ПРЕИМУЩЕСТВА КОМПЬЮТЕРНОЙ ТОМОГРАФИИ СЕРДЦА ПРИ ТРАНСКАТЕТЕРНОМ ЗАКРЫТИИ ДЕФЕКТА МЕЖПРЕДСЕРДНОЙ ПЕРЕГОРОДКИ С ПОМОЩЬЮ СЕПТАЛЬНОГО ОККЛЮДЕРА АМПЛАТЦЕРА

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Цель. Безопасная коррекция дефекта межпредсердной перегородки (ДМПП) может быть осуществлена путем транскатетерного закрытия, с использованием септального окклюдера Амплатцера (СОА). При этом визуализация и оценка степени ДМПП могут выполняться с помощью компьютерной томографии (КТ) сердца. Целью данного исследования была оценка характеристик ДМПП при КТ и сравнение метода КТ с оценкой выраженности ДМПП баллонным катетером.

Материал и методы. Результаты. У 44 больных с ДМПП оценка диаметра дефекта и длины его краев была выполнена с помощью КТ сердца. Все пациенты были разделены на две группы, в зависимости от того, была ли дополнительно выполнена оценка выраженности ДМПП баллонным катетером (Группа 2) или нет (Группа 1). В большинстве случаев выявлялись ДМПП эллипсоидной формы, с максимальным диаметром 19,6±6,5 см и минимальным диаметром 15,5±5,3 см. За исключением двух пациентов, у всех больных были хорошо выражены передние и задние края дефекта. В Группе 1, по сравнению с Группой 2, были достоверно ниже отношение размера окклюдера к наибольшему диаметру ДМПП (1,1±0,1 против 1,3±0,2, соответственно) и отношение области окклюдера к измеренной при КТ области дефекта (1,6±0,3 против 2,2±0,9, соответственно).

Заключение. КТ сердца может успешно применяться для оценки характеристик ДМПП перед транскатетерным закрытием дефекта с помощью СОА. По сравнению с оценкой выраженности ДМПП баллонным катетером, КТ сердца позволяет использовать окклюдер меньшего диаметра.

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Nowadays, transcatheter closure of an atrial septal defect (ASD) with an Amplatzer septal occluder (ASO) (AGA medical, Golden Valley, MN) is a safe and effective method and a good alternative to an operation. An accurate evaluation of the ASD is crucial for successful transcatheter closure. Transesophageal echocardiography (TEE) has been accepted as an excellent method for the complete evaluation of an ASD in transcatheter closure [1], and balloon sizing to decide the appropriate size of the device during the procedure has been generally accepted [2, 3]. But these are tricky procedures because the balloon sizing technique can be inaccurate and troublesome in some circumstance [4] and the TEE, which should be performed under general anesthesia with intubation, is associated with various potential risks [5, 6]. In particular, balloon oversizing has been reported as a high risk for fatal erosion after ASO implantation [7]. Meanwhile, cardiac computed tomography (CT), which that shows superb spatial and temporal resolution with a short scanning time, is regarded as a good tool for the morphologic evaluation of congenital heart diseases [8, 9].

In this report, we describe our experience using cardiac CT not only for the evaluation of ASD size but also for the selection of the appropriate size of device.

Material and Methods

Between November 2009 and February 2011, a total of 44 patients with secundum ASD confirmed at transthoracic echocardiogram (TTE) who were considered as successful candidates for transcatheter closure with ASO were enrolled in the study. The transcatheter closure was scheduled in appropriate patients according to the following criteria: moderate left to right shunt with symptoms or evidence of right heart volume overload that suggest pulmonary to systemic blood flow ratio of 1,5 or greater; body weight of 15 kg or greater; sufficient surrounding rims except a retro-aortic rim; secundum ASD with a long axis shorter than 38mm measured by TTE without the evidences of pulmonary hypertension in TTE. The patients with known congenital heart disease other than ASD, concomitant serious infection or significant atrial arrhythmia were excluded. TTE was performed by one of three experienced pediatric cardiologists using 5 or 3 MHz transducer. Standard TTE evaluation with color Doppler examination was performed in the subcostal, apical four-chamber, parasternal views. An experienced radiologist performed cardiac CT with 64-MDCT scanner at resting without sedation. The target heart rate was around 70 beats /minute. When necessary, a beta antagonist was used. This cardiac CT examination was limited to the heart with ECG gating for the best images during end-systole to early diastole. After the examination, the raw data were reconstructed by a specialized radiologist. The largest size of the ASD was measured at end-systole. The images were reconstructed in various perspectives, including the four-chamber view, short –axis view, oblique sagittal view and coronal view so that the maximal lengths of the rims adjacent ASD were measured. The en-face image from the right atrial side could be visualized as to measure the longest diameter (a) and the shortest diameter (b) of ASD at

