REC Interv Cardiol. 2025;7(3):164-168
https://doi.org/10.24875/RECICE.M25000510

Original article

Transcatheter closure of multiperforated atrial septal defect

Luis Cerdán Ferreira,* Georgina Fuertes Ferre, Juan Sánchez-Rubio Lezcano, and Marta López Ramón

Servicio de Cardiología, Hospital Universitario Miguel Servet, Zaragoza, Spain

ABSTRACT

Introduction and objectives: Multi-fenestrated atrial septal defects (mASD) pose both diagnostic and therapeutic challenges. This study aimed to compare the outcomes of transcatheter closure in patients with mASD vs those with a single ASD at our center.
Methods: We conducted a retrospective, single-center study including adult patients who underwent transcatheter ASD closure from October 2014 through October 2024. Demographic, echocardiographic, and hemodynamic data were collected, with a the 6-month follow-up.
Results: A total of 67 patients were included, 12 of whom (18%) exhibited mASD. Patients with mASD were younger (42 vs 54 years) and more frequently presented with an interatrial septal aneurysm (91% vs 27%; *P* = .001). The use of multiple occlusion devices was more common in patients with mASD (34% vs 4%; *P* = .008). Complications were rare (5.9%) and none occurred in the mASD group. Procedural outcomes, including residual shunt and right ventricular remodeling at the follow-up, were comparable between groups.
Conclusions: Transcatheter closure of mASD is both a safe and feasible procedure, with clinical outcomes similar to those observed in patients with a single ASD.

Keywords: Ostium secundum atrial septal defects. Multi-fenestrated atrial septal defects. Transcatheter closure.

Cierre percutáneo de comunicación interauricular multiperforada

RESUMEN

Introducción y objetivos: La comunicación interauricular (CIA) multiperforada (CIAm) supone un reto diagnóstico y terapéutico. En este estudio se comparan los resultados del cierre percutáneo en pacientes con CIAm y con CIA simple en nuestro centro.
Métodos: Estudio retrospectivo unicéntrico en pacientes adultos con CIA sometidos a cierre percutáneo entre octubre de 2014 y octubre de 2024. Se recopilaron datos demográficos, ecocardiográficos y hemodinámicos, con seguimiento a los 6 meses.
Resultados: Se incluyeron 67 pacientes, 12 de ellos con CIAm (18%). Los pacientes con CIAm eran más jóvenes (42 frente a 54 años) y presentaban con mayor frecuencia aneurisma del tabique interauricular (91 frente a 27%, p = 0,001). El uso de varios dispositivos fue más frecuente en la CIAm (34 frente a 4%, p = 0,008). Las complicaciones fueron raras (5,9%, ninguna de ellas en pacientes con CIAm). Los resultados del procedimiento (*shunt* residual, remodelado del ventrículo derecho) en el seguimiento fueron similares en ambos grupos.
Conclusiones: El cierre percutáneo de la CIAm es factible y seguro, con resultados similares a los observados en pacientes con CIA no multiperforada.

Palabras clave: Comunicación interauricular *ostium secundum*. Comunicación interauricular multiperforada. Cierre percutáneo.

Abbreviations

ASD: atrial septal defect. **ICUS:** intracoronary ultrasound. **mASD:** multifenestrated atrial septal defect. **TEE:** transesophageal echocardiography. **TTE:** transthoracic echocardiography.

* **Corresponding author.**
E-mail address: luis_cerfer@hotmail.com (L. Cerdán Ferreira).
𝕏 @luiscfcf

Received 9 January 2025. Accepted 28 March 2025. Online 3 June 2025.

INTRODUCTION

Atrial septal defect (ASD) is the congenital heart disease most frequently diagnosed in adulthood, with the ostium secundum type being the most prevalent (80% of cases). Since the first transcatheter closures of atrial septal defects, advances in both experience and devices have made the transcatheter technique the method of choice for most patients. However, some specific cases, such as ASDs with multiple defects or multi-fenestrated ASDs (mASDs), which account for 10% of all patients with ostium secundum type ASD, continue to pose diagnostic and therapeutic challenges. Furthermore, the available scientific evidence in this subgroup is scarce.[1-4]

The objective of our study was to analyze and compare the results of the transcatheter closure of mASD vs the transcatheter closure of the remaining patients with ostium secundum type ASD.

METHODS

Study design and population

We conducted a retrospective study that included all cases of transcatheter ASD closure performed in adults older than 18 years at our center from October 2014 through October 2024.

