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SPECIAL ISSUE ARTICLE

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Echocardiographic guidance for transcatheter patent ductus arteriosus closure in extremely low birth weight infants

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Abstract

Echocardiographic imaging provides real-time guidance during transcatheter patent ductus arteriosus (PDA) closure in extremely low birth weight (ELBW) infants. Transthoracic echocardiogram provides detailed assessment of the PDA and surrounding structures prior to, during, and after transcatheter closure. This article aims to review the different echocardiographic techniques and concepts utilized during transcatheter PDA closure in ELBW infants.

KEYWORDS

cardiac catheterization, extremely low birth weight infants, patent ductus arteriosus, transthoracic echocardiogram

1 | INTRODUCTION

Patent ductus arteriosus (PDA) accounts for 5%-10% of all congenital heart diseases and is more common in premature neonates.[1] Around half of premature infants with a birth weight <1 kg and a third <1.5 kg have a PDA at 72 hours of life.[2,3] Hemodynamically significant PDAs increase morbidity and mortality, and odds for death are six times higher in premature infants with a persistent PDA.[4-7] Until recently available treatment options for hemodynamically significant PDAs in premature neonates have been medical treatment or surgical ligation.

Transcatheter PDA closure is considered the procedure of choice in patients >4 kg, and there are decades of experience with this procedure in infants, children, and adults.[8,9] Recently several centers have shown the safety and efficacy of transcatheter PDA closure in extremely low birth weight (ELBW) infants.[10-14] Varying techniques (venous vs arterial access) and locations (cardiac catheterization lab vs neonatal intensive care unit) of transcatheter PDA closure in ELBW infants exist between the centers.[11,14] Currently, transthoracic echocardiographic guidance of transcatheter PDA closure in ELBW infants has become routine despite the variation in technique and location.[11,13-15] The use of echocardiogram guidance allows limited use of contrast agents and radiation typically present in catheter-based procedures.[16] A detailed review of the transcatheter PDA closure in ELBW infants, including patient selection, device overview, and institution experience, is outside the scope of this review. The objective of this review is to describe and highlight the echocardiographic assessment of this new procedure and its potential complications.

2 | PREPROCEDURE ECHOCARDIOGRAM

Controversy exists among the medical community regarding optimal timing of PDA closure in ELBW infants.[2] However, once a hemodynamically significant PDA is identified, transcatheter PDA closure in ELBW infants is a treatment option in centers with experience.[10-15] The decision to perform and timing of transcatheter PDA closure in an ELBW infant takes place prior to the day of the procedure. The preprocedural echocardiogram on the day of the procedure focuses on identifying the size and type of PDA, familiarization of the echocardiographic windows required to image the PDA, and evaluation of cardiovascular structures potentially affected during the procedure.

PDA morphology is highly variable, but recent reclassification of PDA types has been suggested to include the type "F" PDA to describe the common PDA seen in ELBW infants.[17] The "F type" PDAs in premature infants are typically long and tortuous without significant stenosis, similar to the ductus arteriosus seen during fetal life.[16] Evaluation of PDA size is critical to correct device choice. To

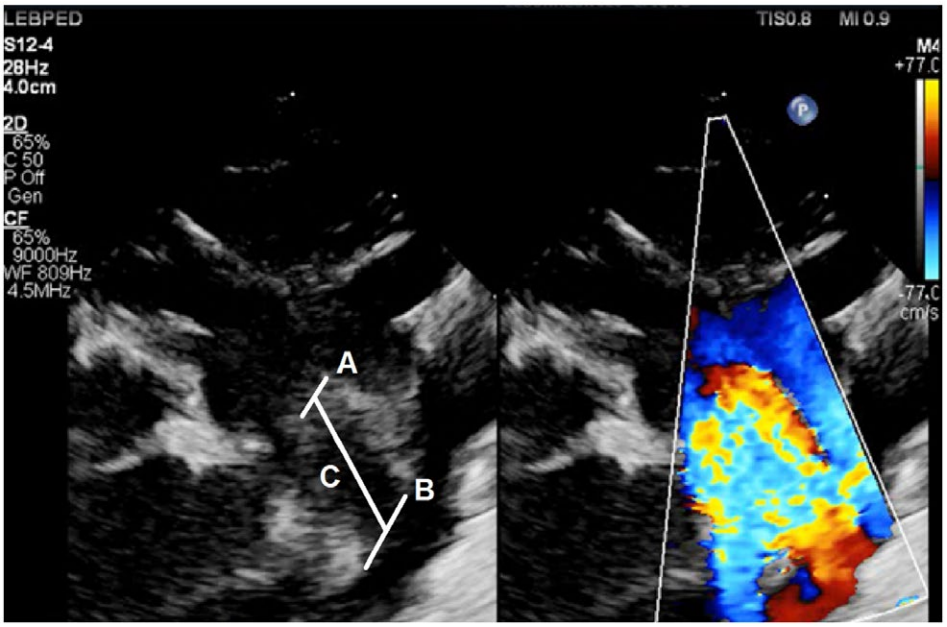

FIGURE 1 High left parasternal transthoracic echocardiogram color compare Doppler of a patent ductus arteriosus. PDA diameter at the pulmonary end (A), aortic end (B), and PDA length (C)

