



A comprehensive program for preterm infants with patent ductus arteriosus

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Abstract

Objectives: Patent ductus arteriosus (PDA) is a common finding in preterm infants. A hemodynamically significant PDA may require intervention for closure. This article aims to describe a transcatheter PDA closure (TCPC) program for preterm infants and the components of a comprehensive outpatient follow-up strategy.

Setting: A multidisciplinary team approach including neonatology, cardiology, anesthesiology, medical transport team, pulmonology, cardiac surgery, neurodevelopmental specialist, nutrition, speech therapy, social work, research collaborators, and other health care specialists is integral to the dedicated care and promotion of wellness of extremely low birth weight (ELBW) infants.

Patients: To date, we have performed TCPC on 134 ELBW infants weighing <2 kg at the time of the procedure, 54 of whom were <1 kg with the smallest weighing 640 g with a median gestation age of 25 weeks (range 23-27 weeks).

Interventions: A comprehensive follow-up strategy with the creation of the Memphis PDA Clinic was implemented.

Outcome measures: Respiratory support, tolerance of enteral feeds, growth, and neurodevelopmental progress are indicators of favorable outcomes.

Results: TCPC has benefited ELBW infants with faster weaning off the ventilator, increase in enteral feedings, and somatic growth with the overall shortening of the hospital length of stay. The Memphis PDA Clinic has ensured optimal postdischarge follow-up to improve long-term outcomes.

Conclusions: TCPC is a safe and effective alternative to manage ELBW infants with a hemodynamically significant PDA. Comprehensive follow-up after discharge provided in a multispecialty clinic developed specifically for this unique population has been successful in improving outcomes.

KEYWORDS

extremely low birth weight, neonatology, neurodevelopmental outcomes, patent ductus arteriosus, pediatrics, preterm infant, transcatheter PDA closure

1 | INTRODUCTION

The ductus arteriosus is present in fetal circulation in order to divert the cardiac output away from the fluid-filled lungs toward the placenta by a connection between the main pulmonary artery and the descending aorta. A patent ductus arteriosus (PDA) in the first three days of life is a normal physiologic remnant in healthy term infants. Conversely, a PDA in preterm infants causes significant clinical sequelae as a result from left to right shunting. It is widely recognized that a hemodynamically significant PDA is known to contribute to increased morbidity and mortality.¹ The increase in pulmonary blood flow in the setting of prematurity leads to pulmonary edema, noncompliant lungs, and worsening of respiratory status, which eventually leads to the development of chronic lung disease (CLD).² Other sequelae of a hemodynamically significant PDA include intraventricular hemorrhage, necrotizing enterocolitis, congestive heart failure, and failure to thrive.^{3,4} Studies have not proven pharmacological therapy to be 100% effective in inducing complete ductal closure. Complications from medical therapy exist including renal insufficiency and bleeding.⁴ Surgical ligation of the PDA is invasive and associated with multiple adverse events including pneumothorax, phrenic nerve palsy, vocal cord paralysis, chylothorax, and scoliosis.⁴ Transcatheter PDA closure (TCPC) provides a minimally invasive alternative. It ensures the immediate closure of the PDA and eliminates the risks associated with other modalities for closure.

2 | TRANSCATHETER CLOSURE IN PRETERM INFANTS

2.1 | Background

TCPC is the accepted technique for children weighing greater than 5 kg. The use of femoral arterial access for this procedure could be associated with vascular injury, limb loss, and bleeding.⁵ In the past few years, TCPC has emerged as a favorable alternative to surgical ligation⁶⁻⁹ in extremely low birth weight (ELBW) infants due to changes in the procedural technique that avoids the requirement of femoral arterial access.¹⁰ Newer devices have been developed whereby TCPC can be performed routinely in ELBW infants with very low risk for adverse events.¹¹ A transvenous-only approach is possible with the use of echocardiography and low dose fluoroscopy. The use of dual imaging modalities has significant benefits. Transthoracic echocardiography assists to confirm optimal device positioning within the PDA without blocking the blood flow into the aorta or the left pulmonary artery. Subsequently, less contrast media and overall less fluid volume are required for the procedure. Fluoroscopy provides the ability to more readily manage inadvertent device complications such as embolization which otherwise cannot be done with echocardiography alone.

