

Clinical study of stand-alone transthoracic echocardiography-guided percutaneous occlusion of patent ductus arteriosus

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ABSTRACT

Objective: We aimed to investigate the feasibility and safety of stand-alone transthoracic echocardiography-guided percutaneous occlusion of patent ductus arteriosus (PDA) without the use of X-ray equipment.

Methods: From January to December 2015, we performed stand-alone transthoracic echocardiography-guided percutaneous PDA occlusion using an occluder delivered via a delivery sheath introduced via femoral vein access without the use of X-ray equipment in 12 PDA patients.

Results: PDA occlusion was successfully performed in all 12 patients. The procedure duration ranged from 30 to 110 min (50.4±22.8 min), and the size of the implanted occluder ranged from 12 to 20 mm (15.2±2.8 mm). No occluder migration, residual shunt, or thrombotic complications were observed in the perioperative period. There was no clinical death, hemolysis, infection, or embolism during patients' hospitalization and the follow-up period.

Conclusion: Stand-alone transthoracic echocardiography-guided percutaneous PDA occlusion without the use of X-ray equipment is a safe and effective procedure. (*Anatol J Cardiol* 2018; 20: 00-00)

Keywords: congenital heart disease, cardiac intervention, echocardiography

Introduction

Patent ductus arteriosus (PDA) is a common congenital heart disease, and its conventional treatment includes open ligation or direct repair with cardiopulmonary bypass, which inevitably leaves large surgical scars and is associated with more complications (1, 2). In recent years, with improvements in percutaneous occlusion techniques, most PDA patients can undergo percutaneous occlusion with satisfactory results. However, the commonly used percutaneous occlusion technique is guided by X-ray, resulting in radiation exposure for surgeons and patients (3-5). In this study, we performed stand-alone transthoracic echocardiography-guided percutaneous PDA occlusion without the use of X-ray equipment in 12 PDA patients and achieved good results.

Methods

This was a retrospective study and was approved by the Ethics Committee of Fujian Medical University, China, and it adhered to the Declaration of Helsinki. Additionally, written informed consent was obtained from the patients or the patient's relatives.

Twelve patients were enrolled from our Cardiovascular Department between January and December 2015. The patients ranged in age from 12 to 35 years and weighed from 30 to 65 kg; the diameter of PDA ranged from 8 to 14 mm. All 12 patients were diagnosed using echocardiography. Other indications for PDA closure included hemodynamically significant left to right shunts and/or significant chamber enlargement and/or mild to moderate pulmonary hypertension, with presence of clinical symptoms. In addition, relatively healthy adults and adolescents with a relatively large PDA diameter (PDA diameter was greater than 14 mm) were selected to facilitate the procedure. The exclusion criteria included presence of other associated congenital heart disease needing surgical intervention, elevated pulmonary vascular resistance with non-reactive drug, uncontrolled chronic congestive heart failure, and inability to obtain a signed consent.

Routine examinations included a standard electrocardiogram, a chest X-ray, and blood tests. Six patients were symptomatic; the symptoms included shortness of breath, palpitations, exercise intolerance, and insignificant chest pain. The chest X-ray film showed pulmonary congestion, and the echocardiography showed hemodynamically significant left to right shunts and/or significant

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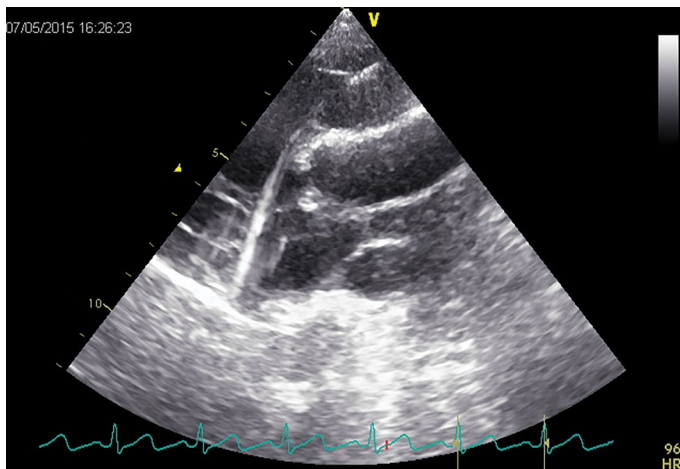


