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Original article

Heart block after transcatheter septal defect closure in infants under 10 kg: clinical outcomes and management options

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ABSTRACT

Introduction and objectives: This study reviewed the management of heart block following transcatheter device closure of perimembranous ventricular septal defects in pediatric patients.
Methods: We evaluated the follow-up and treatment of 1 patient who developed complete atrioventricular block and 5 patients who developed left bundle branch block (LBBB) from January 2019 through December 2023 after transcatheter ventricular septal defect closure in our clinic.
Results: All patients who developed heart block weighed less than 10 kg. The only patient who developed complete atrioventricular block was successfully treated with temporary pacing, returning to sinus rhythm. In 2 of the 5 patients with LBBB, conduction disturbances were observed during the procedure, leading to termination without device release. One patient with postoperative LBBB returned to sinus rhythm following steroid therapy, and another one required surgical device removal. The patient with late-onset LBBB is still under close follow-up with serial ECG and echocardiography.
Conclusions: Heart block after transcatheter closure of perimembranous ventricular septal defect is a serious complication, particularly in young patients with low body weight. Early detection and appropriate management, including procedural interruption, steroid therapy, and surgery when necessary, can lead to favorable outcomes. Careful patient selection and close follow-up are essential to minimize the risk of conduction disturbances.

Keywords: Atrioventricular block. Left bundle branch block. Pediatric patients. Perimembranous ventricular septal defects. Transcatheter closure.

Bloqueo tras el cierre percutáneo de defectos septales en lactantes de menos de 10 kg: resultados y opciones de tratamiento

RESUMEN

Introducción y objetivos: En este estudio se revisó el tratamiento del bloqueo cardiaco después del cierre con dispositivo percutáneo de defectos del tabique ventricular perimembranoso en pacientes pediátricos.
Métodos: Se evaluó el seguimiento y el tratamiento de 1 paciente que desarrolló bloqueo auriculoventricular completo y de 5 pacientes que desarrollaron bloqueo de rama izquierda (BRI), entre enero de 2019 y diciembre de 2023, tras del cierre percutáneo de una comunicación interventricular en nuestro centro.
Resultados: Todos los pacientes que desarrollaron bloqueo cardiaco pesaban menos de 10 kg. El único paciente que desarrolló un bloqueo auriculoventricular completo respondió al tratamiento médico con estimulación temporal y recuperó el ritmo sinusal. En 2 de los 5 pacientes con BRI se observó una anomalía de conducción durante el procedimiento, lo que llevó a finalizarlo sin liberar el dispositivo. Un paciente con BRI después del procedimiento recuperó el ritmo sinusal tras recibir tratamiento con esteroides, mientras que otro requirió la retirada quirúrgica del dispositivo. El paciente con BRI de aparición tardía permanece bajo vigilancia estrecha con electrocardiogramas seriados y ecocardiografía.

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Conclusiones: El bloqueo que se desarrolla después del cierre percutáneo de una comunicación interventricular perimembranosa es una complicación grave, sobre todo en pacientes jóvenes con bajo peso corporal. La detección precoz y el tratamiento adecuado, incluida la interrupción del procedimiento, el tratamiento con esteroides y la intervención quirúrgica en caso necesario, pueden producir resultados favorables. La selección cuidadosa de los pacientes y un seguimiento estrecho son esenciales para minimizar el riesgo de alteraciones de la conducción.

Palabras clave: Bloqueo auriculoventricular. Bloqueo de rama izquierda. Pacientes pediátricos. Defectos septales ventriculares perimembranosos. Cierre percutáneo.

Abbreviations

CAVB: complete atrioventricular block. **LBBB:** left bundle branch block. **LV:** left ventricle. **RV:** right ventricle. **VSD:** ventricular septal defect.

INTRODUCTION

Transcatheter closure of ventricular septal defects (VSD) offers numerous advantages, including less trauma, faster recovery, and a reduced length of stay.[1] However, this technique has complications, such as device embolization, valve malfunction, and arrhythmias. One of the most concerning complications of transcatheter closure of perimembranous VSD is the development of complete atrioventricular block (CAVB).[2] Although this complication is more likely to occur when an inappropriate device is selected, pinpointing the exact cause of the block can sometimes be challenging. Factors significantly contributing to CAVB include young age, low body weight, device malapposition due to septal aneurysm, selection of an excessively large device, and direct device compression. Despite its rarity, CAVB remains a severe complication associated with this procedure.[3]

