select a device with the appropriate size and the surrounding rim dimensions to optimize the placement of the device – should be assessed to select patients for transcatheter ASD closure. The defect must have a maximal balloon sizing diameter of <38 mm. Most ASDs have an ellipsoidal shape and the shape varies during the cardiac cycle [18,19]. The major axis diameter of the defect, measured in the phase of ventricular end systole, is mandatory for selecting the optimal ASO size, especially in patients undergoing the procedure without balloon sizing [20]. Transcatheter closure of a large ASD with a maximal native diameter >25 mm remains challenging and alternative special techniques for deployment of the device are usually required [21]. With regard to the classification of surrounding rims, although there are some differences among studies [9,22,23], distances from the ASD to the aorta (superoanterior rim), superior vena cava (superoposterior rim), right upper pulmonary vein (posterior rim), inferior vena cava (inferoposterior rim), coronary sinus and atrioventricular valve (inferoanterior rim) are assessed. The definition of rim deficiency varies among different studies: <2 mm [24], <3 mm [25], <5 mm [5,9,15,21,23,26–28] and <7 mm [29], but in many studies any rim was considered deficient if its length was <5 mm. Deficiency of superoanterior rim is not an absolute contraindication for the procedure with ASO.

Role of echocardiography

2D and color Doppler transthoracic echocardiography (TTE) can demonstrate the presence of ASDs, chamber dilatation, estimated pulmonary artery pressure, shunt ratio and other coexisting heart disease with high sensitivity and specificity in real-time. The use of tissue Doppler imaging can facilitate an understanding of cardiac diastolic function. Impaired cardiac function before ASD closure may lead to the development of congestive heart failure after ASD closure, especially in elderly patients [30,31]. However, in terms of accurate assessment of ASD morphology, including measurements of maximal diameter and surrounding rims, 2D TTE sometimes has limited ability to clearly visualize ASDs in detail, especially in adult patients, and precise evaluation using transesophageal echocardiography (TEE) is therefore necessary in most ASD patients (Figure 2) [6,9,15].

3D echocardiography provides better spatial visualization and 3D TEE can delineate the 3D structure with high-resolution images. Thus, 3D echocardiography offers the ability to improve display and our understanding of complex lesions such as valvular and congenital heart diseases [32–34]. In addition, although 3D echocardiography was initially based on reconstructed images from serial 2D images, which required cumbersome acquisition and time-consuming offline analysis, real-time 3D echocardiography, using a matrix array transducer, has recently become available in TTE as well as in TEE [35]. 3D TTE is a promising modality to provide comprehensible *en face* image of ASD because of its noninvasiveness, low cost, portability and wide availability [36]. 3D TTE can also provide accurate information of ASD morphology, including location, size and surrounding rims, for transcatheter ASD closure both in children [37–39] and adults [38,40]. However, there are several limitations of 3D TTE at present including dependence on the skill of the operator, restrictive echo window (especially in elderly patients), echo dropout in the region of the mid portion, which can lead to false diagnosis of a large defect [41] and lower temporal and spatial resolutions than those of 2D TTE. On the other hand, ASD morphology can be recognized with a high quality *en face* image using 3D TEE [10,18,19,27,42,43]. Real-time 3D TEE allows for evaluation of ASDs of various shapes, especially in patients with complex-shaped ASD, such as multiple ASDs (Figures 3 & 4) [44,45].

CMR & CT

Although echocardiography has a central role in patient selection for transcatheter ASD closure in clinical practice, CMR imaging and CT can provide complementary information with a large field of view and low-operator dependency.

CMR imaging has been regarded as the gold standard method for evaluation of right ventricular volumes and function and has demonstrated favorable right heart remodeling after transcatheter ASD closure [7]. Previous studies showed that CMR can provide an accurate assessment of shunt flow and morphology of an ASD in both pediatric [46,47] and adult patients [48–50] with high temporal and spatial resolutions. Regarding assessment of ASD morphology for transcatheter closure, Thompson *et al.* demonstrated in 44 adult patients that CMR could identify correctly the type of ASD in 95% of the patients compared with assessment with TEE or intracardiac echocardiography (ICE) [49]. In addition, both CMR and ICE measurements of the defect area correlated with deployed ASO size, especially in patients with ASD area <3 cm^2 or extremely eccentric defects, CMR also correlated significantly with ASO size, although ICE did not [49]. In pediatric patients with an ASD who have inconclusive TTE results, CMR can provide satisfactorily accurate defect size and rim distances compared with TEE measurements [47]. However, lengthy acquisition time is one disadvantage of using CMR and general anesthesia or sedation may be required in pediatric patients.