Figure 1. A multifunctional catheter was advanced into the right ventricle

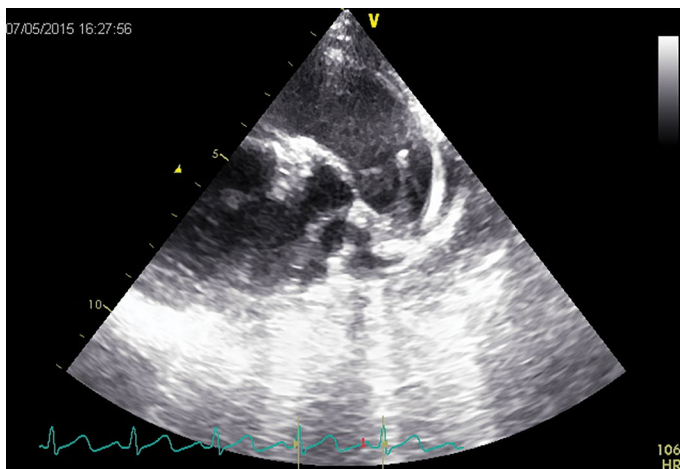


Figure 2. A multifunctional catheter was advanced into the pulmonary artery trunk

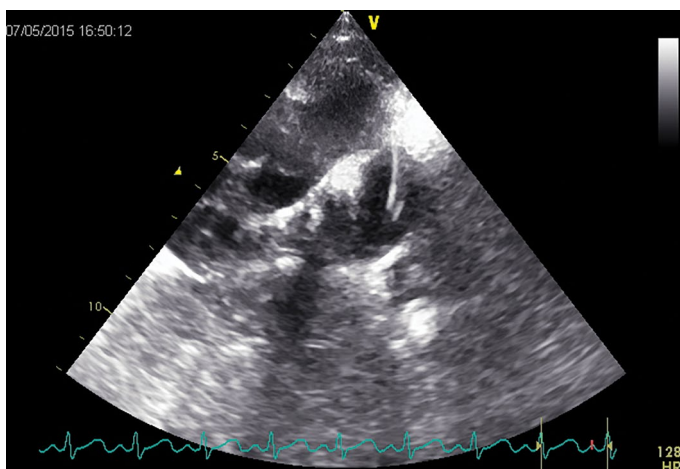


Figure 3. A delivery sheath was inserted into the descending aorta via the ductus arteriosus

chamber enlargement. Eleven patients had mild-moderate pulmonary hypertension, which was assessed using echocardiography (pulmonary artery systolic pressure was < 60 mm Hg). Patients with increased pulmonary vascular resistance with non-reactive

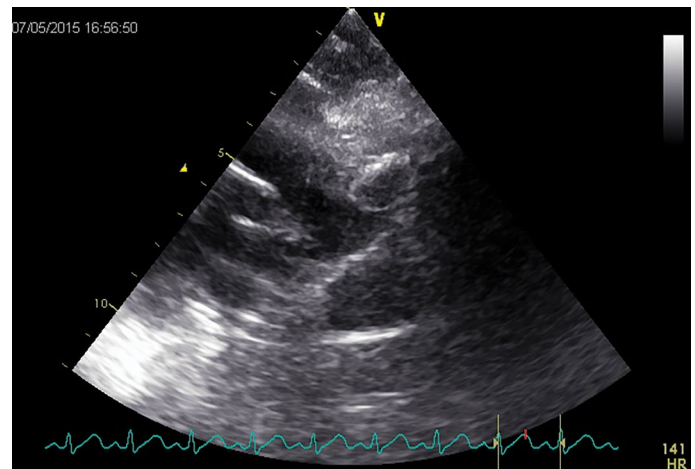


Figure 4. Ductus arteriosus occluder tip was opened

drug were excluded from this study. Thus, cardiac catheterization was not considered as a routine examination.

The Amplatzer PDA device and domestic PDA device were used in this study. The domestic PDA device occluder was similar to the Amplatzer PDA occluder (Shan Dong Visee Medical Apparatus Co. Ltd; China); the latter was cheaper than the former.