The atrioventricular node is located at the posterior superior area of the membranous ventricular septum and branches into the left and right bundles at the lower posterior edge. This close anatomical relationship increases the risk of developing heart block during the transcatheter closure of perimembranous VSD.[1,4,5] Left anterior fascicular block, a variant of left bundle branch block (LBBB), can result in ventricular asynchrony, which negatively impacts hemodynamics and left ventricular function.[6]

CAVB has been reported in 0-6.4% of cases after the transcatheter closure of VSD.[7] Recent publications indicate that this rate is gradually declining. A systematic review by Yang et al. found that 107 of 4394 patients, 107 (2.4%) required permanent pacemaker implantation after the interventional closure of VSD, with a higher incidence rate being reported in young children.[8] Additionally, Bergman et al. reported that CAVB was observed in 1 of 149 (0.7%) patients after the procedure involving various VSD devices at a 6-year follow-up.[7]

We evaluated a total of 180 patients, 42 of whom were under 10 kg, who underwent transcatheter closure of VSD in our center in the last 5 years, focusing on block development in young children. In this article we detail the treatment and follow-up of 1 patient who developed complete CAVB and 5 patients who developed LBBB.

METHODS

From January 2019 through December 2023, a total of 180 pediatric patients (42 of whom weighed less than 10 kg) underwent transcatheter closure of perimembranous ventricular septal defects (VSD) at our center.

The indications for closure included a left ventricular end-diastolic diameter Z score ≥ 2.0; Qp/Qs > 1.5, treatment-resistant heart failure, a cardiothoracic ratio ≥ 0.55 on chest radiography, and growth retardation unrelated to recurrent respiratory infections or malnutrition.

Patients with subaortic edge regurgitation, significant aortic regurgitation, ventricular outflow tract obstruction, mean pulmonary artery pressure > 20 mmHg, or associated surgical heart anomalies were excluded from the study.

The KONAR-MF VSD occluder (Lifetech, China) and Amplatzer Duct Occluder (ADO I and II, AGA Medical Corp., United States) devices were used in the procedures. The Konar MF was used more frequently due to its flexible design (Konar MF: 157, ADO I + ADO II: 23).

The device size was selected based on angiographic measurements, typically choosing a device 1–2 mm larger than the size of the left ventricular defect. In VSD with aneurysmal tissue, the left disc of the device was positioned inside the aneurysmal tissue.

All patients were continuously monitored with electrocardiography during the procedure and underwent serial electrocardiograms (ECG) and echocardiographic evaluations at the follow-up.

RESULTS

Heart block developed in 6 patients, all of whom weighed less than 10 kg: 1 CAVB and 5 LBBB.

Case 1

A 2-year-old female patient, weighing 9.9 kg (3rd to 10th percentile), was being followed by pediatric cardiology for a diagnosis of a VSD. She had a past medical history of failure to gain weight, growth retardation, and 2 hospitalizations due to lower respiratory tract infections. An echocardiogram revealed a perimembranous VSD, measuring 5 mm on the left ventricular (LV) side and 4 mm on the right ventricular (RV) one.

Due to the clinical and hemodynamic significance of the patient's VSD, a decision was made to perform a transcatheter closure. Prior to the procedure, the patient was administered cefazolin (50 mg/kg) and heparin (100 U/kg). The VSD was successfully closed using a Lifetech Konar MFO 6-4 device via antegrade access while the patient remained under general anesthesia. There were no signs of conduction disturbances in the ECG performed intra- and postoperatively. An ECG performed on postoperative day 2 confirmed that

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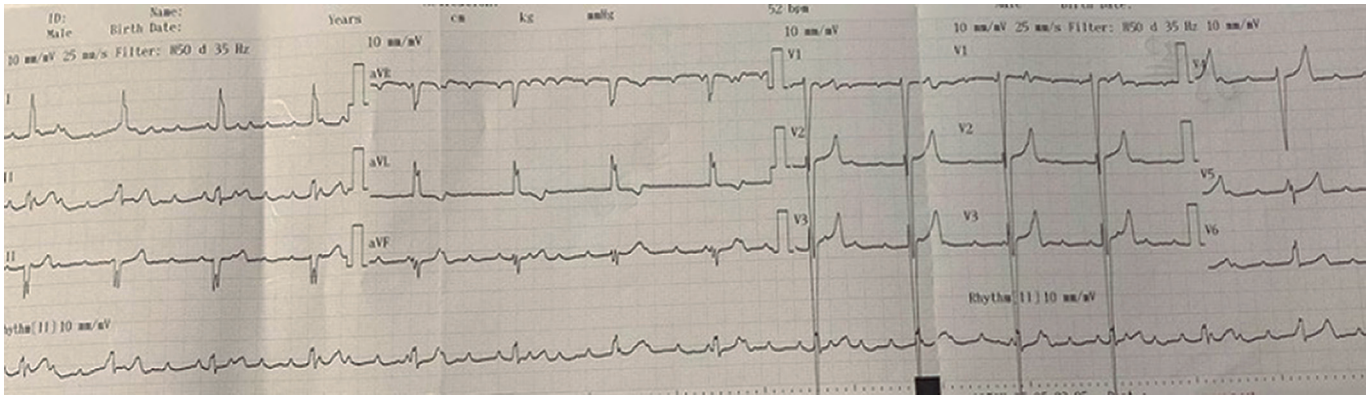

