Received: 3 September 2018 | Accepted: 22 October 2018

DOI: 10.1111/chd.12710

SPECIAL ISSUE ARTICLE

WILEY Congenital Heart Disease

Live broadcast of transcatheter PDA closure in a 700 grams ELBW infant during the International PDA Symposium

Shyam Sathanandam MD | Ashley Gianinni RCIS | Eric Sefton BA | Kaitlyn Greer RT(R) | Nathan Stecchi RDCS | Kimberly Allen RN | Ranjit Philip MD | B. Rush Waller MD

University of Tennessee Health Science Center, LeBonheur Children's Hospital, Memphis, Tennessee

Correspondence
Shyam Sathanandam, MD, University of Tennessee Health Science Center, LeBonheur Children's Hospital, 848 Adams Avenue, Memphis, TN 38103.
Email: shyam@uthsc.edu

Abstract

Objective: The objective of this article is to describe a live case transmission of transcatheter closure of a patent ductus arteriosus (PDA) in an extremely low birth weight (ELBW) infant during the first International PDA Symposium conducted in Memphis, Tennessee.

Setting: A multidisciplinary team approach including audiovisual specialists, information technology specialists, physicians, nurses, and other health care specialists was required to perform the transcatheter PDA closure (TCPC) in an ELBW infant at LeBonheur Children's Hospital and the procedure was broadcast live to the attendees at the International PDA Symposium allowing for a two-way audiovisual discussion during the procedure.

Patient: The patient was a 14 days old 24-week premature ELBW infant, who weighed 700 g at the time of the procedure. The patient was requiring mechanical ventilation secondary to pulmonary hemorrhage. The PDA measured 4 mm in diameter and 12 mm in length.

Interventions: TCPC was performed safely without any procedural complications using a specialized minimally invasive technique.

Outcome Measures: The patient was weaned off the ventilator in < 7 days after the procedure. The child was discharged 9 weeks after the procedure (35 weeks' corrected gestation) weighing 2.2 kg, on full oral feeds and no supplemental oxygen.

Results: The successful TCPC allowed for this child to have an uneventful hospital course. The case also highlights the technical nuances involved in setting up the live transmission.

Conclusions: This case demonstrated to the audience in the International PDA Symposium the feasibility and safety of performing TCPC in an ELBW infant. Live cases are useful in exhibiting the nuances involved in any new technique and allows for best learning experience.

KEYWORDS
ELBW, live case, PDA, TCPC

1 | INTRODUCTION

At LeBonheur Children's hospital in Memphis, Tennessee, the cardiac catheterization lab team, has performed over 120 TCPC in ELBW infants since 2014.[1,2] A TCPC procedure was broadcasted live for the first International PDA Symposium in May, 2018. The patient weighed approximately 700 g. The team assembled for the case consisted of two interventional cardiologists, two diagnostic cardiologists, two anesthesiologists, a certified registered nurse anesthetist, three cath lab staff members, and one sonographer. The case was discussed in great detail and preparations were made to ensure patient safety and optimal patient outcome.

2 | LIVE CASE SET UP

In preparing for the PDA Symposium live stream, our team tested and discussed several different software and hardware solutions. Our goal was to accomplish the live stream in house, at HD 1080p60 quality, at a reasonable cost, while maximizing the use of existing hospital resources. In the planning stage, we decided that all video and audio mixing should happen locally in the cath lab to produce a single video stream with audio to the remote site. This allowed the technicians in the room to have full control over the content, to allow the medical staff to direct what was being transmitted in real time, and to make it possible to cut the live feed at any time for patient safety or privacy reasons.

Live video production was handled by an ATEM Television Studio HD (Blackmagic Design, Port Melbourne, Australia). This video mixer was selected for its features and affordability. We connected two DSLR cameras and one SDI camera via Blackmagic HDMI-SDI extender systems. These extender systems enabled 1080p60 video distribution over inexpensive SDI cables and allowed for optimal cable placement to avoid disruption to normal OR flow. One DSLR camera was mounted on a tripod for wide shots and for Q&A sessions. The second camera was mounted on a handheld stabilization system to allow for smooth handheld detail shots. The third SDI camera was a CV502-M miniature broadcast POV camera (Marshall Electronics, Torrance, California). This camera was mounted to a Z-rail armature (Zacuto, Chicago, Illinois) connected to a Matthews C-stand to allow for robust, stable, and easy adjustment while placed over the patient. The armature and camera were bagged to maintain the sterile field. This flexible setup also allowed for rapid removal in case emergency access was needed. In addition to the live cameras we also had video feeds from the ECHO equipment and the Angio/Fluoro imaging system in the cath lab. This allowed sending any imaging present in the cath lab to the remote site. The final video feed was a PC with graphics and slides illustrating certain aspects of the procedure. This PC was used as the default source before and after the live feed and was the default source in case of any complications that required the live feed to be interrupted.