The occluder size was selected according to the echocardiography results and was generally 4–8 mm larger than the diameter of the ductus arteriosus. During the procedure, the patient was administered systemic heparin (1 mg/kg), and the right femoral vein was punctured; following this, a venous sheath was placed, and then a multifunctional catheter and a loach guidewire were inserted. Under echocardiography guidance, the catheter and guidewire were advanced into the right atrium via the inferior vena cava and then into the right ventricle via the tricuspid before finally advancing into the pulmonary artery via the right ventricular outflow tract (Fig. 1, 2). After locating the ductus arteriosus using echocardiography, the loach guidewire was advanced through the ductus arteriosus to guide the multifunctional catheter into the descending aorta. Next, the loach guidewire was withdrawn, and a hard guidewire was inserted along the multifunctional catheter and advanced into the descending aorta via the ductus arteriosus (confirmed using echocardiography). The multifunctional catheter was withdrawn, and an occlusion delivery sheath was inserted over the hard guidewire and into the descending aorta (confirmed using echocardiography). The inner core and hard guidewire were withdrawn, and an occluder was slowly inserted along the delivery sheath (Fig. 3). The delivery wire was carefully advanced, and under echocardiography guidance, the ductus arteriosus occluder tip was opened; following this, the occluder was pulled back and secured in the ductus arteriosus (Fig. 4). Echocardiography was used to evaluate for any residual shunt. If no residual shunt was found, the occluder was fully opened (Fig. 5). After confirming the occlusion using echocardiography, the delivery sheath was withdrawn. After completion of the procedure, the patient was sent to the intensive care unit, and the tracheal tube was removed after the patient woke up. For anticoagulant therapy, the patient was

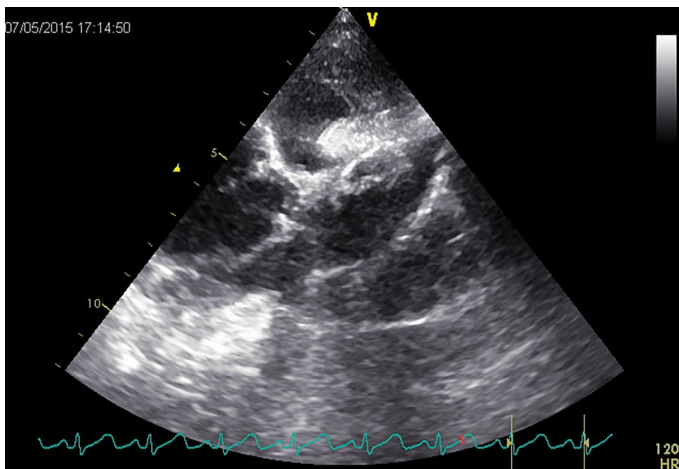


Figure 5. The occluder was fully opened

given oral aspirin for 3 months postoperatively. Patients with cardiac insufficiency were given appropriate cardiac-strengthening and diuretic therapies.

Results

Occlusion was successfully achieved in all 12 patients. The operation time was 30-110 min (50.4 ± 22.8 min), and the size of the occluder used ranged from 12 to 20 mm (15.2 ± 2.8 mm). The postoperative hospital stay was 1.0 ± 0.6 (1–2) days. Minor complications observed in the patients included transient arrhythmias while establishing delivery access during the procedure, which usually resolved without any specific medical treatment. All 12 patients were followed up using echocardiography; no occluder migration, residual shunt to or from large vessels, vessel damage, cardiac rupture, puncture site hematoma, or thrombotic complications were observed. The patients were followed up for 1–2 years, and no occluder migration or thrombotic complications were observed. Four patients with cardiac insufficiency were treated with long-term oral cardiac-strengthening and diuretic therapy; further follow-up of these patients is needed to evaluate treatment outcomes.