Figure 1. Case 1: electrocardiography of complete atrioventricular block after transcatheter closure of ventricular septal defect.

the device was correctly positioned in the absence of residual shunt. The patient was prescribed a 6-month regimen of aspirin at a dosage of 3 mg/kg/day and was discharged without any complications. Three days after discharge, the patient exhibited cyanosis. An ECG revealed the presence of CAVB (figure 1).

Atropine was administered twice at a dose of 0.02 mg/kg. The intervention successfully raised the peak heart rate to 135 beats per minute, and the patient's rhythm normalized to a junctional ectopic rhythm. However, as the CAVB persisted, a temporary transvenous pacemaker was implanted, and the patient was admitted to the pediatric intensive care unit under continuous follow-up. Dexamethasone was initiated at a dosage of 0.6 mg/kg per day.

On hospitalization day 3, the patient's ECG showed a return to sinus rhythm. After the temporary pacemaker was turned off, the patient underwent 24-hour Holter ECG monitoring. The Holter ECG showed a consistent sinus rhythm, meaning there was no evidence of CAVB or advanced second-degree block. On hospitalization day 5, the patient, whose ECG was still showing a consistent sinus rhythm, was discharged with a plan to complete a 10-day regimen of dexamethasone.

During the 3- and 6-month follow-up visits, the patient's ECG continued to show a normal sinus rhythm without the need for medication.

Case 2

A 15-month-old male patient, weighing 8 kg (which is below the 3rd percentile), presented with a VSD and a large patent ductus arteriosus who underwent transcatheter closure at 3.5 months of age due to symptoms of heart failure that remained unresponsive to optimal medical therapy. During follow-up, the patient showed signs of inadequate weight gain and fatigue during feeding. Due to these clinical and hemodynamic indicators, a decision was made to close the VSD at 15 months of age. Echocardiography revealed a defect measuring 5 mm on the LV side and 4 mm on the RV side in the perimembranous region. The defect was closed using a transcatheter approach via retrograde access with a Lifetech Konar MFO 6-4 device.

Postoperative follow-up revealed the widening of the QRS complex. An ECG showed that the patient had developed a LBBB. As a result, the device was removed without being released. The patient then began dexamethasone at a dosage of 0.6 mg/kg per day.

By the end of week 1 of postoperative follow-up, the patient's ECG showed a normal sinus rhythm with no evidence of LBBB.

Case 3

An 8-month-old patient, weighing 6.4 kg (below the 3rd percentile), was monitored for a VSD measuring 5 mm on the LV side and 4.5 mm on the RV side in the perimembranous region. Due to poor weight gain and left ventricular enlargement on the echocardiography, transcatheter closure was performed.

A Lifetech Konar MFO 6-4 device was successfully implanted under general anesthesia without immediate complications. However, 3 hours later, the patient developed a LBBB on the ECG (figure 2). Although dexamethasone was started at 0.6 mg/kg/day, the LBBB persisted by day 4, and the patient was discharged.

During the 1-week follow-up, an incomplete LBBB was noted on the ECG. Dexamethasone treatment went on for another 2 weeks, and at the 1-month follow-up, the LBBB had resolved, indicating successful treatment.

Case 4

A 14-month-old female patient, weighing 8 kg (which falls within the 3rd to 10th percentile), was being monitored for a VSD. The ECG indicated a 6 mm perimembranous VSD. A decision was made to perform the transcatheter closure of the defect. The procedure was performed with a Lifetech Konar MFO 8-6 device via retrograde access in the absence of immediate complications.