aid in choice of the correct device, several echocardiographic measurements of the PDA are made: PDA diameter at the aortic end, pulmonary end, and PDA length (Figure 1). The PDA length can be measured by a straight line from the aortic to pulmonary end or a curvilinear line along the PDA including the ductal ampulla.

ELBW infants have small echocardiographic windows, and the person performing the imaging during the procedure should familiarize themselves prior to the start of the case. The location of the procedure typically dictates what access the imagers have to the neonate during the case. If the procedure is performed in the cardiac catheterization lab, the imagers are typically on the opposite side of the table from the catheterization team. Bedside transcatheter PDA closure in the neonatal intensive care unit presents similar challenges in acquiring reliable echocardiographic images and communicating findings in a timely manner to the catheterization team.[11,14]

The left pulmonary artery (LPA) and aortic arch are potentially affected after transcatheter PDA closure, and any stenosis prior to the procedure should be evaluated.[10-15] The different vascular approaches of the transcatheter PDA closure place different cardiovascular structures at risk. Antegrade approach of transcatheter PDA closure involves crossing the tricuspid and pulmonary valve, and these structures should be evaluated prior to the start of the procedure. It is important to document the presence of any pericardial effusion, biventricular systolic function, and evidence of elevated right ventricular systolic pressure prior to the procedure.

3 | PROCEDURAL ECHOCARDIOGRAM

The goal of echocardiogram-guided transcatheter PDA closure is to provide real-time imaging to assist in the safe and successful closure of a hemodynamically significant PDA. At our institution, we perform the procedure in the catheterization lab with biplane fluoroscopy. There is a theoretical concern of external compression of the ELBW infant with transthoracic echocardiogram so imaging during PDA device deployment is limited. Therefore, echocardiographic images are not obtained until after the PDA device is deployed. Other institutions provide echocardiographic imaging of the antegrade catheter movement from the inferior vena cava to the ultimate position across the PDA.[11,14] Catheter technique and operator preference will dictate the imaging needs of the procedure so discussion about approach and echocardiographic support prior to and during PDA closure is recommended.

There are several different types of PDA devices used for transcatheter PDA closure in the ELBW infant, and the imaging team should understand the different echocardiographic appearances between the devices.[10-15] The Amplatzer Vascular Plug II (AVP II), Amplatzer Duct Occluders (ADO) (St. Jude Medical, St. Paul, Minnesota), and Micro Vascular Plug (MVP) (Medtronic, Minneapolis, Minnesota) are all used for transcatheter PDA closure in ELBW infants.[10,13,14] All of these devices are manufactured differently with different materials and appear different on echocardiogram (Figure 2).[10,13,14] The AVP II and ADO devices have retention discs that could cause LPA or aortic arch obstruction, and the MVP has a proximal polytetrafluoroethylene partial covering that creates echocardiographic artifact in this region (Figure 2).

Once the PDA device is deployed within the PDA, echocardiographic imaging should evaluate the device position prior to detachment. A high left parasternal view should identify the length of PDA device allowing for simultaneous evaluation of the PDA device, aortic arch, and LPA. Residual shunting around the device and LPA or aortic arch obstruction are the most common complications after device

