Cardiology in the Young

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Transcatheter closure of atrial and ventricular septal defects in patients with dextrocardia: a clinical analysis

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Original Article

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Abstract

Objective: To assess the feasibility of transcatheter closure in patients with dextrocardia and isolated atrial septal defect or ventricular septal defect. *Methods:* A retrospective analysis was performed on the clinical data of 10 patients with dextrocardia and atrial septal defect or ventricular septal defect from June 2013 to January 2023 and successfully underwent transcatheter closure. Patient data were meticulously collected. *Results:* The study cohort comprised 10 patients, with three males, aged between 3 and 38 years. Intraoperative right heart catheterisation revealed the following measurements: the mean pulmonary arterial pressure of 20.5(18,24,3) mmHg, and a pulmonary-to-systemic flow ratio of 1.80(1.58,2.15). There were five atrial septal defects, with defect diameters of 26(20,30) mm, comprising three dextroversion and two mirror-image dextrocardia. Intraoperative echocardiography confirmed the absence of any residual shunt. Among them, a patient with mirror-image dextrocardia, atrial septal defects, and interrupted inferior vena cava required an alternative approach due to femoral vein limitations. The right internal jugular vein was punctured, and a 22 mm atrial septal occluder was successfully deployed via this route. The study identified five ventricular septal defects, with defect diameters of 4(3.5,5.5) mm, including two dextroversion and three mirror-image dextrocardia. Upon post-operative repeat left ventriculography, no residual shunt was detected in all but one case, which exhibited a minimal residual shunt. Throughout the perioperative period and subsequent post-operative follow-up, no severe complications were observed. *Conclusion:* For patients with dextrocardia accompanied by simple CHD, transcatheter closure is a viable option when interventional treatment is indicated. Although transcatheter closure of atrial septal defects or ventricular septal defect in patients with dextrocardia presents unique challenges, it is safe and effective when the anatomical nuances of dextrocardia are thoroughly understood.

Introduction

Dextrocardia is a rare congenital cardiovascular malformation characterised by the displacement of the heart from the left to the right side of the thoracic cavity, and its precise incidence is still largely unknown. However, it is estimated to occur in approximately 1 out of every 8,000 to 25,000 live births.[1] This condition is frequently accompanied by other cardiac anomalies, with the prevalence of these additional malformations varying significantly depending on the situs, from as low as 5% in cases of situs inversus to as high as 90% in situs solitus.[2,3] Chen et al.[4] performed a comprehensive clinical analysis on 194 individuals with dextrocardia, revealing that each patient presented with diverse CHD. Among these, the incidence rates were as follows: ventricular septal defect at 58.8%, atrial septal defect at 52.1%, pulmonary stenosis at 54.6%, and double-outlet right ventricle at 44.8%. Dextrocardia is categorised into three types[5]: mirror-image dextrocardia with visceral transposition, dextrocardia with visceral situs solitus, and cardiac dextroposition. In addition to the heart's displacement, the internal cardiac structure may range from completely normal to being associated with simple malformations such as atrial atrial septal defect and ventricular septal defect, or even complex cardiovascular deformities like transposition of the great arteries. At present, patients with complex cardiac deformities in conjunction with dextrocardia often necessitate surgical intervention. However, with advancements in interventional treatment for CHD and the refinement of procedural techniques, dextrocardia accompanied by simple CHDs, such as atrial septal defect and ventricular septal defect, can also be managed through transcatheter closure methods.[6–8] This study presents the clinical characteristics and interventional treatment outcomes of 10 cases involving dextrocardia combined with atrial septal defect and ventricular septal defect admitted to our department. The primary objective is

to evaluate the safety and feasibility of transcatheter closure in patients with dextrocardia who present with isolated atrial septal defect and ventricular septal defect.

Methods

Study patients

This study retrospectively selected patients with dextrocardia combined with atrial septal defect or ventricular septal defect who were successfully treated with interventional therapy at the Congenital Heart Disease Department of General Hospital of Northern Theater Command from June 2013 to August 2023. This investigation was approved by the Ethics Committee of General Hospital of Northern Theater Command Ethics and conformed to the principles of the Declaration of Helsinki and its later amendments.

