PedsCases Podcast Scripts

This is a text version of a podcast from Pedscases.com on "**Cyanotic Congenital Heart Disease.**" These podcasts are designed to give medical students an overview of key topics in pediatrics. The audio versions are accessible on iTunes or at www.pedcases.com/podcasts.

Cyanotic Congenital Heart Disease

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 27, 2019

Introduction:

Hi, my name is Shealynn Carpenter and my name is Brie Cawston-Grant. We are second year medical students at the University of Alberta. This PedsCases podcast is meant to be a brief overview of cyanotic congenital heart diseases for medical students. This will not be an extensive overview, but instead we will be focusing on one common case presentation. This podcast was created under the supervision of Dr. Jessica Foulds, a pediatrician, and Dr. Lily Lin, a pediatric cardiologist, both at the University of Alberta.

Learning Objectives

1. To review the etiology, pathophysiology, and presentation of common cyanotic congenital heart diseases in a newborn.
2. To develop an approach to the differential diagnosis of a cyanotic newborn based on signs, symptoms and age of presentation.
3. To contrast pulmonary and cardiac etiologies in cyanotic neonates.
4. To review investigations and physical exam findings for cyanotic heart defects.
5. To understand the principles of treatment for common cyanotic heart defects.

Brief Overview of Congenital Heart Disease

Before we start our case, let's provide a brief overview of what cyanotic congenital heart diseases are. A congenital heart disease is defined as a structural or functional malformation of the heart or great vessels that occurs during gestational development. Congenital heart diseases are the most common type of congenital defect and occur in approximately 1% of the general population [1]. Congenital heart disease is a broad topic that includes several conditions that are typically categorized as either acyanotic or cyanotic. This podcast will focus on cyanotic heart diseases.

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.

Cyanotic heart defects include several different anatomic malformations that are characterized by the presence of a right-to-left shunt, reduced blood flow to the lungs, or a combination of both. A shunt is essentially blood flowing through an atypical pathway. Specifically, a right-to-left shunt allows the mixing of deoxygenated blood (from the right side of the heart) with the oxygenated blood (from the left side of the heart), which will enter the systemic circulation.

Let's briefly explore how this occurs. With normal heart physiology, outside of the neonatal period, the right side is at a lower pressure than the left. Therefore, blood in the heart flows along its pressure gradient, from a higher pressure to a lower pressure (left to right). For cyanotic heart disease to exist, there must be an underlying pathology that results in oxygenated and deoxygenated blood mixing or simply not enough blood flow getting to the lungs.

Recognition of cyanotic heart disease is a very important topic because without proper treatment it often leads to early mortality. Congenital heart disease is the leading cause of infantile death [2]. Therefore, prompt recognition, diagnosis and treatment of cyanotic heart lesions is a critical skill for those caring for pediatric patients.

Clinical Scenario

Chief Complaint:

Let's start with our clinical case. Suppose you are a rural family medicine resident in Bonnyville. Just 4 hours ago you helped deliver a baby boy, John. John was delivered at term with a 57th percentile birth weight and appeared well at birth. However, you have just been paged and told that he has developed blue lips and fingers and now has an O2 saturation of 68% as measured by pulse oximetry of the right hand.

Let's pause here and discuss what we should be thinking as we prepare to go see John. This could be a critically ill child and you need to be prepared to support their ABCs. At this point we only know that John has blue lips and a low O2 saturation. Remember that central cyanosis presents as a blue-purple-ish tinge on the lips, tongue, oral mucosa or trunk. It is easiest to see cyanosis where the skin is thin.

First, how do you know if John has central or peripheral cyanosis? Peripheral cyanosis can also present with a blue-purple-ish tinge of the fingers, but it only affects the extremities not the lips or inside the mouth. Peripheral cyanosis, also known as acrocyanosis, has a normal arterial oxygen saturation. Whereas for central cyanosis to be evident clinically, the oxygen saturation will be less than approximately 80% to 85% [3]. Therefore, because of his low O2 saturation and purple lips, John has central cyanosis.

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.

Central cyanosis is a common presentation for many pulmonary conditions, so your differential diagnosis must include both pulmonary and cardiac causes. At his point, differentiating between a cardiac and pulmonary cause is critical and should guide your history taking, physical exam and further investigations.