With advancement of CT technology in recent years, electrocardiographic gated multidetector CT allows for evaluation of not only extracardiac anatomy, but also intracardiac anatomy, with high temporal and spatial resolutions, multiplanar reconstruction capabilities and wide field of view [51]. Quaife *et al.* demonstrated that ASD area, measured by CT angiography with multiplanar reformation images, was strongly correlated with ICE measurements of balloon cross-sectional area calculated as a circle, although CT angiography appeared to slightly overestimate the defect size in larger ASD when compared with balloon sizing. Especially in patients with a large ASD (>15 mm) or inferior rim deficiency, CT angiography was superior to conventional TEE [24]. Although the rapid acquisition time is a major advantage of CT angiography over echocardiography and CMR, ionizing radiation exposure is one of the major limitations of CT angiography, especially in pediatric patients [52]. In addition, use of contrast agent may induce renal failure, especially in elderly patients with impaired renal function.

Real-time imaging during transcatheter ASD closure in the catheterization laboratory

Although conventional transcatheter intervention, as represented by percutaneous coronary intervention, has been performed mainly under angiographic and fluoroscopic guidance, structural heart interventions, including interventions for congenital and valvular heart disease, require more detailed anatomical information with high quality real-time imaging during the procedure, because of the complex structure of disease and their complex procedures.

In transcatheter ASD closure, either TEE or ICE and fluoroscopy are more commonly used for guiding the procedure. There are several checkpoints in guidance of the procedure with echocardiography in the catheterization laboratory. First, ASD morphology and other comorbid abnormalities such as valvular heart disease, ventricular function or pulmonary hypertension evaluated in the echocardiographic laboratory preprocedurally, should be confirmed just prior to the procedure in the catheterization laboratory. A prominent Eustachian valve can interfere with the procedure with valve tissue becoming trapped on the delivery cable [53]. In guidance of the procedure, checking the position of the tip of the guide wire and catheters, measurement of balloon sizing diameter with the stop flow method, using color Doppler if necessary, ensuring the position of the device after deployment, and assessment of residual shunt and potential complications before and after releasing the device are required (Supplementary Figure 1). Although transcatheter ASD closure has been established as a reliable and safe procedure [4–6,54] and echocardiography contributes greatly to the procedural result, several complications caused by the procedure have been reported. The most frequent major complication is device embolization. A multicenter retrospective study of surgery for complications of transcatheter ASD closure over a 10-year period (1997–2007), revealed that early emergency operations were required due to device embolization (n = 22), thromboembolism, cerebral ischemia or stroke (n = 4), hemopericardium (n = 5), significant residual shunt (n = 6), early endocarditis (n = 1) and esophageal perforation (n = 1) [55]. In a survey of ASO company-designated proctors, the incidence of ASO embolization was 0.55% (21 embolizations in 3824 device placements). Most of the embolizations occurred because of an inadequate rim or undersized device [56]. In patients with a pacemaker lead in the right atrium, the device can entrap the lead accidentally (Figure 5) [57]. In addition, occurrence of complications was associated with hospital procedural volume [58]. When complications have required surgical management after the procedure, the patients can have a worse prognosis than for those patients who have undergone primary surgical ASD closure [55]. Therefore, meticulous preprocedural evaluation of the ASD and precise guidance of the procedure, including selection of optimal device size using high-quality imaging, should be mandatory.

Echocardiography as a tool for guiding the procedure

TEE

TEE can provide high-resolution multiplanar images with high frequency capability from the outside of the heart. Echocardiography is mobile, but the size of its console for connecting the TEE probe has conventionally been large. TEE-guided intervention usually requires patients to be under general endotracheal anesthesia because of the length of the interventional procedure and the discomfort associated with TEE; therefore, there has usually not been enough room around the head of the patient due to the anesthetic equipment, C-arms and console of the echocardiography in the catheterization laboratory during TEE-guided intervention. Thus, several portable consoles have recently become available and some TEE probes can be connected to these consoles (Figure 6 & Supplementary Table 1).

A matrix-array 3D TEE probe (X7-2t; Philips Medical Systems, MA, USA) in which 2500 elements are used, not only enables easy visualization by providing comprehensible *en face* 3D images, but also provides high-quality 2D TEE images with the same probe. Since temporal and spatial resolutions of 3D TEE images have been limited compared with those of 2D TEE images, the ability to switch freely between 2D and 3D modes is important for guiding the procedure in the catheterization laboratory. Comprehensible 3D TEE images contribute to a quick understanding of ASD morphology by interventionalists and echocardiographers. This is especially highlighted in patients with a complex-shaped ASD especially (Figure 7). Real-time 3D TEE was useful for understanding the complication in our case, with a torn atrial septum during the procedure, and it allowed us to choose an appropriate therapeutic strategy [59]. For determining the maximal ASD diameter, correct measurement of which is critical for selecting the optimal device size in patients without balloon sizing or with inadequate balloon sizing diameter due to a large defect or inferoposterior rim deficiency, 3D TEE is more useful than 2D TEE or ICE [27,60,61].