Inclusion criteria:

1. Diagnosis of atrial septal defect or ventricular septal defect: Patients must have a confirmed diagnosis of atrial septal defect or ventricular septal defect as determined by echocardiography.
2. Diagnosis of dextrocardia: Dextrocardia must be diagnosed via a standard fluoroscopy, which should show that the majority of the heart is located in the right hemithorax with the cardiac apex pointing towards the lower right. Additionally, an abdominal ultrasound examination of the liver and spleen is required to ascertain whether the condition is mirror-image dextrocardia. Unlike mirror-image dextrocardia, dextroversion typically does not involve transposition of the visceral organs. Echocardiography can provide crucial insights into the morphological features, functional conditions, and potential associated abnormalities in cases of dextrocardia.
3. Successful transcatheter closure: Patients must have undergone successful transcatheter closure treatment for either atrial septal defect or ventricular septal defect.
4. Absence of other CHD: There should be no other forms of CHD present that would necessitate surgical intervention.
5. No irreversible pulmonary hypertension: Patients must not exhibit signs of irreversible pulmonary hypertension.

Indications for interventional treatment[9]:
Atrial septal defect:

1. Interventional treatment is indicated for patients aged 3 years or older and weighing at least 10 kg with a secundum atrial septal defect. Specifically, secundum atrial septal defect patients who exhibit signs of right ventricular volume overload in the absence of pulmonary hypertension or left heart disease are advised to undergo atrial septal defect closure, irrespective of symptom presence.
2. Anatomical considerations: If the atrial septal defect's edge is at least 5 mm away from the coronary sinus, superior and inferior vena cava, and pulmonary vein openings, and at least 7 mm away from the atrioventricular valve, without concurrent cardiac deformities necessitating surgical intervention, transcatheter treatment is deemed feasible.

Ventricular septal defect:

1. Perimembranous ventricular septal defect: Patients aged 3 years or older and weighing at least 10 kg with a perimembranous ventricular septal defect, characterised by a diameter ranging from 3 to 14 mm, are candidates for intervention if they present with clinical symptoms or signs indicative of left heart overload, with a pulmonary-to-systemic flow ratio greater than 1.5.
2. Anatomical proximity to valves: The upper edge of the ventricular septal defect should be at least 2 mm away from the aortic valve, and the posterior edge should be at least 2 mm away from the tricuspid valve. Additionally, there should be no aortic regurgitation and no prolapse of the right coronary cusp of the aorta.
3. Muscular ventricular septal defect: Patients aged 3 years or older with a muscular ventricular septal defect who exhibit clinical symptoms or signs of left heart overload, with a pulmonary-to-systemic flow ratio greater than 1.5, are considered suitable for intervention.

Transcatheter closure of atrial septal defect and ventricular septal defect

Pre-operative preparation protocol: patients are required to fast from food and water for a period of 6 hours prior to the procedure. Prophylactic antibiotics are administered 30 minutes before the operation to reduce the risk of infection. Infants and young children are administered intravenous ketamine for general anaesthesia, while adults receive 1% lidocaine for local anaesthesia. Following routine disinfection, successful puncture of the right femoral artery and vein is performed. Intravenous heparin is administered at a dosage of 100 U/kg to prevent thrombosis. Subsequently, an additional 1/4 to 1/3 of the initial dose is administered every hour to maintain anticoagulation throughout the procedure. The occluders used in this study are either **atrial septal defect and ventricular septal defect** occluders manufactured by Shanghai Shape Memory Alloy Material Co., Ltd., in China, or the second-generation Amplazer Ductus Occluder produced by Abbott Medical Co., Ltd., in the USA.

Atrial septal defect with dextrocardia interventional treatment process (illustrated in Figure 1)

The procedure commences with a routine puncture of the right femoral vein, followed by the insertion of a 6-F end-hole catheter. When there is difficulty with the femoral venous approach, the right internal jugular venous approach can be considered for occlusion. This catheter is skilfully guided through a series of chambers and vessels: right femoral vein → right atrium → right ventricle → pulmonary artery, with the purpose of measuring the pulmonary artery and right ventricular pressures. Next, the end-hole catheter is deftly navigated through the interatrial communication, entering the left atrium and subsequently the left upper pulmonary vein. At this stage, a 0.035-inch diameter by 260 cm length reinforced guide wire is meticulously introduced into the left upper pulmonary vein. The selection of the occluder size is determined based on the maximum atrial septal defect diameter, as measured by transthoracic echocardiography, with an additional 4–6 mm increment. For larger atrial septal defects, the occluder size can be further increased by an additional 2–4 mm, making it