Table 1

The general characteristics of atrial septal defects

		Min	Max	Mean	S.D
Age (yr)		10,0	77,0	41,3	15,4
Body weight (Kg)		32	77	57,7	9,2
Op/Qs		1,0	6,0	2,7	1,0
Longest diameter (mm)		8,0	34,0	19,6	6,5
Shortest diameter (mm)		4,0	31,0	15,5	5,3
#Defect area (mm^2)		25,1	827,4	262,3	163,7
AS		0	17	2,1	3,5
Rims (mm)	AI	8,2	32,6	18,8	3,5
	PS	4,2	31,6	17,2	5,8
	PI	4,4	39,1	23,3	6,1
	Post	11,0	36,0	21,7	7,6

Commentary: #defect area = 3,14 (longest diameter/2) (shortest diameter/2); AS – anterior-superior; AI – anterior-inferior; PS – posterior-superior; PI – posterior-inferior; Post – posterior; Min – minimal value; Max – maximal value; S.D – standard deviation.

The general characteristics of atrial septal defects showing various eccentricities and the shortest anterior superior rims.

ventricular end-systole (Fig. 1). We expressed non-circularity of the defects as $\sqrt{1-(b^2/a^2)}$. From the en-face image, the area of the defect was calculated by the area formula as 3,14*a*b/4 and the area of the device as 3,14*(device size)^2/4. And we measured the lengths of 5 rims on CT images: anterior superior rim, anterior inferior rim,

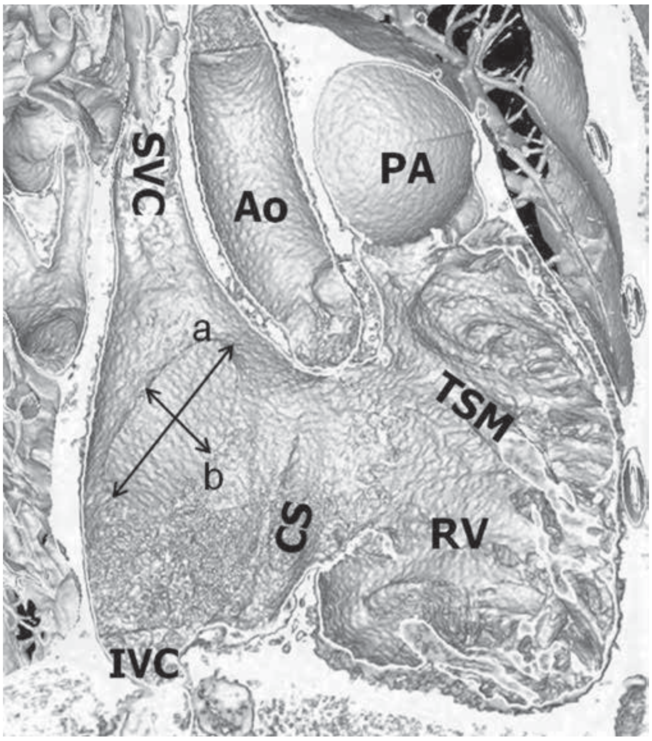

Figure 1. Three dimensional reconstructed image of atrial septal defect. The defect is secundum defect and not circular but ovoid. a, longest diameter of defect; b, shortest diameter of defect; SVC, superior vena cava; IVC, inferior vena cava; CS, coronary sinus; AO, aorta; RV, right ventricle; TSM, trabecular septo-marginalis; PA, pulmonary artery.

Table 2

The differences between two groups

	Group 1		Group 2		P
	Mean	S.D	Mean	S.D	
Longest diameter (mm)	22,1	6,0	16,6	5,8	0,005
Shortest diameter (mm)	17,6	4,9	12,9	4,7	0,003
Defect area (mm^2)	325,5	170,7	186,6	119,4	0,003
*Ratio of area	1,6	0,3	2,2	0,9	0,006
#Ratio of diameter	1,1	0,1	1,3	0,2	0,019

Commentary: *Ratio of area = area of device waist/defect area, #Ratio of diameter = device size/longest diameter; Min – minimal value; Max – maximal value; S.D – standard deviation.