However, after the procedure, an ECG showed the development of LBBB. The patient began dexamethasone at a dosage of 0.6 mg/kg/day. After discharge, she was closely monitored through frequent outpatient follow-up. Despite ongoing treatment, LBBB persisted, and echocardiography performed at the 1-week follow-up showed onset of aortic regurgitation. At the 3-week follow-up, the device was surgically removed and the VSD repaired. This decision was made because her echocardiography showed increased aortic regurgitation, and the lLBBB persisted on her ECG.

Case 5

A 12-month-old male patient, weighing 7 kg (below the 3rd percentile), was admitted to the clinic with symptoms of growth retardation and evidence of left ventricular enlargement on echocardiography. The patient exhibited a perimembranous VSD measuring 6 mm on the LV side and 3.5 mm on the RV side. The defect was closed using a Lifetech Konar MFO 6-4 device, delivered through a transcatheter procedure, which went completed smoothly

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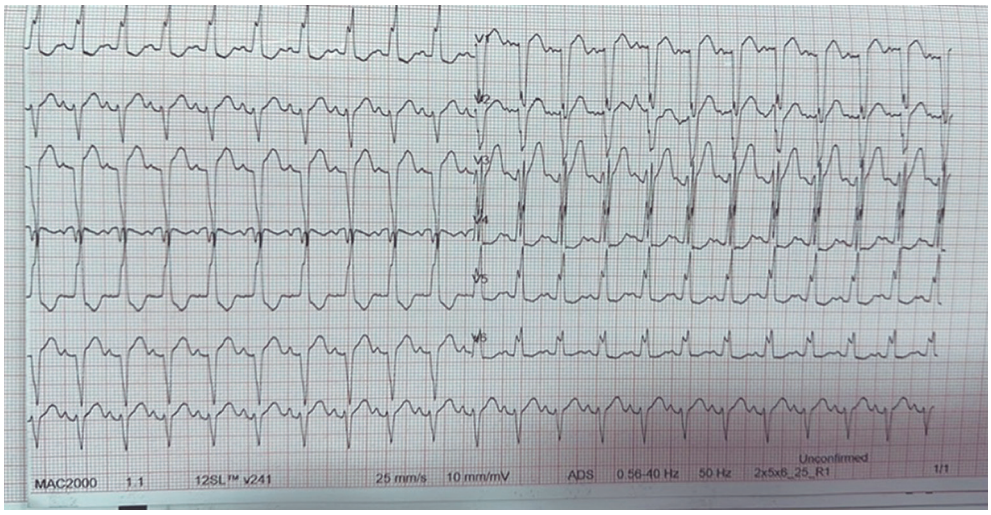

Figure 2. Case 3: electrocardiography of left bundle branch block after transcatheter closure of ventricular septal defect closure.

and without conduction disturbances being observed on the ECG at the follow-up. Echocardiography confirmed that the device had been implanted appropriately and in the absence of residual shunt. However, at the 4-year follow-up, LBBB was observed on the ECG. Since the left ventricular functions remained normal on echocardiography, the patient remained under close follow-up in the outpatient clinic without any additional treatment.

Case 6

A decision was made to perform a transcatheter closure of a VSD in an 11-month-old female patient who weighed 9 kg (falling within the 25th to 50th percentile). She had been on optimal medical therapy for heart failure and exhibited left ventricular dilatation on echocardiography. The defect measured 7 mm on the LV side and 4 mm on the RV side.

The procedure was performed via retrograde access using a Lifetech Konar MFO 7-5 device. After device implantation, QRS complex widening was observed on the monitor, and an ECG confirmed the development of LBBB. The device had to be removed without being released.

The patient began dexamethasone at a dose of 0.6 mg/kg/day. Four weeks after the procedure, the patient's ECG showed a return to sinus rhythm in the absence of LBBB.

The patients' demographic and clinical characteristics are shown in table 1.

DISCUSSION

Blocks that occur after transcatheter closure of perimembranous VSDs are primarily caused by the conduction bundle close proximity to the defect.[9,10] The edge of the perimembranous VSD is located in an area of fibrous continuity between the atrioventricular valves, which forms the posteroinferior border. In this region, the atrioventricular conduction bundle leaves the central fibrous body and runs just subendocardial. This position makes it vulnerable to damage from devices used to close perimembranous VSDs.[9]

AVB due to direct mechanical compression of the atrioventricular node typically occur immediately after performing the procedure or 2 to 7 days after percutaneous closure. Later onset AVB may result from inflammation and fibrosis.[2,9] CAVB are usually observed in the early postoperative period. In patients undergoing transcatheter closure, the timing of AVB formation can be unpredictable, with most cases being detected 2 to 7 days after the procedure.[7,10] However, late-onset AVBs have been reported as late as 2 to 4 weeks or even 10 to 20 months after the procedure. The need for permanent pacemaker implantation is greater in younger patients.[7] Although in our patient with complete AVB, symptoms developed 4 days after the procedure, there was no need for permanent pacemaker implantation.