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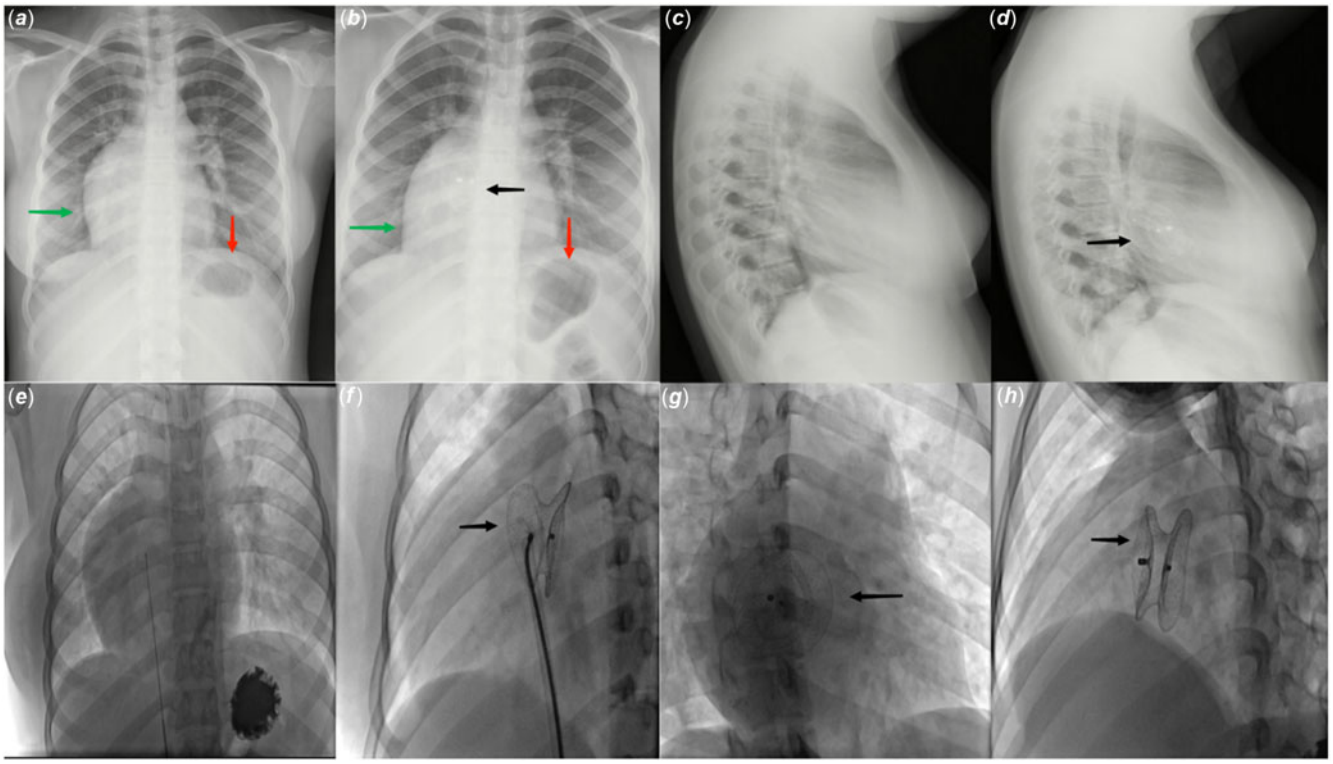

Figure 1. Chest fluoroscopy examination and transcatheter closure process for atrial septal defect with dextrocardia (female, 30 years old). (***a***) and (***c***) Pre-procedure chest anteroposterior and lateral fluoroscopy images, respectively, showcasing the initial state prior to the closure intervention. (***b***) and (***d***) Post-procedure chest anteroposterior fluoroscopy images, demonstrating the results following the closure procedure. (***e***) A guide wire is introduced into the right femoral vein and tracks along the right edge of the spine, illustrating the initial step in the catheterisation process.(***f***) A 40 mm atrial septal defect occluder is successfully deployed, as visualised in this image. (***g***) and (***h***) Final anteroposterior and lateral fluoroscopy images post-release of the occluder, confirming the device's position and effectiveness. (The green arrow indicates the cardiac apex pointing to the lower right, the red arrow points to the gastric bubble on the left side, and the black arrow highlights the atrial septal defect occluder.)

8–10 mm larger than the measured defect diameter, ensuring a secure and effective closure.

Based on the dimensions of the occluder, an appropriate type of delivery sheath is selected. Guided by a reinforced guide wire, the sheath is meticulously positioned at the ostium of the left upper pulmonary vein. Under the vigilant surveillance of fluoroscopy and echocardiographic monitoring, the occluder is precisely delivered to the site of the atrial septal defect using a metal delivery apparatus to effectively occlude the atrial septal defect. The imaging perspectives are crucial for the assessment of the occluder's configuration. A left anterior oblique 30° plus cranial 20°, along with an anteroposterior view (which can be adjusted based on the specific anatomical conditions), are employed to scrutinise the occluder's shape. Bedside echocardiography is then utilised to confirm that the occluder is optimally positioned, without impeding valve function. The stability of the occluder is further assessed by applying multiple gentle tugs, ensuring there is no displacement or abnormal positioning. Upon verification of these criteria, the occluder is safely released, completing the interventional procedure.