2.2 | Institutional Experience

To date, we have performed TCPC on 134 ELBW infants that weighed <2 kg at the time of the procedure, 54 of whom were <1 kg with the smallest weighing 640 g. The median gestation age for these patients

is 25 weeks (range 23-27 weeks). We receive referrals from four NICUs in the Memphis area as well as from four additional NICUs within the city's 100-mile radius (Figure 1). The institution's reputation for having the most experience with this procedure has spurred referrals from three cities over 300 miles away.

With increasing institutional experience, surgical ligation of PDAs in ELBW infants has decreased (Figure 2). We have performed observational retrospective studies that demonstrated faster weaning off ventilator and oxygen support in ELBW infants undergoing TCPC vs. surgical PDA ligation. The rate of enteral feedings accelerates post-TCPC with rapid somatic growth. These advantages of TCPC shorten the overall NICU length of stay. Morbidities associated with surgery including post-PDA ligation syndrome are not encountered with TCPC. Strong support from the neonatologists, NICU nursing staff, congenital cardiac surgeons, anesthesiologists, and the cardiology division at large has influenced this transition in practice.

It was necessary to create and implement a systematic means for managing pre- and postprocedure high-risk infants who are geographically located further away in the NICU than in the cardiac intensive care unit which is adjacent to the cardiac catheterization lab. Inpatient consultation and management are performed methodically according to a Monday to Friday schedule. The interventional cardiology service makes regular rounds on Mondays in the NICU. This is to ensure close follow-up of patients who remain hospitalized following TCPC. Echocardiograms, vital sign trends, and other pertinent diagnostic information are reviewed. The neonatologists and nursing staff provide valuable information regarding the patients' clinical progress which allows for timely discharge planning and procurement of additional resources and services needed once home. Patients who are receiving medical management for PDA closure and who may become candidates for TCPC are also evaluated on Mondays. Tuesdays are reserved for reviewing of the diagnostic studies obtained on Monday and for scheduling patients referred for TCPC. Procedures are preferentially scheduled for Wednesdays and Thursdays. It is critical to consider the day and timing of closure in these high-risk patients. The beginning to middle of the week is preferred to have more week days to allow for postprocedure monitoring. Fridays involve rounding again on postprocedure patients and revisiting consultations for potential TCPC candidates.

3 | COMPREHENSIVE FOLLOW-UP

3.1 | NICU follow-up

Comprehensive follow-up of ELBW infants following discharge is imperative. While the rate of survival of ELBW infants has increased, the rates of morbidity from conditions secondary to prematurity still persist.¹² With the shorter length of NICU stays, infants with continuing medical problems and a tenuous medical status are being discharged to households with varying levels of familiarity with their complex conditions.¹² Comanagement in the outpatient setting by subspecialties involved in their course is of utmost importance to ensure quality care and interdisciplinary