Discussion

PDA is a common congenital heart disease, and conventional treatments include PDA ligation via a left posterior and lateral incision or direct repair via a midline incision with cardiopulmonary bypass, with satisfactory outcomes. Such surgical methods are more suitable for the premature and newborn infants. However, these methods inevitably leave large surgical scars; furthermore, intraoperative pulmonary oppression may cause pulmonary damage, and cardiopulmonary bypass may cause certain complications (6, 7). In recent years, improvements have been made in percutaneous occlusion techniques to achieve satisfactory outcomes in older children and adults; however, during the procedure, the operators and patient are exposed to X-ray radiation,

and these techniques require large, expensive X-ray equipment, which is not available in grass-roots hospitals in China. Moreover, percutaneous occlusion is usually performed in the intervention room, which is not equipped to handle emergencies such as occluder migration (8-11). Thus, both conventional surgical treatment and percutaneous occlusion have their advantages and disadvantages (12, 13). In recent years, numerous cardiac surgery centers have experimented with minimally invasive transthoracic occlusion, combining the features of both percutaneous occlusion and surgical treatment (14, 15). Transthoracic occlusion avoids the need for cardiopulmonary bypass and allows for rapid postoperative recovery. Moreover, only a small incision is needed in the left chest, thus, preserving the physical appearance. In addition, the shallow surgical approach makes it easy and convenient to establish device delivery access while avoiding X-ray radiation. The procedure is performed by a surgeon in the operating room; in case of occlusion failure, the case can easily be converted to a conventional surgery, without the need to transfer the patient from the intervention room to the operating room. However, it is very important to select the right treatment for each patient (16).

In our hospital, we have successfully performed stand-alone transthoracic echocardiography-guided percutaneous atrial septal defect occlusion in more than 100 patients as well as minimally invasive transthoracic PDA occlusion in more than 80 patients without the use of X-ray equipment. To further improve outcomes following minimally invasive procedures, with the accumulation of the previous experience, we performed stand-alone transthoracic echocardiography-guided percutaneous PDA occlusion without the use of X-ray equipment. The diameter of PDA was measured using the parasternal view in the preoperative transthoracic echocardiography. Then a relatively suitable PDA occluder (with a diameter=diameter of PDA+4-8 mm) was chosen. From our limited experience, for a 10-mm wide PDA, we chose a 14-18 mm occluder. If the 14 mm occluder could be dragged back into the pulmonary artery, we would choose a 16-18 mm occluder. Catheter angiography can help obtain accurate data on PDA; however, according to other reports and our clinical experience, TTE also provides relatively reliable data. During the procedure, the surgeon needed to make only a right femoral vein puncture. In this study, the procedure was successfully performed in all the patients, with no major complications during the perioperative or follow-up period. The high success rate observed in our study is considered to be associated with appropriate patient selection.

Standard percutaneous PDA occlusion may cause arterial complications. Many recent studies have confirmed the feasibility of PDA occlusion via femoral access. Thanopoulos et al. (17) reported 110 cases of stand-alone echocardiography-guided percutaneous PDA occlusion via femoral access and concluded that the procedure was safe and feasible. Baykan et al. (18) and Garg et al. (19) reported successful stand-alone percutaneous PDA occlusion via femoral access and noted the wide range of indications for this procedure. Khan et al. (20) reported two successful cases of stand-alone echocardiography-guided percutaneous

PDA occlusion: one case involved a 6-month-old patient with PDA and heart failure, and the other case involved a 6-year-old patient with PDA and chronic renal failure. Chen et al. (21) showed that transthoracic echocardiography could substitute for angiography in guiding percutaneous PDA occlusion, thus, streamlining the procedure and reducing complications. Tanidir et al. (22) concluded that using an appropriate echocardiographic assessment technique could reduce patient exposure to radiation and contrast agent during transcatheter PDA occlusion. Other studies have also confirmed the role of transthoracic echocardiography as a safe and feasible stand-alone guidance technique (23-25). Moreover, studies have shown that transthoracic echocardiography enables a more accurate measurement of the diameter of the ductus arteriosus (26).