Transcatheter treatment process for ventricular septal defect with dextrocardia (illustrated in Figure 2)

The procedure begins with a routine puncture of the right femoral artery and vein. A 5/6F pigtail catheter is then carefully inserted through the right femoral artery, navigating sequentially through the descending aorta, aortic arch, ascending aorta, and finally into the left ventricle. This catheter is utilised to measure both aortic and left ventricular pressures and to perform left ventriculography at a right anterior oblique 50° plus cranial 20°. During this phase, the diameters of the ventricular septal defect on both the left and right ventricular sides are measured, along with the distance from the aortic valve. Next, a Judkins right 4 catheter is introduced and carefully retracted retrograde through the aorta, reaching the left ventricle. Guided by a guide wire, the catheter tip is deftly manoeuvred through the ventricular septal defect into the right ventricle. A 260-cm-long, 0.032-inch super-slippery guide wire is then threaded through the catheter and advanced into the right ventricle, subsequently pushed further into either the pulmonary artery or the superior vena cava. Subsequently, an additional 6-F end-hole catheter is inserted into the right femoral vein, traversing the right femoral vein, right atrium, right ventricle, and ultimately the pulmonary artery. This catheter is employed to measure the pulmonary artery and right ventricular pressures, completing the comprehensive assessment of the cardiovascular system in this unique patient presentation. A snare catheter is meticulously guided to the pulmonary artery with the aim of capturing the super-slippery guide wire. Once captured, the wire is carefully retracted, following a path through the right ventricle, right atrium, inferior vena cava, and finally out through the right femoral vein, thereby establishing a secure femoral artery-vein track wire.

Under the vigilant monitoring of transthoracic echocardiography and fluoroscopy, a delivery long sheath is advanced through the ventricular septal defect and into the left ventricle. An occluder is selected, with a diameter that is at least 2 mm larger than the smallest diameter measured via angiography, ensuring a proper fit

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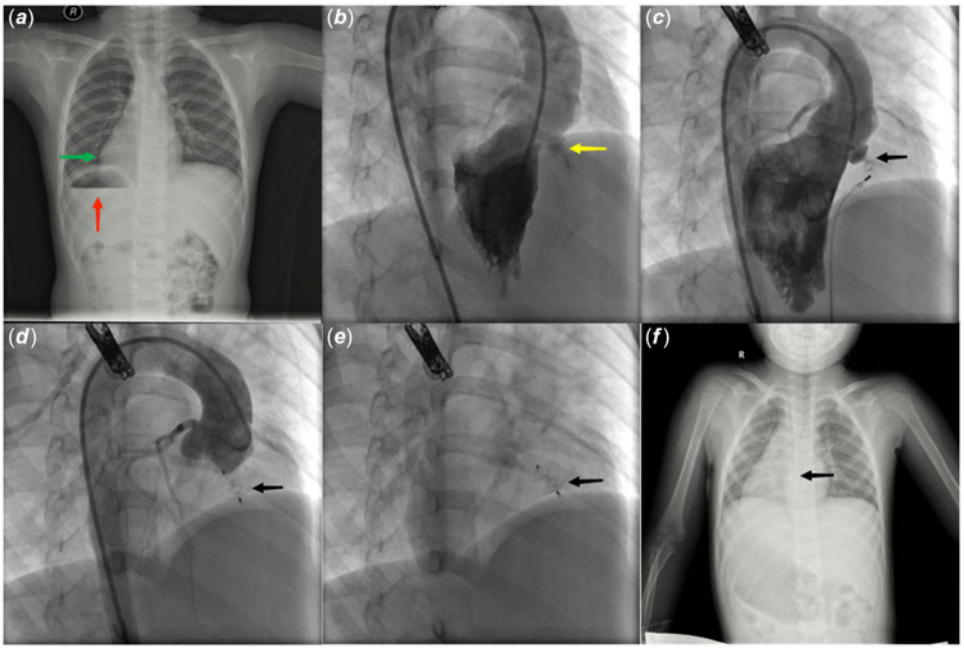