Finally, you'll note that we mentioned John's oxygen saturation was measured from the right hand. Taking a right-hand saturation (or a preductal sat) and taking one in a lower limb (a postductal sat) can also help you in your assessment of a newborn with cyanosis. The terms pre and postductal refer to locations relative to the ductus arteriosus, which is a connection between the main pulmonary artery and the proximal descending aorta. It is important for fetal circulation before the lungs are functioning. We would generally expect the preductal sat to be the same as the postductal. A difference of greater than 3% as per the Canadian Pediatric Society (or greater than 5% clinically) is considered significant. If a preductal sat is higher than the postductal there's a right to left shunt through a patent ductus arteriosus to the lower body. What's interesting is that if transposition of the great arteries (TGA) also has either coarctation or pulmonary hypertension, the preductal sat is LOWER than the postductal! [4]

HPI and Gestational History:

Moving back to the case, on arriving to see John, the first thing you do is ask for more information from the parents and nurses while your senior physician checks the equipment in the room and assesses your patient. You are told John was feeding well and had been active until just 5 minutes ago when his parents noticed that his lips were blue, and he felt cold. The nurse provided oxygen therapy but there was no improvement of John's O2 saturation. On prompting, John's mother states that she had routine prenatal screening with a normal 18-week ultrasound.

Again, let's pause here and discuss the significance of John's history at this point. First, let's discuss the role of prenatal screening in narrowing down your differential diagnosis. A fetal anatomic survey using an ultrasound is performed at 18-22 weeks gestation for all pregnant mothers [5]. This routine ultrasound can sometimes detect cardiac abnormalities. If cardiac abnormalities are detected the mother will be referred and the health care team will be prepared to treat the infant at birth. However, not all cardiac abnormalities can be visualized at 22 weeks, and some smaller defects cannot be detected prenatally. The rate of congenital heart diseases that are detected prenatally varies with the type of heart lesion and experience of the person performing and interpreting the scan. Over the past decade, there has been improvements in both the ultrasound equipment technology and education with standardization of the screening ultrasound views, including not just looking at the heart chambers but also the great vessels. Locally, our detection rates are >80% for the major critical congenital heart lesions. So, even though John had a normal prenatal ultrasound he may still have a cardiac defect.

Risks for CHD include both maternal and fetal factors. Fetal chromosomal abnormalities pose a very high risk of the fetus having a variety of cardiac malformations. Approximately one third of infants with a chromosomal abnormality will also be born with congenital malformations [6]. Significant maternal risk factors for CHD include exposure to cardiac teratogens during pregnancy, including both medications and illness exposure, and a family history of congenital heart disease in a first degree relative to the mother [7]. There are many more maternal risk factors, and these are just a few examples. If the mother is considered high risk, she can be referred directly for an echocardiogram of the fetus [8]. This screening allows for parents to be informed on management options before and after birth, as well as prognostication, and it allows for immediate medical care to be provided at birth.

Now, the nurse provided an important finding when she said that John's oxygen saturation did not improve when he was given oxygen. This is a modified version of the hyperoxia test, which is used to differentiate between a pulmonary or cardiac cause of cyanosis. A traditional hyperoxia test is performed by measuring the infant's arterial blood gas when the infant is breathing room air. Then measuring their arterial blood gas again after the infant has been given 100% oxygen for 10 minutes. If the partial pressure of oxygen increases with oxygen therapy this indicates a pulmonary cause of the cyanosis, If the partial pressure of oxygen remains less than 150mmHg, then a cardiac cause is likely. However, more often in clinical practice instead of taking an arterial blood gas the oxygen saturation is measured. Because John's O2 saturation did not increase with oxygen therapy this should increase your suspicion that John has a cardiac disorder.

Physical Exam:

Together, you and your senior physician examine John. John has a heart rate of 170bpm, a respiration rate of 58 breaths/min, his right-hand oxygen saturation has remained at 68%, and his vitals are otherwise normal. John is breathing at the upper limit of normal, but there is no evidence of increased work of breathing on physical exam. On cardiac exam, you hear a normal S1, but a single S2. No murmurs were appreciated. You also note that he has a reduced capillary refill. No other significant findings are found when completing other system reviews. You preceptor asks you what you think is highest on John's differential diagnosis?