Audio was handled via 4 QLXD wireless systems (Shure America, Niles, Illinois) with E6 headset elements (Countryman, Menlo Park, California) and a wired shotgun microphone as a backup. Audio was mixed on a Soundcraft EPM8 (Samsung, Seoul, South Korea). Return audio from the remote site was handled by a QSC K8 (Costa Mesa, California) powered speaker. All production equipment was installed on a rolling table to allow for easy movement into and out of the cath lab. This allowed to set up, test, and troubleshoot issues both in the cath lab and offline in our offices over the course of several weeks with minimal impact to normal operations. This setup also improved reliability of the system. Other peripheral equipment included two large flat panel displays mounted to portable truss to allow staff to see the live feed in real time and a return video feed using Zoom (San Jose, California) and an inexpensive Logitech webcam from the remote site.

At the conference center, a rental A/V company was used to provide two 1080p60 projectors and screens, audio reinforcement, and a video presentation switcher to allow switching between multiple sources including the redundant presentation computers, primary and secondary video streams, and the PC running the Zoom session. This setup enabled any source to be displayed and allowed us the flexibility required in case of technical issues. In the planning stage, two simultaneous video streams were used for redundancy. The primary stream was handled by a Teradek Cube (Teradek LLC, Irvine, California) system comprised of a 655 encoder and 675 decoder. The Teradek Core cloud service was used to link the encoder and decoder and provide remote hardware management. The secondary live feed was handled by Vidyo—a telehealth platform. The hospital has a full Vidyo (Hackensack, New Jersey) deployment including an on-premise server which made it an ideal backup platform. During testing, we were never able to achieve the desired quality; however, it was sufficient to serve as a backup solution. At the conference center, we requested two wired connections with a minimum 30-Mbps connection speed. We made several visits and test calls to the conference center to ensure their network was setup correctly to handle the simultaneous streaming connections.

One drawback of the Teradek system is that it is designed for one-way video/audio transmission. To have two-way communication with the remote site, a Zoom web-conference session for return video and audio was used. This setup introduced 2-4-second audio delays but in the testing phase, this was deemed acceptable, allowing for the highest quality video to be sent to the remote site. During the actual conference, the audio delays inhibited effective communication and we decided to alternate between the Teradek feed for portions that did not require two-way communication and use Vidyo for the more interactive portions of the live stream. This solution worked well. Unfortunately, about 45 minutes into the live feed, the wired network connections slowed down considerably and we were unable to maintain the wired Teradek or Vidyo connections. We switched the PC running Vidyo to a wireless network for the remainder of the live stream and even with limited bandwidth; Vidyo did an excellent job with highquality video and two-way audio. Figure 1 illustrates the live transmission of the procedure performed at the Hospital to the audience in the conference center.

FIGURE 1 Live broadcast of transcatheter PDA closure in a 700-g ELBW infant during the International PDA Symposium. A, Setup for the live transmission in the cardiac cath lab. B, Procedure being performed at LeBonheur Children's Hospital. C, Attendees of the International PDA Symposium experiencing the live broadcast of the procedure at the conference center with two-way interactive audio and video discussions

3 | THE PROCEDURE

The child was a 24-week premature neonate who is now 14 days of age. The birth weight of the child was 660 g and 700 g at the time of the procedure. The child was unable to be weaned off the ventilator. The patient had a bout of pulmonary hemorrhage at the first week of life. She was diagnosed to have a large PDA. A course of indomethcin had failed to close the PDA and resulted in mild renal dysfunction. The neonate had no intraventricular hemorrhage or necrotizing enterocolitis, but was not tolerating enteral feeds. Therefore, this child was referred for TCPC. This child was transferred from another Hospital within town the day before the planned procedure.