Figure 2. Chest fluoroscopy examination and transcatheter closure process for mirror-image dextrocardia with ventricular septal defect (male, 5 years old). (***a***) Pre-closure anteroposterior fluoroscopy image of the heart, providing a baseline view before the intervention. (***b***) A pigtail catheter is inserted through the femoral artery and advanced into the left ventricle for left ventriculography. The image reveals left-to-right shunting at the ventricular septum, indicative of the ventricular septal defect. (***c***) Post-closure left ventriculography demonstrates the absence of residual shunting, confirming the effectiveness of the closure procedure. (***d***) Aortography performed above the aortic valve shows no evidence of aortic regurgitation, an important consideration in the assessment of the ventricular septal defect and its treatment. (***e***) Image captured after the release of the occluder, illustrating the final position of the device within the heart. (***f***) Post-closure anteroposterior fluoroscopy image of the heart, showcasing the post-procedure cardiac configuration. (The green arrow indicates the cardiac apex pointing to the lower right, the red arrow points to the gastric bubble on the left side, the yellow arrow highlights the ventricular septal defect, and the black arrow indicates the ventricular septal defect occluder.)

and sealing effect. This occluder is then carefully positioned through the sheath at the site of the ventricular septal defect. A repeat left ventriculography is performed to meticulously observe for any residual shunting, indicating the effectiveness of the occluder placement. Upon achieving satisfactory results as confirmed by both transthoracic echocardiography and chest fluoroscopy, the occluder is securely released. For cases with larger defects or those that present a challenge in establishing a track, a larger delivery long sheath can be opted for. In such instances, the track guide wire can be retained for additional support. Once the occluder is satisfactorily placed, the guide wire can be safely withdrawn, completing the procedure.

Post-operatively, the sheath and catheters are removed, and hemostasis is achieved by compression at the puncture sites of the affected limbs. The femoral vein puncture site is compressed with a salt bag for 4 hours, and the femoral artery puncture site is compressed with a salt bag for 6 hours. The patient remains bedridden for 12 hours, and prophylactic antibiotics are administered for 1 day to prevent infection. Low molecular weight heparin (100 U/kg, every 12 hours) is given as a subcutaneous injection for anticoagulation starting 24 hours after closure. Aspirin is orally administered at a dosage of 3 to 5 mg/kg daily starting from the first post-operative day for a total of 6 months. On the second post-operative day, a chest fluoroscopy, electrocardiogram, and echocardiography are performed. An additional electrocardiogram is performed 48 hours and on the fifth day after the ventricular septal defect closure catheterisation. Follow-up with outpatient electrocardiogram and echocardiography is scheduled at 1, 3, 6 months, and 1 year after discharge.

Statistical analysis

Continuous variables were expressed as either means ± standard deviation or median [(lower quartile (Q1) and upper quartile (Q3)]. Discrete variables were presented as frequencies or percentages. All data were analysed using SPSS 25.0 software (SPSS, Inc., Chicago, Illinois). A p-value < 0.05 was considered statistically significant.

Results

Patient demographics and study characteristics

The study cohort comprised 10 patients with the age of 26.00 (11,32.75) years and the weight of 58.00 (23.5,67.5) kg. The cardiothoracic ratio was 0.52 (0.48,0.56). Among the study participants, we identified five cases of atrial septal defect, comprising two males and three females. Among these, three patients presented with dextroversion, while two had mirror-image dextrocardia. Additionally, there were five cases of perimembranous ventricular septal defect, including one male and four females. In this group, two patients had dextroversion and three exhibited mirror-image dextrocardia. All patients underwent successful interventional closure treatment, with the procedural duration ranging from 25 to 68 minutes. Intraoperative right heart catheterisation revealed the mean pulmonary artery pressure of 20.5 (18,24,3) mmHg, the systolic pulmonary artery pressure of 40 (34.5,41) mmHg, and the pulmonary-to-systemic flow ratio of 1.80 (1.58,2.15).

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Pre-operative and post-operative analysis of atrial septal defect cases

As detailed in Table 1, the diameter of atrial septal defect was 26(20,30) mm, and the diameter of the used occluder devices was 34(28,38) mm for the closure, and intraoperative transthoracic echocardiography confirmed the absence of residual shunting in all cases. Among these cases, one patient presented with mirror-image dextrocardia combined with an atrial septal defect and an absent hepatic segment of the inferior vena cava. Due to the limitations in sheath length, access to the left atrium was not feasible, and the support force provided was insufficient, leading to the abandonment of the femoral vein approach for closure. An alternative access route was then employed; the right internal jugular vein was punctured, and a 6-F end-hole catheter was guided through the right internal jugular vein, superior vena cava, and right atrium, successfully traversing the interatrial communication into the left atrium. A reinforced guide wire was subsequently introduced into the left atrium, followed by the placement of a 12-F delivery sheath. Ultimately, a 22 mm atrial septal defect occluder manufactured by Shanghai Shape Memory Alloy Co., Ltd., was successfully deployed for closure.