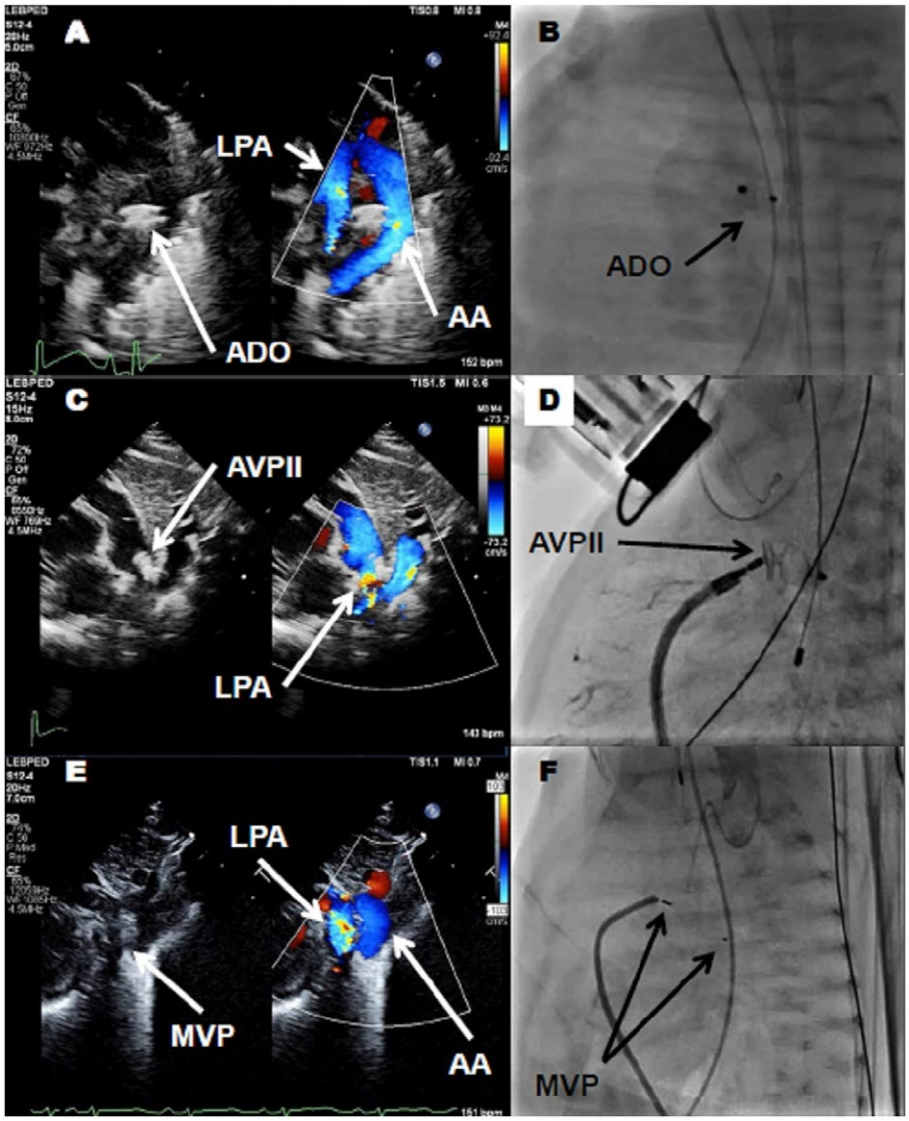

FIGURE 2 High left parasternal transthoracic echocardiogram color compare Doppler and lateral angiogram of different transcatheter PDA devices. Amplatzer Duct Occluder (ADO). Amplatzer Vascular Plug II (AVPII). Aortic arch (AA). Left pulmonary artery (LPA). Micro Vascular Plug (MVP)

deployment[10-15] (Figure 3). Echocardiographic color and spectral Doppler assessment of the LPA and aortic arch can aid in evaluation of stenosis (Figure 3). Should any of these complications occur after deployment, the echocardiogram provides real time assessment to aid in decision regarding device repositioning or retrieval. Once the device is detached from the delivery catheter, imaging is repeated to ensure no change in device position.

4 | POSTPROCEDURE ECHOCARDIOGRAM

Quick evaluation of potentially affected cardiovascular structures after transcatheter PDA closure is prudent. Evaluation of pericardial effusion, valves crossed during the procedure, systolic function, and evidence of elevated right ventricular systolic pressure can be performed in a timely manner as not to prolong the procedure further. A more detailed evaluation 1-6 hours after PDA closure is recommended specifically to evaluate postligation cardiac syndrome (PLCS). PLCS is characterized by hypotension requiring inotrope support and respiratory failure usually occurring 6-12 hours after the procedure, and is described in up to 40%-50% of surgical cases.[18] Variations in timing and protocol of echocardiographic evaluation of cardiovascular function after PDA closure exist.[18,19]

The function protocol should include evaluation of volume loading (left atrial size, mitral valve inflow, and left ventricular end-diastolic diameter) and myocardial performance (ejection fraction measurements and tissue Doppler velocities).[18] The complete echocardiogram protocol should evaluate cardiovascular function in addition to specific complications associated with transcatheter PDA closure previously mentioned. The PDA device position with residual shunting (2D, color, and spectral Doppler),