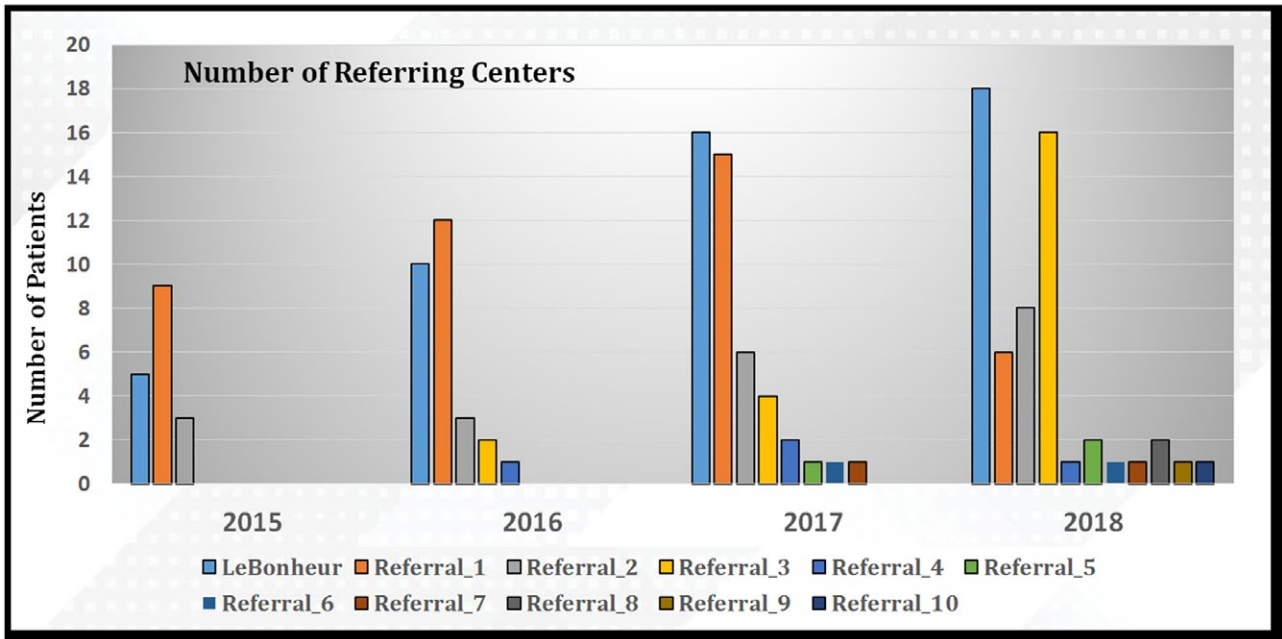


FIGURE 1 Graph showing the increase in the number of patients referred and the number of referring centers for transcatheter PDA closure for ELBW infants