Pre-operative and post-operative analysis of ventricular septal defect cases

For the five ventricular septal defect cases under study, the defect diameter of ventricular septal defect was 4(3.5,5.5) mm, and the occluder sizes selected for closure were as follows: a 9 mm symmetrical ventricular septal defect occluder, a 5/4 mm second-generation Amplazer Ductus Occluder, a 10 mm symmetrical ventricular septal defect occluder, a 12 mm symmetrical ventricular septal defect occluder, and a 9 mm A4B2 ventricular septal defect occluder. In one instance, a patient with ventricular septal defect and mirror-image dextrocardia experienced moderate aortic regurgitation following the deployment of the initial oversized occluder. Consequently, a second suitable device was utilised to achieve a successful outcome. Post-operative repeat left ventriculography revealed no residual shunting in all but one case, which exhibited a small amount of residual shunting. At the 1-year follow-up, transthoracic echocardiography confirmed the absence of residual shunting in all patients.

Post-operative evaluation and complications

Upon pre-discharge evaluation following catheterisation, chest fluoroscopy, electrocardiograms, and echocardiograms were conducted and did not reveal any significant abnormalities. The post-operative course was generally uneventful, with the exception of a single case of hematoma at the puncture site observed after closure of a ventricular septal defect, a trace residual shunt in another ventricular septal defect patient, and atrial premature beats in two patients with atrial septal defect. No patients encountered severe complications such as malignant arrhythmias, pericardial effusion, or device detachment during both the perioperative period and the subsequent post-operative follow-up phase.

Discussion

Congenital cardiac positional anomalies arise from abnormal development and rotation of the embryonic primary heart tube, categorising into two primary types: total cardiac displacement and cardiac axis displacement. Dextrocardia, a subtype of cardiac axis

Table 1. Data of all patients with dextrocardia undergoing transcatheter atrial or ventricular septal defect closure

No.	Age (year)	Weight (kg)	Gender	Mirror-image dextrocardia	Size of defect (mm)		C/T ratio	Qp/Qs	PAP (mmHg)		Device		Residual shunt		Other complications
					Type	Size (mm)			sPAP	mPAP	Type	Size	Immediate	One year	
1	26	81	Female	No	VSD	4	0.46	1.5	40	18	VSDO	9	No	No	Haematoma
2	5	24	Male	Yes	VSD	3	0.57	1.4	21	14	ADO-II	5/4	Small	No	—
3	3	12	Female	Yes	VSD	5	0.56	1.6	52	25	VSDO	10	No	No	—
4	25	65	Female	Yes	VSD	6	0.56	1.7	40	24	VSDO	12	No	No	The first device had moderate residual shunt and then changed to the second device
5	26	62	Female	No	VSD	4	0.46	1.6	36	20	VSDO	9	No	No	—
6	13	22	Male	No	ASD	26	0.51	1.9	44	21	ASDO	34	No	No	—
7	38	54	Female	No	ASD	32	0.51	2.1	40	20	ASDO	40	No	No	Atrial premature beats
8	31	75	Male	Yes	ASD	14	0.52	1.9	30	18	ASDO	22	No	No	Atrial premature beats
9	38	54	Female	No	ASD	26	0.49	2.3	40	24	ASDO	34	No	No	—
10	30	65	Female	No	ASD	28	0.55	2.4	40	25	ASDO	36	No	No	—

ASD = atrial septal defect; VSD = ventaicular septal defect; ASDO = atrial septal defect occluder; VSDO = ventaicular septal defect occluder; ADO-II = the second-generation Amplazer Ductus Occluder; C/T ratio = cardiothoracic ratio; Qp/Qs = pulmonary-to-systemic flow ratio; PAP = pulmonary arterial pressure; sPAP = systolic pulmonary arterial pressure; mPAP = mean pulmonary arterial pressure.

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displacement, can be further classified using Van Praagh's segmental approach into the following distinct forms [10–12]:

1. Mirror-image dextrocardia: This is a true form of dextrocardia, relatively rare, and occurring in approximately one in ten thousand cases. It is characterised by a complete reversal of the positional relationship of the heart and great vessels, as well as the position of thoracic and abdominal organs. Specifically, the right atrium and liver are located on the left side of the spine, while the left atrium and gastric bubble are on the right side. The left lung typically has three lobes, the right lung has two lobes, and the bronchi on both sides exhibit reversed morphology. Although this condition usually does not cause symptoms and does not require haemodynamic changes, some cases may be associated with other cardiovascular malformations such as atrial septal defect, ventricular septal defect, pulmonary valve stenosis, and tetralogy of Fallot, with an incidence rate typically below 10%. Hou et al.[3] found that mirror-image dextrocardia may be combined with up to 12 CHDs, predominantly complex CHDs, including double outlet of the right ventricle (27.0%), corrected transposition of the great arteries (17.0%), and tetralogy of Fallot (16.0%). In our series, three out of four cases of mirror-image dextrocardia were associated with perimembranous ventricular septal defect, and one with atrial septal defect.
2. Isolated dextrocardia: Also known as dextroversion or pseudo dextrocardia,[3] the heart descends and rotates poorly to the left, or even to the right, during the developmental process, causing the heart to shift to the right side of the chest to varying degrees, with the heart apex pointing to the right front. However, the anatomical relationship between the left and right atria and ventricles is normal, and the relationships between the various cardiac chambers do not exhibit mirror-like changes. This type is often caused by displacement and rotation of the heart and is frequently accompanied by more complex cardiovascular malformations such as single ventricle, single atrium, atrial septal defect, and transposition of the great vessels. Hou et al.[14] found that adult dextroversion often combines with four types of CHD, with the situs solitus, ventricular left-loop, and leftward transposition of the great arteries type corrected transposition of the great arteries being the most common (80.0%), followed by AIII type double inlet of the ventricle (10.0%), situs solitus, ventricular left-loop, and leftward transposition of the great arteries type double outlet of the right ventricle (6.7%), and isolated atrial septal defect (3.3%). In our series, four out of six dextroversions were combined with secundum atrial septal defect, and two with perimembranous ventricular septal defect.
3. Cardiac dextroposition: This condition results from the displacement of the heart to the right chest due to lung, pleural, or diaphragmatic lesions. The heart's position is shifted, but there is no phenomenon of cardiac rotation or visceral reversal, and no changes in lead I of the electrocardiogram. In our series, no patients were classified under this type.

Patients with dextrocardia often present with complex internal cardiac malformations, particularly those with dextroversion who exhibit a significantly higher likelihood of having complex intracardiac malformations compared to those with mirror-image dextrocardia.[15] Surgical repair continues to be the primary treatment for complex CHD. However, with the evolution of minimally invasive surgical techniques, interventional therapy has emerged as the preferred treatment method for simpler forms of CHD, such as secundum atrial septal defect, perimembranous ventricular septal defect, and patent ductus arteriosus, owing to its minimal invasiveness and expedited recovery. There are documented cases of successful interventional therapy in patients afflicted with various forms of dextrocardia and CHD.[6–8,16–18] Nonetheless, for patients with mirror-image dextrocardia, interventional treatment poses unique challenges due to the altered heart position and the variability in the positions of the atrioventricular and great vessels. This necessitates that the operator adjust their spatial imagination and operational habits, which undoubtedly amplifies the procedural complexity. Echocardiography is pivotal in the treatment process, encompassing pre-operative diagnosis, indication selection, intraoperative guidance and monitoring, immediate post-operative assessment of the closure effect, and subsequent follow-up examinations. For patients with dextrocardia who have combined atrial septal defect and ventricular septal defect, it is imperative to ascertain the size of the defect, the condition of the edges, and the distance from the mitral, tricuspid, and aortic valves prior to catheterisation to prevent closure failure or valve damage.

Patients with dextrocardia undergoing interventional treatment for isolated CHD share similar indications, procedural steps, perioperative management, and post-operative follow-up as those with a normally levocardia. However, the presence of dextrocardia introduces certain operational nuances that must be carefully considered during interventional closure procedures. For patients with ventricular septal defects, regardless of whether they have mirror-image dextrocardia or dextroversion, specific adjustments are necessary. For instance, when performing left ventriculography, deploying the occluder, and assessing its shape, the conventional left anterior oblique 50° with cranial 20° view is typically replaced with a right anterior oblique 50° with cranial 20° view. As depicted in Figure 3, the direction and positioning of the guide wire during the establishment of the femoral arteriovenous pathway differ. In patients with dextroversion, the blood flow direction and guide wire positioning are analogous to those with a normal left-sided heart, but they contrast with those observed in mirror-image dextrocardia, necessitating mirrored operational techniques. Recognising and adapting to these differences during the surgical procedure is essential for the successful navigation of the guide wire through the defect and the establishment of the arteriovenous pathway. Meticulous attention to these operational adjustments not only enhances the success rate of the catheterisation but also minimises the risk of intraoperative complications.

Study limitations

This study acknowledges several inherent limitations that warrant consideration. The retrospective design and the small sample size may introduce selection bias, potentially skewing the generalisability of our findings. Additionally, the absence of a control group precludes direct comparative analysis with other surgical approaches. The sample, drawn from a single centre and limited in number, may not provide sufficient power to draw statistically significant conclusions, further limiting the broad applicability of our results. In view of these constraints, there is a pressing need for larger-scale, prospective, and multicentre studies to validate the safety and efficacy of the treatment protocols employed.