After the perimembranous closure of VSD, bundle branch block is a more finding than CAVB. Right bundle branch block occurs more frequently than LBBB, likely because the right bundle branch is smaller and more prone to damage. While bundle branch blocks usually develop within 1 week after transcatheter closure, cases have been reported up to 3 years after the procedure.[11] Most bundle branch blocks may resolve spontaneously or with steroid treatment, such as IV dexamethasone at 1 mg/kg/day or oral prednisone at 1-2 mg/kg/day.[2,9] Close follow-up of patients is essential within the first 7 days after the procedure.[10] LBBB has been reported to lead to abnormal left ventricular remodeling and heart failure.[11]

If CAVB occurs intraoperatively while crossing the defect, it is advisable to abandon the procedure. For postoperative CAVB, high doses of IV steroids followed by a 2-week regimen of oral steroids are recommended.[9] The decision to remove the device is complex and depends on the patient's symptoms, parental preference, and the experience of the clinic.[9]

If AVB resolves with steroid therapy, leaving the device in place is recommended. In symptomatic patients, a temporary pacemaker should be implanted, and response to steroid treatment should be monitored.[9] In our patient with complete AVB, and in the 2 patients who developed postoperative LBBB, these blocks resolved after 2 weeks of steroid treatment, and sinus rhythm was restored. These patients have been closely monitored for any potential recurrence of the block.

For those patients who developed intraoperative bundle branch blocks, the devices were removed without release, as suggested in the literature.

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Table 1. Demographic and clinical characteristics

Case	Age, months	Body weight, kg	VSD LV side (mm)	VSD RV side (mm)	Device	VSA	Approach	Time of block developing	Block	Administration	Follow-up
1	25	9.9	5	4	6-4	No	Antegrade	Day 4	CAVB	Transient pacemaker	Sinus
2	15	8	5	4	6-4	No	Retrograde	Intraoperatively	LBBB	Not released	Sinus
3	8	6.4	5	4.5	6-4	No	Antegrade	Hour 2	LBBB	Dexamethasone	Sinus
4	14	8	6	5.5	8-6	Yes	Retrograde	Hour 3	LBBB	Surgery	Sinus
5	11	7	6	3.5	6-4	No	Retrograde	Year 4	LBBB	Follow-up	LBBB
6	11	9	7	4	7-5	No	Antegrade	On the Intraoperatively	LBBB	Not released	Sinus

CAVB, complete atrioventricular block; LBBB, left bundle branch block; LV, left ventricle; RV, right ventricle; VSA, ventricular septal aneurysm; VSD, ventricular septal defect.

In the patient who developed postoperative LBBB, which did not regress during follow-up, the device was surgically removed, and the VSD was repaired. The LBBB regressed with the removal of pressure on the left bundle branch.

Factors such as young age, low body weight, improper device positioning according to septal aneurysm and the choice of a large device have been identified as significant contributors to the development of conduction block.[3] In our 5-year review, we observed that 5 of 180 cases of LBBB occurred in children weighing under 10 kg, which underscores the importance of age and body weight in the risk of developing LBBB.

To minimize the risk of a heart block, it is essential to prevent trauma and inflammation to the heart conduction tissue.[4,7] This means an experienced operator should perform the procedure, using appropriately sized and flexible devices for the defect, and avoiding large carrier sheaths.[7,9] The KONAR-MF VSD occluder, or KONAR-MFO, has become the primary choice in recent years for device selection due to its procedural flexibility, soft structure, and defect compatibility. We prefer to use KONAR-MFO in patients with low body weight and young age.[3,12] While keeping septal aneurysmal tissue within the device during device implantation increases the risk of block, placing the left disc of the device inside the aneurysm may reduce the risk of block by removing it from the conduction system.[13] Additionally, it is important to note that optimal medical therapy may be effective in cases without complete AVB basing the final treatment decision on the patient's response.[9]