The group 1 refers the patients not using a balloon sizing technique and the group 2 refers the patients using a balloon sizing technique during transcatheter device closure. These showed statistically significant differences between two groups except eccentricity.

posterior rim, posterior superior rim and posterior inferior rim (Fig. 2).

Transcatheter closure was performed by one of three pediatric cardiologists under the guide of an intra-cardiac echocardiogram (ICE) or TEE. Especially transcatheter closure under general anesthesia was done only when the guide of TEE was necessary. The patients were divided into two groups by the operator: not using a balloon sizing technique by one operator (group 1), and using a balloon sizing technique by one of other two operators (group 2) during transcatheter device closure. The device size depended on size of the defects and the flexibility of the adjacent rims around the defect. The size of the device was decided by the operator with stop flow technique in group 1. On the other hand, the size of the device in group 2 was decided on the basis of the longest diameter measured from cardiac CT before transcatheter closure. The size of ASO was 2 or 4 mm larger than the longest diameter measured from cardiac CT.

The data were expressed as mean ± standard deviation and we compared the ratios of the device size to the longest diameter measured on CT between groups 1 and 2. We also compared the ratio of the device area to the defect area calculated based on cardiac CT images between group 1 and 2. For statistical analysis, we used SPSS program of 11.5 version and significant difference was defined when p-values <0,05.

The study protocol was approved by the institutional review board.

Results

We studied 44 patients (9 males and 35 females). The age of the patients ranged from 10 to 77 years (41,3±15,4). Body weights ranged from 32 to 77 kg (57,7±9,2). The shunt ratio checked by cardiac catheterization was 2,7±1,0 (Tab. 1). Cardiac CT was done successfully without any complications. After CT evaluation, all ASDs were closed successfully with an ASO.

Characteristics of the ASDs (Table 1)