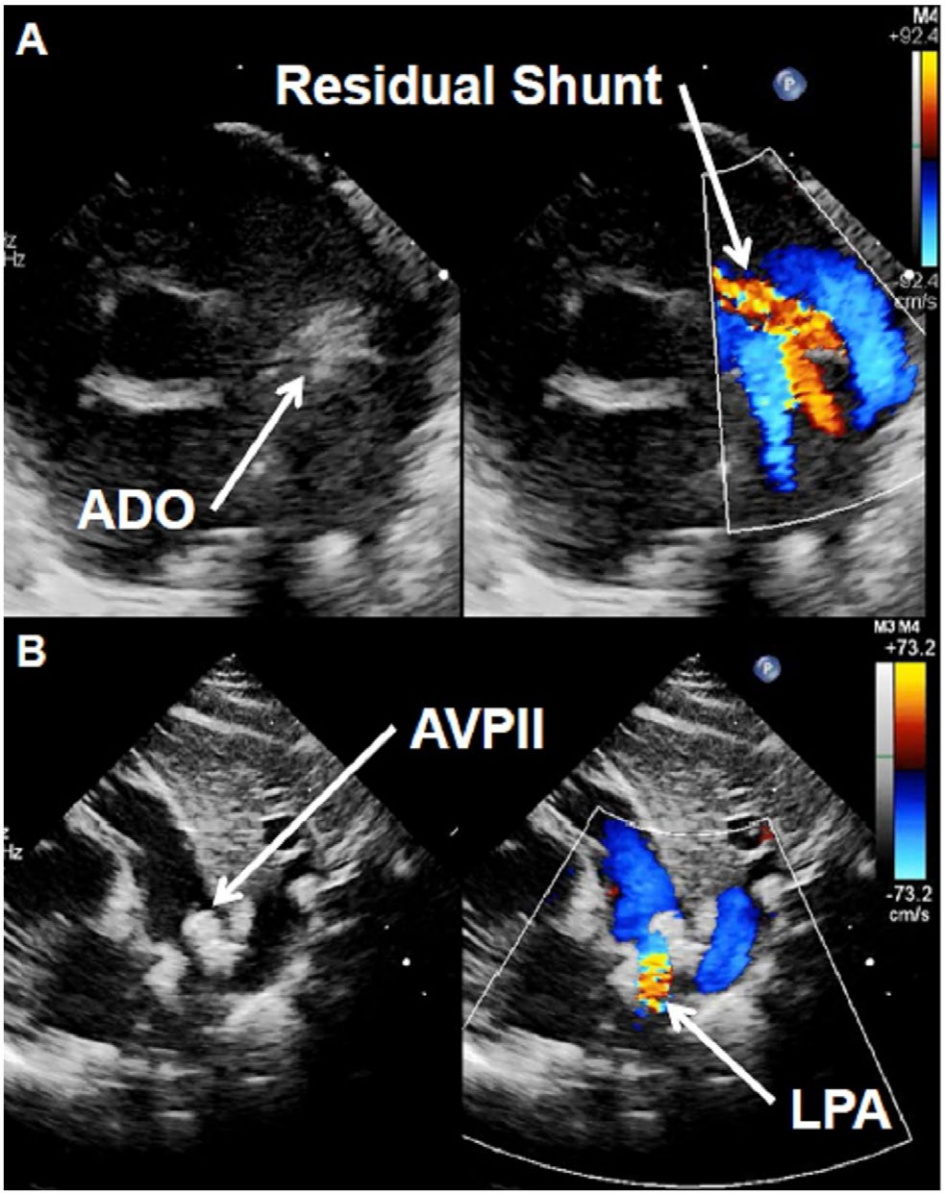

FIGURE 3 High left parasternal transthoracic echocardiogram color compare Doppler of different complications of transcatheter PDA device closure. A, Residual left to right shunt after initial placement of an Amplatzer Duct Occluder (ADO). B, Left pulmonary artery (LPA) stenosis after initial placement of an Amplatzer Vascular Plug II (AVPII). Both devices were repositioned with no residual shunting or obstruction

LPA evaluation (2D, color, and spectral Doppler), aortic arch evaluation (2D, color and spectral Doppler, abdominal aorta spectral Doppler), pulmonary and tricuspid valve evaluation (2D, color, and spectral Doppler) if antegrade approach used, pericardial evaluation, and evaluation of elevated right ventricular systolic pressure (ventricular septal wall motion) should be added to the functional protocol.

5 | CONCLUSIONS

Transthoracic echocardiogram provides real time imaging to assist in the safe and successful closure of a hemodynamically significant PDA in ELBW infants. The echocardiogram provides detailed assessment of the PDA before, during, and after transcatheter closure. The quick cardiovascular assessment by echocardiogram allows input on PDA device positioning and potential complications vital to success of the procedure. Detailed echocardiogram protocols associated with transcatheter PDA closure vary by the different catheter-based techniques that exist for closure in ELBW infants.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest with the contents of this article.

AUTHOR CONTRIBUTIONS

Wrote the manuscript, performed echo evaluation of PDA closures: Johnson

Reviewed the manuscript, performed transcatheter PDA closure: Sathanandam

Reviewed the manuscript, performed echo evaluation of PDA closures: Naik, Philip

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