The reported rate of complete heart block after the surgical closure of VSD is < 2%. While the risk of CAVB (1-5%) in interventional closure of VSD raises concern, recent publications indicate a decreasing trend in the rates of CAVB.[2,9,10] In our series, CAVB developed in only 1 patient (0.5%) and resolved with steroids after temporary transvenous pacing. Yang et al. (2012) reported that 8 of 228 patients (3.5%) developed postoperative LBBB.[14] In a retrospective study of 2349 patients published in 2019, Wang et al. reported LBBB in 57 patients (2.4%) after the transcatheter closure of perimembranous VSD.[11] In our center, LBBB developed in 5 of 180 transcatheter closures of VSD (2.7%), and the device was not implanted in 2 patients due to the development of intraoperative LBBB. Follow-up continues for our patient who developed late-onset LBBB.

Limitations

This study was conducted at a single center and retrospectively. Although patients were regularly monitored, longer follow-up periods are required, especially to detect conduction disturbance that may arise in the late period. Results may vary depending on the use of different devices or results obtained from different centers.

Considering these limitations, the findings should be interpreted with caution, particularly on the development of conduction block in low-birth-weight children. Further studies with larger sample groups, multicenter designs, and prospective follow-up data are required.

CONCLUSIONS

The risk of heart block in transcatheter procedures performed at experienced centers is lower than anticipated. Interventional closure of VSD has emerged as a viable alternative to surgery, providing benefits such as less trauma, faster recovery, and a reduced length of stay. With the arrival of newly developed devices, the risk of heart block in the transcatheter closure of VSD is steadily decreasing. Additionally, treatment often restores sinus rhythm in patients, and any heart block that may occur typically does not persist.

DATA AVAILABILITY

The raw data supporting the conclusions of this article will be made available by the authors upon request to any qualified researcher.

FUNDING

None declared.

ETHICAL CONSIDERATIONS

The study protocol was approved by the SBU Tepecik Training and Research Hospital ethics committee in full compliance with national rules and regulations and the ethical principles outlined in the revised Declaration of Helsinki (2008). Prior written informed consent and assent was obtained to participate in this study from each patient or caregiver. Furthermore, the authors confirm that sex and gender variables were considered in full compliance with the SAGER guidelines.

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STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

No artificial intelligence technologies were utilized in the conception, data analysis, writing, or revision of this manuscript.

AUTHORS' CONTRIBUTIONS

S. Oksuz and K. Yildiz designed the study protocol, analyzed the integrity of clinical data, and revised it. N. Narin and R. Aktas contributed to the conception and design, acquisition, and critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects of work, ensuring integrity and accuracy. M.A. Atlan and S. Oksuz critically reviewed the article. R. Aktas and E. Gerceker contributed to the design, collected clinical data, and interpreted the results. C. Karadeniz provided editing and supervision. S. Oksuz took the lead in writing and reviewing the entire draft. All authors critically discussed the results and read and approved the final draft.

CONFLICTS OF INTEREST

None declared.

WHAT IS KNOWN ABOUT THE TOPIC?

- The transcatheter closure of perimembranous VSD offers advantages such as less trauma, faster recovery, and a reduced length of stay vs surgical procedures.
- One of the most serious complications of transcatheter closure is CAVB and LBBB, which can develop, particularly in small and low-weight children.
- The development of heart block may be associated with factors such as the anatomical proximity of the device to the conduction system, inappropriate and large device selection, and device malapposition relative to the septal aneurysm.
- The rate of CAVB has been reported between 0% and 6.4%. This rate, however, has been decreasing in recent years with the use of newly developed devices.
- Although CAVB and LBBB usually occur within the first week after the procedure, they can occur later as well.
- Early diagnosis, steroid therapy, temporary pacemaker implantation, and device removal if necessary can restore sinus rhythm in most cases.

WHAT DOES THIS STUDY ADD?

- This study presents original data on the development of conduction block following transcatheter perimembranous closure of VSD in underweight children.
- In particular, the use of new-generation, flexible, and small-sized devices (eg, Konar-MF) has demonstrated that procedural success and safety can be improved.
- The study highlights that serious complications, such as conduction block primarily emerge in the early stages; however, with appropriate patient selection, close follow-up, and prompt intervention, these complications can be largely reversed.
- By emphasizing the importance of patient selection and device selection in low-weight and small children, the study supports the transcatheter closure of VSD as a safe and effective option for this patient group.
- The study contributes to the literature, particularly in terms of complication management and device selection in high-risk patient groups.

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