The initial step for the case was preparing the room for a baby of such a small size. The temperature in the cath lab was increased to 76°; the Bair Hugger (3M, Maplewood, Minnesota) and heat lamps were also turned on so that the room would be warming while the cath lab team transported the patient from the NICU. The anesthesia team had a "hot-line" prepared in the event any blood products may be needed during the procedure. Once the room was prepped, the team proceeded to the NICU to retrieve the patient. After receiving bedside report from the NICU, the team safely transported the patient to the cath lab. In order to support thermoregulation, the patient was transported using a Giraffe Shuttle, and the Neopuff was used for ventilation.

Once the patient had successfully arrived to the cath lab, the team prepared to move the baby to the procedure table. All monitors, IVs, and ventilation equipment were positioned so that the baby could be moved with as little stimulation as possible. The heat lamp and Bair Hugger were used to keep the baby warm while the team positioned her for the procedure. After proper positioning was done, the echo team performed a preprocedure TTE (transthoracic echocardiogram),[3] and the baby was prepared and draped for the procedure. The PDA measured 4 mm in diameter and 12 mm in length with low-velocity left to right shunt. A CVL drape is always used for TCPC in ELBW infants. A CVL drape consists of a clear window surrounding the fenestration. A CVL drape is most beneficial because it maintains the sterility of the groins with the adhesive fenestration, but also allows the team to visualize the baby under the drape during the procedure.

Case start began with a time out performed by the official case recorder. Ultrasound was utilized to guide femoral venous access. A 21-guage needle and a 0.018″ wire were used to access the right femoral

vein and a 4 French, 7-cm sheath was placed in vein using the Seldinger technique.[4] No intravenous heparin was administered. However, heparinized saline was used to flush the sheath. A 4 French, 65-cm angled glide catheter (Terumo, Shibuya, Tokyo, Japan) and an 0.035″ Wholey wire (Medtronic, Minneapolis, Minnesota) were advanced through the sheath and used to cross the PDA into the aorta. The Wholey wire was removed, and a syringe of Optiray 320 (Guerbet, Villepinte, France) was attached to the catheter. An angiogram was then performed by injecting 0.5 mL of contrast through the glide catheter within the PDA in LAO 15° and Caudal 15° on the frontal plane and a straight lateral plane to visualize the PDA. The PDA measured 4 mm in diameter and 12 mm in length. Once the size of the PDA was approximated, using fluoroscopy and echocardiogram, an appropriate size closure device was selected The PDA closure device was prepared and advanced through the four French glide catheter into the PDA and deployed. A TTE was performed to confirm the position of the device. After all team members agreed the device was in a good position, the device was detached. An angiogram was performed, and more TTE images were obtained to guarantee optimal placement.

The team was concerned about mild LPA (left pulmonary artery) stenosis that was visualized on the TTE. It was established that the best outcome for this patient would require him to remove the PDA closure device. Due to the LPA stenosis, it was determined that a different PDA closure device would be safer and more favorable for this patient. After agreeing on the new course of action, a 5-mm snare was advanced through the glide catheter. The device was easily snared and internalized into the glide catheter and retrieved. The new device was prepared and placed using the same technique as the first device. After all required imaging was complete, it was agreed upon that the PDA was successfully occluded. The child tolerated the procedure well. There was no stenosis of the aorta or the LPA. The heart had good systolic and diastolic function and no pericardial effusion was noted on TTE. The case end involved the venous sheath being removed, and manual pressure was held until hemostasis was achieved. Once hemostasis was obtained, a single Tegaderm dressing was applied to the site, and the process of returning the patient to the NICU was begun.

The Giraffe Shuttle, which had been plugged in during the procedure to maintain appropriate temperature, was brought into the room. Once again, all monitors, IV's, and ventilation equipment were positioned for a smooth transition from the procedure table to the Giraffe incubator (GE Healthcare, Chicago, IL). The Neopuff was used for transport back to the NICU. Once the team arrived in the NICU with the patient, a full report was given.

4 | DISCUSSION

Transcatheter PDA closure is less invasive than surgical ligation. This live case demonstrated, that a transcatheter PDA closure can be performed successfully and, most importantly, safely even in extremely small infants.[1,3,5] Even when problems occur, the team is prepared to pause, speculate about what the other options are, and to execute a new plan of action to maximize benefit patient. There is a learning curve to this procedure. Our team has demonstrated the efficacy and safety of this procedure. During the International PDA Symposium, this was authenticated.