The patients' demographic, echocardiographic, and hemodynamic data were collected, including a 6-month follow-up following the intervention, assessing residual shunt and echocardiographic parameters such as right ventricular remodeling. This is a retrospective study in which the patients' informed consent was obtained for the use of their interventional procedure for research purposes. The authors confirm that the interventions were performed in full compliance with the regulations of the Clinical and Ethical Research Committee and the Declaration of Helsinki of the World Medical Association.

Endpoints

The primary endpoint of this study is to analyze the clinical and echocardiographic results of the transcatheter closure of mASDs. Similarly, these results are compared with those obtained after the transcatheter closure of simple (non-multi-fenestrated) ostium secundum type ASDs.

Statistical analysis

Qualitative variables are expressed as percentages and the continuous ones as mean and standard deviation, or as median with interquartile range, depending on whether they follow a normal distribution. For inter-group comparison, the chi-square test or Fisher's exact test was used for qualitative variables, and the Student's t-test or the Mann-Whitney U test for continuous variables, as appropriate. The threshold for statistical significance was set at $P < .05$. Analyses were performed with SPSS software (version 21; IBM Corp, Armonk, NY, United States).

RESULTS

During the study period, a total of 67 transcatheter closures of ostium secundum type ASDs were performed in patients older than 18 years. The patients' baseline characteristics and ASDs, the procedure, and the results are shown in table 1. The mean age of the population was 52 years, with a predominance of women (65%).

Table 1. Baseline characteristics of all patients undergoing transcatheter atrial septal defect closure

Variable	Total (n = 67)
Age	52 ± 14 years
Sex, female	44 (65%)
ASD size	14 ± 6 mm
Atrial septal aneurysm	26 (38%)
Closure indication: RV dilatation	59 (88%)
Perioperative imaging	
TEE + fluoroscopy	44 (66%)
ICUS + fluoroscopy	11 (16%)
TEE + ICUS + fluoroscopy	12 (18%)
Number of implanted devices	
1	61 (91%)
2	5 (7.5%)
3	1 (1.5%)
Device size	20 ± 7 mm
Perioperative complications	4 (5.9%)
Grade 0 shunt at 6 months	55 (82%)
Residual shunt grade ≥ 2 at 6 months	0 (0%)
Preoperative PASP	32 ± 9 mmHg
Postoperative PASP	27 ± 7 mmHg
RV (baseline EDD)	44 ± 7 mm
RV (follow-up EDD)	38 ± 6 mm

ASD, atrial septal defect; EDD, end-diastolic diameter; ICUS, intracoronary ultrasound; PASP, pulmonary artery systolic pressure; RV, right ventricle; TEE, transesophageal echocardiography.

The most common indication for ASD closure was dilation of the right ventricular dilatation (88%). In most cases (91%), transcatheter closure was performed with a single device; however, due to anatomical complexity, 5 patients required 2 devices and 1, 3 devices. The combination of transthoracic echocardiography (TTE) and fluoroscopy was the advanced imaging modality selected to guide the procedure in 65% of cases. Four out of all patients had perioperative complications. Three of these complications were due to device embolization, and all recovered uneventfully; 1 patient presented paroxysmal atrial flutter that required pharmacological cardioversion with amiodarone. All patients progressed favorably and were discharged at 24 hours without complications. At follow-up, 82% had no residual shunt, and zero cases of grade ≥ II shunt were found.

Twelve out of all the patients with ASD closure (18%) had ≥ 2 atrial septal defects, whose characteristics are shown in table 2. The patients' mean age was 42 years, with an equitable sex distribution. Right heart dilatation was the most common reason for closure (83%), with 2 patients presenting with strokes. All patients were in New York Heart Association functional class I-II/IV.

Regarding the echocardiographic study of mASDs, all patients underwent a TEE prior to the procedure. Patients had between 2

Table 2. Baseline characteristics, procedure, and outcomes of patients undergoing transcatheter closure of multi-fenestrated atrial septal defects