The longest diameters of the defects ranged from 8,0 to

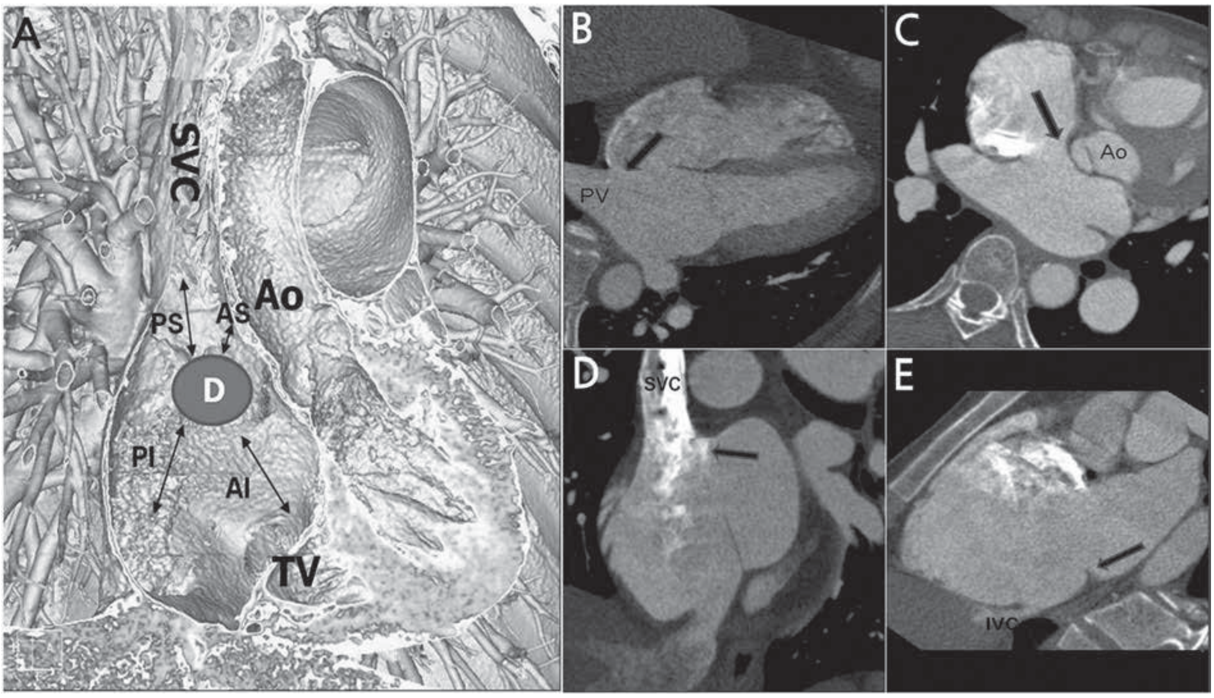

Figure 2. (**A**) Three dimensional image showing different four rims surrounding defect. D, atrial septal defect; AS, anterior superior; AI, anterior inferior; PS, posterior-superior; PI, posterior-inferior; SVC, superior vena cava; TV, tricuspid valve; AO, aorta. (**B**) Arrow in axial tomography image indicating posterior rim deficiency. PV, pulmonary vein. (**C**) Arrow indicating anterior superior rim deficiency. AO, aorta. (**D**) Image indicating posterior superior rim deficiency. SVC, superior vena cava. (**E**) Image indicating posterior inferior rim deficiency. IVC, inferior vena cava.

34,0 mm (19,6±6,5); the shortest diameters from 4,0 to 31,0 mm (15,5±5,3). The area was 262,3±163,7 mm^2.

The majority of defects were of the oval not circular type with an eccentricity of 0,57±0,20 (0,0–0,9). The 5 rims had various lengths. The lengths of the anterior superior rims were 2,1±3,5 mm, those of the anterior inferior rims were 18,8±5,8 mm, those of the posterior rims were 21,7±6,6 mm, those of the posterior superior rims were 17,2±6,2 mm, and those of the posterior inferior rims were 23,3±7,6 mm. The anterior superior rim was absent in 29 defects and the posterior inferior rims were less than 10 mm in only 2 patients.

Between Group Differences (Table 2)

Among 44 patients, 24 patients (4 males and 20 females) were in group 1 and the others 20 patients (5 males and 15 females) were in group 2. The ages and body weights of the two groups were not significantly different (42,7±11,9 yr vs 39,7±18,9 yr and 57,7±9,4 kg vs 57,7±9,2 kg). The longest diameters and the shortest diameters of group 1 were longer than those of group 2 (22,1±6,0 vs 16,6±5,8 mm and 17,6±4,9 vs 12,9±4,7 mm). So, the defect areas of group 1 were larger than those of group 2 (325,5±170,7 mm^2 vs 186,6±119,4 mm^2), When we compared the ratios of the occluder area to the defect area, those of group 1 were significantly smaller than those of group 2 (1,6±0,3 vs 2,2±0,9, $p<0,05$). The ratios of the device size to the longest diameter measured on CT between groups 1 and 2 were significantly different (1,1±0,1 vs 1,3±0,2, $p<0,05$).

Procedure and Follow Up

The device sizes implanted ranged from 9 mm to 38 mm (median = 24 mm). There were some combined findings on CT. Most of the combined findings were associated with the coronary artery, all of which were clinically insignificant except one case. In that case, a stent in the left main coronary artery was implanted successfully immediately after the ASO implantation. In another patient, a patent ductus arteriosus was combined with ASD and they were closed simultaneously. A balloon assisted technique was used for closure of the largest defect (34 mm) in group 1. There were no significant complications during the procedure except transient arrhythmia. No embolization of the device was noticed after the implantation. The follow-up echocardiogram was done 6 months later in a limited number of cases and showed no significant residual leak except for one patient who had mild pulmonary hypertension, and two defects of which one defect was left open intentionally.

Discussion

Transcatheter closure of a secundum atrial septal defect with Amplatzer septal occluder has become an alternative to surgery which has a morbidity associated with sternotomy, cardiopulmonary bypass and perioperative complications, especially in old ages. The accurate assessment of the location, the size of the ASD and the surrounding rims is essential not only for determining whether device closure is appropriate, but also, for determining the appropriate device size.

Cardiac CT has high spatial and time resolution allowing acquisition of good images of normal and pathologic features of the cardiovascular system in great detail in as little as 10 seconds [8, 10]. Even though TEE can show the entire anatomy of an ASD and facilitates monitoring of transcatheter procedures for implantation of ASO [1, 11] it is associated with some inconveniences. Ko et al reported that there were no significant differences between cardiac CT and TEE in measurement of ASD size. They also reported that cardiac CT is helpful for revealing coexisting anomalies that could be overlooked on TEE [12].