Performing a live case on a 700-g infant requires a lot of courage and conviction. Every step must go smooth including the transmission.[6,7] It is imperative to have redundant video transmission paths. We had three separate systems for the live stream and required all three for a successful conference. We would recommend extensive testing with all network providers to ensure reliable connection speeds. For critical applications or additional redundancy, the addition of a bonded cellular network connection could be utilized. Teradek makes several systems that are compatible with their Cube system and Core cloud platform. We would also recommend that if 2-way communication is important that you identify and test solutions that incorporate that feature. If we were to do this again, we would use the Teradek system as the primary video feed and use a secondary system that incorporated echo cancelation to transmit the 2-way audio. The video and audio feeds would be approximately 2 seconds out of sync; however, we believe this would be acceptable, that it would not be noticeable, and would give participants the best possible experience.

This child tolerated feeds after the PDA was occluded and was off mechanical ventilation in < 7 days after the procedure. The child continued to grow with no other comorbidities. The child was discharged (35 weeks' corrected gestation) weighing 2.2 kg, on full oral feeds and no supplemental oxygen. Children like this one are followed in a multispecialty PDA clinic for a period of 3 years. In this clinic, the outcomes from this procedure are evaluated including neurodevelopmental development of these children. This case exhibited to the audience in the International PDA Symposium the elements required for TCPC in an ELBW infant.

5 | CONCLUSIONS

This live case transmission of performing transcatheter PDA closure in a 700-g ELBW neonate demonstrated the feasibility of the procedure. There was concern for mild stenosis of the left pulmonary artery. During, this live transmission, the feasibility and safety of device retrieval was also demonstrated. The PDA was then successfully closed using a different device without any complication. The child was eventually discharged home within a few weeks with no significant comorbidities. This is a new therapy. Feasibility and safety of this procedure may help improve outcomes of ELBW infants.

CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

AUTHOR CONTRIBUTIONS

Drafting article, critical revision of article, approval of article: Sathanandam.

Drafting article, critical revision of article: Gianinni, Sefton, and Greer.

Critical revision of article: Stecchi and Allen.

Critical revision of article, Approval of article: Philip and Waller.

ORCID

Shyam Sathanandam http://orcid.org/0000-0001-8639-0852
Ranjit Philip http://orcid.org/0000-0003-3748-0215

REFERENCES

1. Philip R, Waller BR, Agrawal V, et al. Morphologic characterization of the patent ductus arteriosus in the premature infant and the choice of transcatheter occlusion device. *Catheter Cardiovasc Interv*. 2016;87(2):310-317.
2. Sathanandam S, Justino H, Waller BR, Radtke W, Qureshi AM. Initial clinical experience with the Medtronic Micro Vascular Plug™ in transcatheter occlusion of PDAs in extremely premature infants. *Catheter Cardiovasc Interv*. 2017;89(6):1051-1058.
3. Paudel G, Philip R, Zurakowski D, Balduf K, Fahnhorst S, Waller BR, et al. Echocardiographic guidance for trans-catheter device closure of patent ductus arteriosus in extremely low birth weight infants. *JACC*. 2018;71(suppl 11):A576.
4. Alexander J, Yohannan T, Abutineh I, et al. Ultrasound-guided femoral arterial access in pediatric cardiac catheterizations: a prospective evaluation of the prevalence, risk factors, and mechanism for acute loss of arterial pulse. *Catheter Cardiovasc Interv*. 2016;88(7):1098-1107.
5. Zahn EM, Peck D, Phillips A, et al. Transcatheter closure of patent ductus arteriosus in extremely premature newborns: early results and midterm follow-up. *JACC Cardiovasc Interv*. 2016;9(23):2429-2437.
6. Waksman R, Thomas M, Gloekler S, et al. The impact of live case transmission on patient outcomes during transcatheter aortic valve replacement: results from the VERITAS study. *Cardiovasc Revasc Med*. 2014;15(2):63-68.
7. MacKay CR. Ethical considerations of live case transmissions. *JACC Cardiovasc Interv*. 2009;2(9):892-893.

How to cite this article: Sathanandam S, Gianinni A, Sefton E, et al. Live broadcast of transcatheter PDA closure in a 700 grams ELBW infant during the International PDA Symposium. *Congenital Heart Disease*. 2019;14:85–89. https://doi.org/10.1111/chd.12710