Patient	Total	1	2	3	4	5	6	7	8	9	10	11	12
Age (years)		52	33	27	39	60	41	30	50	36	32	50	61
Sex		Male	Female	Female	Female	Male	Female	Male	Male	Male	Female	Male	Female
No. of defects		2	2	2	3	2	2	3	3	4	2	2	2
Largest defect size		8.5 mm	4 mm	10 mm	2 mm	10 mm	12 mm	6 mm	14 mm	3 mm	10 mm	14 mm	6 mm
Location		AS	AS	AS	AS	AS	AS	Central	AS	PI	AS	AS	AS
IDD		19 mm	13 mm	7 mm	12 mm	10 mm	6 mm	18 mm	17 mm	< 1 mm	8 mm	10 mm	16 mm
Aneurysm		Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Closure indication		Dilated RV	Stroke	Dilated RV	Stroke	Dilated RV	Dilated RV	Dilated RV	Dilated RV	Dilated RV	Dilated RV	Dilated RV	Dilated RV
TEE/ICUS		TEE + ICUS	TEE + ICUS	TEE	TEE	TEE	TEE + ICUS	TEE	TEE	TEE	TEE	TEE	TEE
N. of devices		2	2	2	1	1	1	1	2	1	1	1	1
Device type		Amplatzer SO (AGA Medical, United States)	Amplatzer SO, Amplatzer Cribriform (AGA Medical, United States)	Figulla Flex (FFO, Occlutech GmbH, Germany)	Amplatzer Cribriform (AGA Medical, United States)	Amplatzer Cribriform (AGA Medical, United States)	Amplatzer SO (AGA Medical, United States)	Amplatzer Cribriform (AGA Medical, United States)	Amplatzer SO (x2) (AGA Medical, United States)	Amplatzer Cribriform (AGA Medical, United States)	Amplatzer SO (AGA Medical, United States)	Occlutech (Occlutech Int. AB, Sweden)	Amplatzer Cribriform (AGA Medical, United States)
Device size		10, 14 mm	8, 18 mm	7.5, 12 mm	35 mm	30 mm	16 mm	40 mm	18, 8 mm	25 mm	14 mm	16 mm	35 mm
Residual shunt at 24 h (grade)		1	0	1	0	0	1	0	0	0	0	1	0
Residual shunt at 6 months (grade)		0	0	1	0	0	1	0	0	0	0	1	0
Complications		No	No	No	No	No	No	No	No	No	No	No	No
Preoperative PASP	24 mmHg	32 mmHg	28 mmHg	–	24 mmHg	28 mmHg	28 mmHg	29 mmHg	22 mmHg	24 mmHg	15 mmHg	15 mmHg	33 mmHg
PASP at 6 months	23 mmHg	25 mmHg	26 mmHg	–	22 mmHg	25 mmHg	23 mmHg	25 mmHg	28 mmHg	23 mmHg	12 mmHg	12 mmHg	29 mmHg
Baseline RV (EDD)	42 mm	49 mm	28 mm	36 mm	30 mm	51 mm	38 mm	45 mm	51 mm	50 mm	43 mm	49 mm	42 mm
RV (EDD) at 6 months	37 mm	43 mm	27 mm	28 mm	29 mm	42 mm	34 mm	42 mm	42 mm	41 mm	39 mm	42 mm	41 mm

AS, anterosuperior; EDD, end-diastolic diameter; ICUS, intracoronary ultrasound; IDD, interdefect distance; PASP, pulmonary artery systolic pressure; PI, posteroinferior; RV, right ventricle; SO, septal occluder; TEE, transesophageal echocardiography.

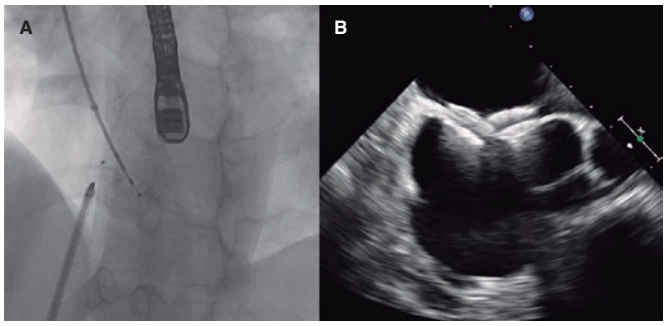

Figure 1. A: fluoroscopic image of the closure of a multi-fenestrated atrial septal defect with 2 devices guided by fluoroscopy, transesophageal echocardiography, and intracoronary ultrasound. **B:** transesophageal echocardiography, mid-esophageal plane, showing the 2 implanted closure devices.

(66% of cases) and 4 atrial septal defects. The most common location of the largest defect was anterosuperior (10 patients), and most (92%) had an associated atrial septal aneurysm (defined as a displacement > 10 mm). The sizes of the largest defects and the distance between the defects are shown in table 2. No patient had pulmonary hypertension prior to the procedure.