We can acquire three dimensional reconstructed images that are helpful for identifying the features of ASD. As we expected, most of the defects were ellipsoids with various degrees rather than circles. But we chose the size of the ASO on the premise of a circular defect. We chose the size of the ASO on the basis of the longest diameter of the ASD. There were a few ellipsoidal defects with a severe degree of eccentricity (0,9) in our series, but after implantation of the ASO, no specific complications were found. But in our opinion, considering the eccentricity can allow one to choose a smaller ASO.

For the transcatheter closure of an ASD, identification of deficient rims is very important. Most of the cases that went to surgical closure had a deficient rim in the posterior-inferior area with a large defect. ASD with anterior-superior or retro aortic rim deficiency was very common in our series, but as the previous reports had said it didn't matter of the successful device [13–15]. But the posterior-inferior rim has been accepted as an absolute check point for deciding the transcatheter device closure of an ASD. Durongpisitkul et al reported that an adequate posterior inferior rim (at least 10mm long) was very important for successful ASD closure with an ASO. But TEE was not adequate for measurement of the posterior inferior rim in some of their patients [16]. On the other hand, cardiac CT can accurately show the posterior-inferior rims, which ranged from 4,4 mm to 39,1 mm in our series. Two patients with a posterior-inferior rim deficiency of less than 10 mm (8,1 mm and 4,4 mm) were included in our series with a successful closure; the defect sizes were 34 mm and 32 mm for the longest diameter. This means that cardiac CT can play an important role in evaluating the candidate for transcatheter closure with ASO.

Even though stretched balloon sizing during the procedure has been considered the gold standard for selecting the size of the device, stretched balloon sizing could overestimate the actual ASD size [17, 18]. Moreover, that blind technique makes changes in dynamic geometry and in the thin surrounding rims of the ASD. There were some reports that three dimensional TEE providing en face view of ASD could be used instead of balloon sizing for the selection of ASO size [19, 20]. Also, Zanchetta et al used intracardiac echocardiography as a new efficient device selection method instead of balloon sizing [21]. We used cardiac CT as a size measuring method instead of balloon sizing and chose devices that were 2 mm or 4 mm larger than the longest diameter. Ko et al reported that they chose devices 1 mm or 2 mm larger than the longest diameter [12]. We cannot yet determine uniform rules for selection of an appropriately sized ASO based on the cardiac CT image. Usually, various factors such as the size, rim thickness and age influence the selection. Even though the sizes of the defects were different between two groups, the size of the ASOs implanted in the group that did not use the balloon sizing method was smaller than in the other group. Complications from over sizing could be prevented by using cardiac CT instead of balloon sizing as a device selection method.

Our procedure was performed smoothly without significant complications. There was no device embolization immediately or later after the implantation. No significant leak was found on follow up echocardiography 6 months after the implantation. In addition, cardiac CT gave us more information about surrounding structural abnormalities such as airway compression and atherosclerotic changes and cardiac volume overloading.

Conclusions

Cardiac CT can be a good modality for the evaluation of the size and the location of an ASD and the appropriateness for transcatheter closure of ASD with ASO. In spite of the small number of cases and lack of long-term data, cardiac CT as a size measuring method instead of balloon sizing for the selection of ASO is worthy of further study.

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Usefulness of cardiac computed tomography in transcatheter closure of atrial septal defect with amplatzer septal occluder

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Background: Atrial septal defect (ASD) can be closed safely by transcatheter closure with an Amplatzer septal occluder (ASO) with cardiac computed tomography (CT) being used to image and evaluate the ASD. The purpose of this study was to evaluate the characteristics of Secundum ASD by CT and to determine whether cardiac CT is an alternative to balloon sizing.

Methods and Results: Forty-four ASD cases were evaluated by cardiac CT. we measured the defect diameters and lengths of the rims. The patients were divided into two groups: not using a balloon sizing technique (group 1), and using a balloon sizing technique (group 2). Most ASD cases showed ellipsoid defects with 19,6±6,5 cm for the longest diameter and 15,5±5,3 for the shortest. Except for two patients, they had sufficient posterior-inferior rims. We observed that the ratios of the device size to the longest diameter and the ratios of the occluder area to the defect area measured on CT were significantly smaller in group 1 than those in group 2 (1,1±0,1 vs 1,3±0,2 and 1,6±0,3 vs 2,2±0,9).

Conclusions: Cardiac CT is useful for evaluating ASDs for transcatheter closure with an ASO. It can allow the operator to select a smaller size device than when using a stretched balloon sizing technique.

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Key Words: atrial septal defect, cardiac computed tomography, Amplatzer septal occluder.

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