The semi-invasive nature of the TEE procedure is one of the major limitations of TEE-guided interventions. Due to the recent advancement concerning the TEE probe, a miniature-sized multiplane micro-TEE probe has also become available. Micro-TEE (S8–3; Philips Medical Systems) is equipped with M-mode, 2D, color, pulse- and continuous-wave Doppler (Figure 8). Although this probe is obviously useful for small infants, the use of this probe for adult patients has the potential to reduce the patient's discomfort during the procedure (Figure 9). Stec *et al.* reported the use of micro-TEE probe for 12 patients undergoing atrial fibrillation ablation enabled all patients to tolerate the procedure in the supine position without sedation for a mean of 54 ± 17 min [62]. Although image quality and rise in probe temperature should be improved in the future [62], a downsized TEE probe will be a promising tool during guidance of the procedure for both pediatric and adult patients.

Another limitation of TEE is poor visualization of the inferoposterior rim if it is deficient. In some pediatric and young adult patients with a small left atrium, a large TEE probe may interfere with deployment of the device due to the TEE probe pressing on the left atrium toward the inter-atrial septum from the outside of the heart (Figure 10) [63].

ICE

ICE has recently undergone remarkable developments in image resolution, tissue penetration, catheter size and its manipulations. As a result, it has been used widely in clinical settings for monitoring and guiding in the field of electrophysiology and structural heart interventions [64]. Originally, transcatheter ASD closure was undertaken with TEE guidance; however, excellent ICE imaging, capability of manipulating the ICE catheter for interventionalists and visualization and interpretation of images with local anesthesia have led to the spread of the ICE-guided procedure [64–68]. The ICE-guided procedure does not require an anesthesiologist or, in some instances, even an echocardiographer. These advantages result in shorter fluoroscopic and procedural time [66,68], and reduced hospital stay compared with the TEE-guided procedure. Phased-array ICE imaging during transcatheter ASD closure can provide equivalent information compared with TEE imaging, including information on blood flow with color Doppler. In addition, a previous study demonstrated that success rate, complication rate and rate of complete defect closure during a 6-month

Box 1. Factors in deciding whether to choose transesophageal echocardiography or intracardiac echocardiography for guidance of transcatheter atrial septal defect closure.

Factors in institutions
- Healthcare system in each country
- Hospital procedural volume
- Availability of apparatus
- Availability of anesthesiologist and echocardiographer

Factors in patients
- Age of patient
- Morphology of ASD (large defect, multiple defects, inferoposterior rim deficiency)
- Left atrium size
- Comorbidity of patient
- Preference of the patient

Factors in interventionalists
- Preference of the interventionalist
- Training

ASD: Atrial septal defect.

follow-up period were similar in patients who underwent ICE-guided procedure and patients who underwent the TEE-guided procedure [69]. In addition, ICE is superior to TEE for visualization of the inferior interatrial septum (Figure 11). An expensive and nonreusable ICE catheter is one of the disadvantages of the ICE-guided procedure, although total costs for ICE and TEE were reported to be comparable because general anesthesia was not necessarily required [70]. Current limitations of ICE, other than cost, include single-plane imaging, sheath size and incapability of 3D imaging (Supplementary Table 2).

TEE-guided procedure or ICE-guided procedure for ASD?

Each echocardiographic modality has some drawbacks and advantages, both modalities can be performed safely and can provide images of excellent quality for transcatheter ASD closure. Therefore, selection of modality depends on factors of the institution, patients and interventionalists (Box 1).

Future perspective

The development of real-time 3D TEE has made a great impact on structural heart interventions, especially in patients who have a complex structure and require a complicated procedure. One of the advantages of the 3D echocardiography-guided procedure, compared with the 2D procedure, is the unnecessity of mental spatial reconstruction of complex morphology of ASD in the catheterization laboratory. 3D ICE will be available in the near future (Figure 12) [71]. Although cost is an issue in a single-use 3D ICE catheter, this development will greatly contribute to the field of structural heart interventions.

Meanwhile, miniaturized TEE probe size may enable a transnasal approach in adult patients during the procedure, eliminating the necessity for general anesthesia [72,73]. Although the spatial resolution is still limited in the currently available micro-TEE probe, a new release of the probe is expected, and development of a miniaturized TEE probe will solve the problem of cost in the ICE-guided procedure.

Conclusion

Transcatheter closure has become the standard treatment for an ASD and its safety and effectiveness are widely accepted in most cases of secundum ASD. However, morphologic variation of ASDs is common and imaging modalities with high diagnostic ability and patient-friendliness are therefore required.

Supplementary data

Supplementary data accompanies this paper and can be found at www.futuremedicine.com/doi/suppl/10.2217/ICA.11.73

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