Regarding the procedure, all cases were guided by transesophageal echocardiography (TEE) and fluoroscopy, and 3 of them by intracoronary ultrasound (ICUS). In most cases, a single closure device was used (66% of patients); however, in 4 cases, 2 devices were needed, which were implanted during the same procedure (simultaneous implantation). The most widely used devices were the Amplatzer Septal Occluder (AGA Medical, United States) and the Amplatzer Cribriform (AGA Medical, United States). In one procedure, the Figulla Flex device (FFO, Occlutech GmbH, Germany) was used, and in another, the Occlutech device (Occlutech International AB, Sweden). Figure 1 shows one of the procedures that required 2 devices and was fluoroscopy-, TEE-, and ICUS-guided.

Transcatheter closure was successful in all patients with mASD, without intraoperative complications. Transthoracic echocardiography (TTE) was performed 24 hours after closure and, then, 6 months later. Acetylsalicylic acid monotherapy was prescribed at discharge and maintained for 3 months, except for the 2 patients who had a stroke.

At 6 months, 75% showed no residual shunt, while the remaining 25% showed a grade 1 shunt (minimal, without hemodynamic consequences). Most patients with right ventricular dilatation, (8 out of 9 patients) showed a reduction in the baseline right ventricular end-diastolic diameter after the procedure. There were no strokes at the follow-up.

Table 3 compares the characteristics and results of transcatheter closure in patients with a single ASD and with mASD. In our cohort, patients with mASD were significantly younger (42 vs 54 years; $P = .011$), with no statistically significant differences in sex distribution (50% vs 69%; $P = .207$). The mASD group had smaller defects (8 mm vs 16 mm in the single ASD group) and a higher prevalence of atrial septal aneurysm (91% vs 27%). In both groups, the most frequent indication for closure was right heart dilatation. No differences were observed in the choice of imaging modality during the procedure or in the mean size of the implanted device. However, patients with mASD more frequently required > 1 device (single device in 66% vs 96% in the single ASD group). There were no inter-group differences regarding complications or the presence of residual shunt during follow-up.

Table 3. Comparison of patients with transcatheter closure of single vs multi-fenestrated atrial septal defect

Variable	Single ASD (n = 55)	Multifenestrated ASD (n = 12)	*P*
Age	54 ± 14 years	42 ± 11 years	.011
Female sex	38 (69%)	6 (50%)	.207
ASD size	16 ± 6 mm	8 ± 4 mm	.001
Septal aneurysm	15 (27%)	11 (91%)	.001
Closure indication: RV dilatation	49 (89%)	10 (83%)	.577
Perioperative imaging: TEE + fluoroscopy	35 (63%)	9 (75%)	.223
No. of implanted devices	53 (96%)	8 (66%)	.008
Device size	19 ± 7 mm	22 ± 8 mm	.283
Perioperative complications	4 (7%)	0 (0%)	.335
Residual shunt grade 0 at 6 months	48 (87%)	9 (75%)	.280

ASD, atrial septal defect; RV, right ventricle; TEE, transesophageal echocardiography.

DISCUSSION

Transcatheter closure of ostium secundum ASD has become a safe and effective alternative in adult patients. Our study analyzed the results of transcatheter ASD closure in patients older than 18 years, highlighting the differences between single ASD and mASD.

At our center, transcatheter closure has proven to be safe and effective in patients with mASD. The results obtained indicate a high success rate associated with the procedure, with the absence of significant intraoperative complications and a good short- and mid-term safety profile.

A relevant finding is that patients with mASD were significantly younger than those with a single ASD, which could be explained by the earlier detection of these defects due to more evident symptoms, or by the presence of atrial septal aneurysm, which in our cohort was significantly more frequent in the mASD group. This data is consistent with the literature, which describes a strong association between atrial septal aneurysm and the presence of multiple defects.[5]

As expected, the use of multiple devices was more common in the mASD group than in the single ASD group. Although most cases were treated with a single device in patients with mASD, a considerable percentage (40%) required additional devices due to greater anatomical complexity. This finding highlights the importance of a thorough preoperative planning and the need to guide the intervention with TEE or ICUS. Although the TEE provides a wider field of view, the ICUS is particularly useful in certain situations, as it allows for a more precise visualization of the posteroinferior border of the atrial septum.[6]

The described complications associated with transcatheter ASD closure include arrhythmias, atrioventricular block, and device erosion. Device embolization is usually a consequence of inadequate size or incorrect placement, and its incidence rate is < 1%. In our cohort of patients, complications were a rare finding, with only 3 cases of device embolization and 1 of supraventricular arrhythmia being reported. In the literature, there are doubts on whether these complications are more common when implanting

multiple devices; however, in our patients with mASD, 40% of whom needed > 1 device, no complications were observed.[7]

Most patients with mASD showed complete closure of the defect at 6 months (75%), and the remaining 25% had a minimal shunt without hemodynamic consequences. A high percentage of patients with right heart dilatation showed favorable right ventricular remodeling. Furthermore, the absence of strokes during the observation period indicates the effectiveness of the procedure in terms of secondary prevention in this subgroup of patients.