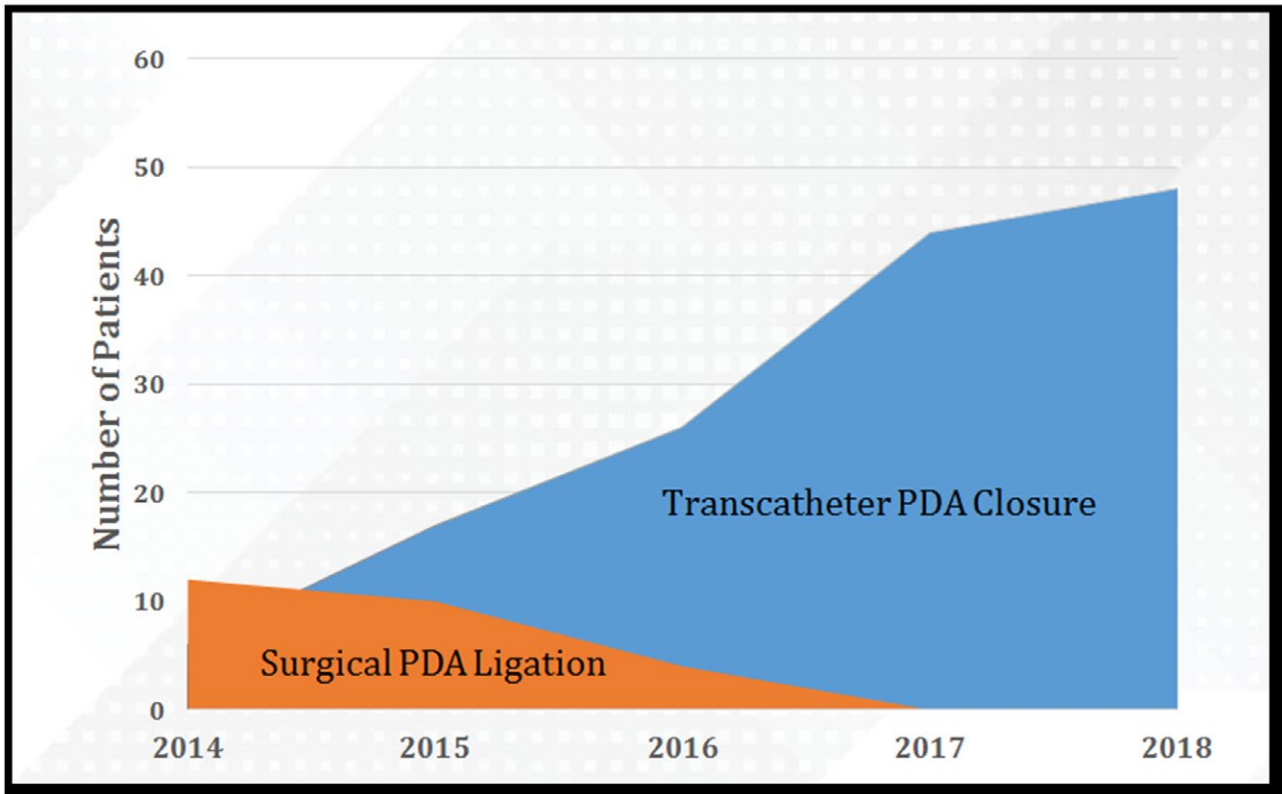


FIGURE 2 Graph showing the increase in the number of ELBW infants undergoing transcatheter PDA closure with a decline in the number of surgical ligation of the PDA

communication continues. Furthermore, providers with expertise in ELBW infants are integral to supporting primary care providers who may be concerned about their own lack of specialized training

in the care of these infants.¹² Providers in NICU follow-up clinics are uniquely situated to aid the primary care provider in early identification of medical issues affecting these infants.

Evaluation and surveillance of neurodevelopmental outcomes is a key component of follow-up clinics. The risk for neurodevelopmental deficits is inversely related to gestational age, making ELBW infants at a relatively high risk for a host of deficits.¹³ Developmental delay, hearing and vision impairment, behavioral problems, and academic challenges can be detected through routine screening.¹³ Assessments should be performed by skilled personnel at specific time points related to corrected gestational age.^{14,15} Early identification of deviations in neurodevelopmental progress is crucial for quick enrollment into early intervention programs and is accomplished through standardized evaluation within specialized NICU follow-up clinics.¹⁴

3.2 | The Memphis PDA Clinic

An outpatient multispecialty clinic for ELBW infants who have undergone TCPC has been developed at our institution within the past year. The large population of ELBW infants who have undergone this procedure proved to have unique needs that necessitated the development of the clinic. Since TCPC is a new therapy for ELBW infants, it is essential for these patients to be followed in a dedicated multispecialty clinic. This clinic was established to compliment the NICU follow-up clinic in order to provide comprehensive care and services that these high-risk infants require. This has improved the overall attendance at follow-up appointments. Cardiology, pulmonology, nursing, nutrition, speech therapy, social work and research coordinators are integral members of the multispecialty team. Echocardiograms are performed with specific imaging requirements and following a specific timeline. They are performed by a group of dedicated sonographers and read by dedicated cardiologists, all of whom have previously participated in intra- and postprocedure noninvasive imaging of these infants. Infants with CLD and pulmonary hypertension are easily comanaged by cardiology and pulmonology within the PDA clinic setting. Diuretics, oxygen, and pulmonary hypertension medications can be managed concurrently and with seamless communication between the two subspecialties. Dedicated nurses are trained to provide neurodevelopmental assessment with standardized screening tools. Timely referrals are made to early intervention services and to developmental pediatricians when deficits are identified. A registered dietitian evaluates growth and manages the nutritional problems identified during clinic visits. Speech therapy is available for consultation for infants requiring further assessment of feeding abilities. Social work assists with procuring nonmedical resources for the families and is an integral link to early intervention programs. Patients are scheduled for clinic initially at 1 month postdischarge, then at corrected ages of 6, 12, 24, and 36 months or more frequently if clinically necessary. Annual appointments are subsequently made at 4 and 5 years of age and they are followed for every 3 years thereafter. At age 15 they are seen every 5 years until transition to adult congenital cardiology if indicated.

4 | CONCLUSIONS

TCPC is a safe and effective way to manage ELBW infants with a hemodynamically significant PDA. ELBW infants who have undergone TCPC are at a higher risk for hospital readmission and death during the first year of life compared to healthy term infants.¹⁴ Comprehensive follow-up after discharge may reduce these risks and can be provided in a multispecialty clinic developed specifically for this unique population.

AUTHOR CONTRIBUTIONS

Drafting the article, Critical revision of the article, and Approval of the article: Leah Apalodimas and Shyam Sathanandam.

Critical revision of the article and Approval of the article: Benjamin Rush Waller, Ranjit Philip, Judy Crawford and Jordan Cunningham.

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