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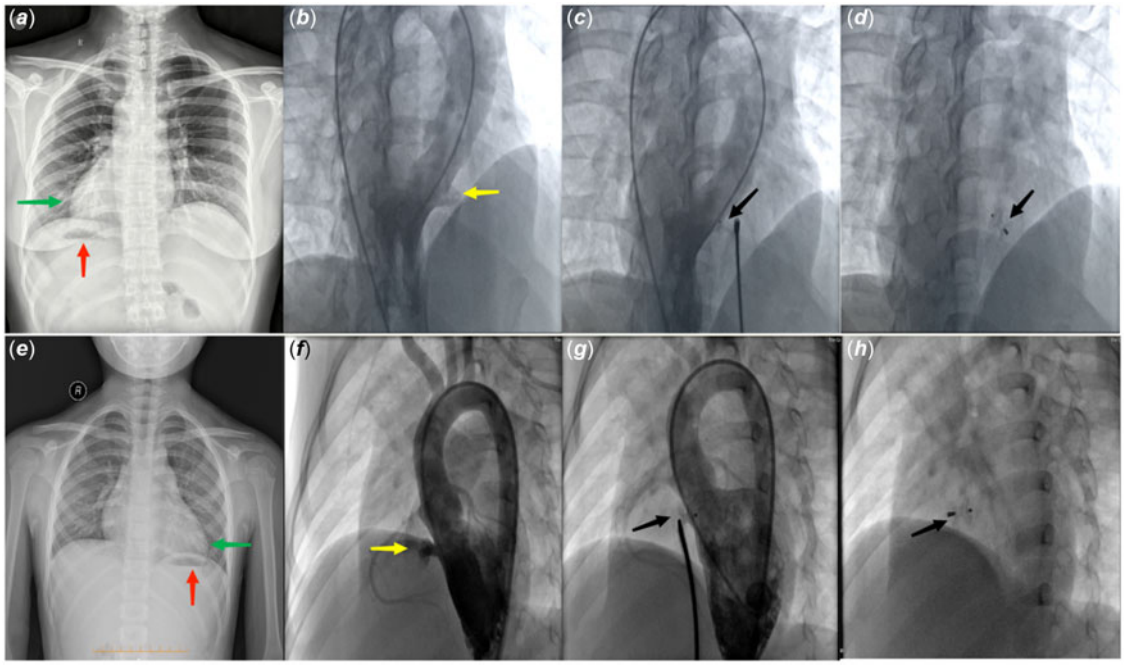

Figure 3. Comparative analysis of chest fluoroscopy and interventional closure for ventricular septal defects in patients with mirror-image dextrocardia and normal levocardia. (***a***) and (***e***) Anteroposterior fluoroscopy images of the heart prior to the closure procedure, showcasing the initial state for both patient groups. (***b***) and (***f***) Insertion of a pigtail catheter through the femoral artery into the left ventricle for left ventriculography. The images demonstrate left-to-right shunting at the ventricular septum, a characteristic feature of ventricular septal defects. (***c***) and (***g***) Repeat left ventriculography post-closure reveals the absence of residual shunting, indicating a successful closure in both dextrocardia and levocardia patients. (***d***) and (***h***) Final images after the release of the occluder, displaying the occluder's position and confirming the procedural outcome in both patient groups. (The green arrow denotes the direction of the cardiac apex, the red arrow points to the gastric bubble; the yellow arrow highlights the ventricular septal defect; the black arrow indicates the ventricular septal defect occluder.)

Conclusions

When addressing CHD through interventional closure in patients with mirror-image dextrocardia and dextroversion, who possess unique cardiac anatomical structures, physicians must have an in-depth understanding of cardiac anatomy and imaging. This expertise is crucial for the accurate assessment of the indications for interventional procedures. Intraoperatively, doctors should tailor their surgical approach to the patient's specific anatomical features and conduct a comprehensive risk assessment for the perioperative period. Based on this assessment, they must develop strategies to mitigate these risks. For patients who are suitable candidates, interventional closure offers a safe and effective alternative to traditional surgery. This approach reduces the associated risks and provides a less invasive treatment option, thereby improving patient outcomes and recovery.

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Availability of data and materials. Readers can access the data used in the study by contacting the corresponding author.

Author contribution. The authors confirm contribution to the paper as follows: study conception and design: Qiguang Wang; data collection: Jiawang Xiao, Xianyang Zhu, and Jianming Wang; analysis and interpretation of results: Jiawang Xiao, Xianyang Zhu, Jianming Wang, Zhongchao Wang, Jingsong Geng, and Qiguang Wang; draft manuscript preparation: Jiawang Xiao. All authors reviewed the results and approved the final version of the manuscript.

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