Limitations

Among the limitations of our study, the following stand out: first, those inherent to its observational and retrospective design, in addition to being single-centered. Furthermore, the number of patients with mASD is relatively small (n = 12), which reduces statistical power. The absence of a control group of patients with mASD treated conservatively or with surgical closure prevents direct comparisons on the relative benefits of each strategy. Prospective studies with a larger sample size and prolonged follow-up will be necessary to confirm our findings and optimize the management of these patients.

CONCLUSIONS

Although the transcatheter closure of mASD is a solid therapeutic option in selected patients, with results comparable to those observed in patients with a single ASD, the need for prospective and multicenter studies remains to confirm these findings and optimize the therapeutic strategy in this group of patients.

FUNDING

None declared.

ETHICAL CONSIDERATIONS

Informed consent was obtained from all patients for the use of their interventional procedure for research purposes. The authors confirm that procedures were performed in full compliance of the regulations of the Clinical and Ethical Research Committee, and of the Helsinki Declaration of the World Medical Association. The authors confirm that sex and gender variables have been taken into consideration according to the SAGER guidelines.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence has not been used for the development of this work.

AUTHORS' CONTRIBUTIONS

L. Cerdán Ferreira and M. López Ramón contributed to data collection. L. Cerdán Ferreira performed the statistical analysis. G. Fuertes Ferre, J. Sánchez-Rubio Lezcano, and M. López Ramón contributed to result interpretation. L. Cerdán Ferreira and G. Fuertes Ferre wrote the article, which was later reviewed by G. Fuertes Ferre, J. Sánchez-Rubio Lezcano, and M. López Ramón.

CONFLICTS OF INTEREST

None declared.

WHAT IS KNOWN ABOUT THE TOPIC?

- Ostium secundum type atrial septal defect is the most widely diagnosed congenital defect in adults, and its transcatheter closure has become the treatment of choice in most cases.
- Multi-fenestrated atrial septal defects represent approximately 10% of cases of ostium secundum type atrial septal defect and pose a diagnostic and therapeutic challenge due to their greater anatomical complexity. Although transcatheter closure is feasible, the available evidence in this type of patients is still limited.

WHAT DOES THIS STUDY ADD?

- This study shows that transcatheter closure of multi-fenestrated atrial septal defect is safe and effective, with a high success rate and absence of intraoperative and longer-term complications.

REFERENCES

1. Brida M, Chessa M, Celermajer D, et al. Atrial septal defect in adulthood: a new paradigm for congenital heart disease. *Eur Heart J*. 2022;43:2660-2671.
2. Masseli J, Bertog S, Stanczak L, et al. Transcatheter closure of multiple interatrial communications. *Catheter Cardiovasc Interv*. 2013;81:825-836.
3. Yang Y, Xu Z, Jiang S, et al. Simultaneous Transcatheter Closure of Multiple Atrial Septal Defects Using Dual Amplatzer Septal Occluder Devices. *Am J Med Sci*. 2016;352:245-251.
4. Butera G, Romagnoli E, Saliba Z, et al. Percutaneous closure of multiple defects of the atrial septum: procedural results and long-term follow-up. *Catheter Cardiovasc Interv*. 2010;76:121-128.
5. Silvestry FE, Cohen MS, Armsby LB, et al. Guidelines for the Echocardiographic Assessment of Atrial Septal Defect and Patent Foramen Ovale: From the American Society of Echocardiography and Society for Cardiac Angiography and Interventions. *J Am Soc Echocardiogr*. 2015;28:910-958.
6. Fuertes-Ferre G, Hernández Hernández F, López Ramón M, Sánchez Rubio J, Sánchez Insa E, Galache Osuna JG. Transcatheter closure of a complex atrial septal defect after occluder device embolization. *Cardiovasc Revasc Med*. 2017;18:34-37.
7. Bradley EA, Zaidi AN. Atrial Septal Defect. *Cardiol Clin*. 2020;38:317-324.