To ensure the success of this procedure, clinicians must first pay attention to appropriate patient selection. In this study, the patients selected were relatively healthy adults and older children with a relatively large ductus arteriosus diameter, making the establishment of delivery access and sheath placement easy. Because of the relatively large diameter of the ductus arteriosus, preoperative echocardiography showed left ventricular enlargement and cardiac insufficiency in some cases. During the procedure, transthoracic echocardiography was crucial and required the involvement of an experienced echocardiographer. Usually, we can diagnose PDA using parasternal and suprasternal ultrasonic views and measure the shape, length, and width of PDA using color Doppler imaging. Based on our extensive experience in performing many minimally invasive transthoracic PDA occlusion and percutaneous atrial septal defect occlusion procedures, we are confident that transthoracic echocardiography can help obtain better images than transesophageal echocardiography in PDA cases, especially when guiding the delivery catheter into the right heart and ductus arteriosus with images of continuous thoracic sections. Moreover, in this study, the patients were mechanically ventilated; this reduced the effect of spontaneous breathing on the echocardiography and made it easier to examine the entire ductus arteriosus at the left upper section and suprasternal fossa section and to measure the inner diameter of the ductus arteriosus. Furthermore, the procedure must be performed by a surgeon, preferably with experience in open surgery and minimally invasive transthoracic occlusion, even intervention procedures for large vessels. Without X-ray-assisted positioning, the spatial perception of the surgeon and timely communication with the echocardiographer are particularly important. Surgeons or cardiologists without adequate experience or collaboration should opt for a conventional procedure. Another advantage of this procedure is that if there is an emergency, it can be converted to surgical repair within the operative room.

Precautions for the procedure include the following. 1) When placing the loach guidewire and multifunctional catheter, echocardiography may be performed to locate the inferior vena cava at the xiphoid section to guide the loach guidewire and the multifunctional catheter into the right atrium and, after adjusting the direction of

the catheter tip, into the right ventricle and then into the pulmonary artery. This step may require the use of different multifunctional catheters with different shapes and repeated attempts; care must be taken to operate gently to prevent accidental damage to the heart. It is more challenging to establish PDA occlusion access than atrial septal defect occlusion access. 2) Once the multifunctional catheter is inserted into the descending aorta, its location must be verified from different angles. In our experience, we have observed that the images obtained during echocardiography-guided access are usually quite clear, but echocardiography images from multiple sections must be obtained to verify that the multifunctional catheter is indeed inserted into the descending aorta via the ductus arteriosus; transesophageal echocardiography may be performed if necessary. In this study, we collected a blood sample via the multifunctional catheter for blood gas analysis. When placing the hard guidewire, the insertion depth should be assessed, the movement must be gentle, and real-time echocardiography positioning should be performed to prevent damage to large vessels or the atrium. 3) The occluder should be deployed slowly. In our experience, we have observed that the quality of echocardiography images of the descending aorta is generally poor; thus, after the delivery sheath is confirmed to be in the descending aorta, the occluder should be advanced slowly. After the occluder tip is opened, the occluder is pulled back into the ductus arteriosus and deployed only after the location has been confirmed using multiple imaging sections. 4) If the pulmonary artery pressure is high and acute vasoreactivity occurs, the procedure is aborted.

We believe that the classic percutaneous PDA occlusion technique is mature with proven results and remains the preferred treatment option for PDA. For some patients, such as those for whom X-ray is contraindicated, the procedure described in this study may be performed. This study has certain limitations: the sample size was small, and the case criteria were highly selective and, thus, may not be widely applicable. In future studies, we will further investigate inclusion criteria, operating procedures, and perioperative care. In addition, echocardiography is visually less effective than X-ray in displaying the ductus arteriosus, requiring the echocardiographer to thoroughly understand the ductus arteriosus and accurately measure its maximum inner diameter to provide a reference for occluder size selection. Grossly inaccurate measurements may lead to incorrect occluder selection, requiring occluder replacement and thereby increasing the procedure risks and cost. The procedure described in this study places high demands on the surgeon in terms of clinical experience, multi-disciplinary collaboration, and a long learning curve.

Conclusion

In summary, we believe that it is safe and feasible to perform stand-alone transthoracic echocardiography-guided percutaneous PDA occlusion, which is a minimally invasive procedure that preserves physical appearance and does not require cardiopulmo-

nary bypass. The procedure can be performed under transthoracic or transesophageal echocardiography guidance, with no need for large X-ray equipment. In case of occlusion failure, the procedure can be immediately converted to a surgical case, thus, eliminating any potential concerns. However, performing transthoracic echocardiography-guided percutaneous PDA occlusion is technically challenging, and care must be taken when using this technique.

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