Differential Diagnosis:

Let's consider John's differential diagnosis. Cyanosis is most commonly caused by an underlying pulmonary pathology, so we'll start by considering a few common pulmonary disorders:

1. *Transient tachypnea of the newborn presents hours after birth, typically when an infant is born quickly or by caesarian section. The infant will usually have a respiratory rate greater than 60 and increased work of breathing.*
2. *Congenital abnormalities of the airway.*
3. *Neonatal pneumonia.*

Another diagnosis to consider is persistent pulmonary hypertension of the newborn, which is neither a purely pulmonary nor cardiac cause. There are many other things that could be on our differential, however, we will highlight at this point that our patient has no increased work of breathing and had no rise in oxygen saturation during the hyperoxia test, so a cardiac cause should be the highest on our differential.

Let's consider which cyanotic heart disorder John is most likely presenting with. A helpful mnemonic that students may use to remember the most common cyanotic heart diseases are the 5Ts and a P. The 5Ts are:

1) *Tetralogy of Fallot (TOF)*
2) *Transposition of the great arteries (TGA)*
3) *Truncus arteriosus*
4) *Tricuspid atresia*
5) *Total Anomalous Pulmonary Venous Connection (TAPVC)*

And the P is Critical Pulmonary Stenosis or Pulmonary Atresia. Of these 5Ts and a P, the most common are tetralogy of Fallot and transposition of the great arteries. The definitive investigation to determine which cyanotic congenital heart defect is present is an echocardiogram, but there are clues on CXR and ECG that can indicate which congenital heart disease is the highest on your differential before performing the echo.

So, in John's case let's see if we can determine if TOF or TGA is higher on his differential diagnosis. The key thing to consider is his age. TOF typically presents later than TGA. TOF can also present via heart failure even later in childhood if there is only mild right ventricle outflow tract obstruction. TGA more commonly presents within hours of birth when the ductus arteriosus begins to close. TAPVC and the Ps would also be higher on our differential based on the age of presentation. Because John is just 4 hours old this indicates that TGA should be highest on our differential diagnosis. Is this consistent with John's physical exam findings? The physical exam findings of TOF are similar to TGA: a right ventricular heave and a single soft S2. However, TOF more commonly has a systolic ejection murmur due to pulmonary outflow tract obstruction [9]. There is a great video on TOF available on pedscases.com that is worth checking out should you like more information on this lesion.

Investigations and Treatment:

Returning to our case, you tell your preceptor that TGA is highest on your differential diagnosis and they agree. After conversations with neonatology and cardiology, John is

immediately started on a prostaglandin infusion and stabilized for transport to a pediatric cardiac center. Then, an echocardiogram is performed which confirms that John does have TGA. While waiting for the transport team you do an ECG, which is normal, showing the expected neonatal right-side dominant pattern. If you did a CXR (which in this circumstance is not necessary as a pulmonary cause is not likely) it may have shown the classic CXR finding which is an “egg on string” shaped heart. As well, if you’re not confident in your diagnosis a CXR may help differentiate pulmonary vs cardiac disease by evaluating whether pulmonary blood flow is normal, increased or decreased, or help in considering cardiac lesions associated with various pulmonary blood flow patterns.

Pathophysiology:

Now that we know that John has transposition of the great arteries, what exactly is the pathophysiology of TGA?

TGA can be visualized as a normal heart, except with the aorta exiting from the right ventricle, and the pulmonary arteries exiting from the left ventricle. This creates two independent circuits of blood flow; one circuit is the oxygenated blood flowing to and from the lungs and the other is the deoxygenated blood flowing throughout the body. As you can imagine, this condition is incompatible with life. Therefore, all TGAs require an ASD for the infant to survive. This defect allows the two parallel circuits of blood flow to mix, specifically the left to right shunt across ASD allows for the oxygenated blood from the lung blood circuit (Lungs-LA-LV-MPA-Lungs) to mix with the deoxygenated blood from the body blood circuit (body-RA-RV-aorta-body). If you have a large enough ASD to allow for good mixing of blood, then a patent ductus arteriosus is not necessary. However, keeping the ductus arteriosus open does provide another potential source for the mixing of blood between the two circuits.

TGA usually presents within hours to the first couple of weeks after birth. Initial treatment involves giving prostaglandin or alprostadil. This improves mixing across an ASD by maintaining the ductus arteriosus and increasing left atrial pressure, and it also provides a second source of blood mixing via the ductus arteriosus. You should never hesitate to start prostaglandin therapy as it can be life-saving for a ductal dependent lesion. The definitive treatment for TGA is to perform an arterial switch operation and transpose the aorta and pulmonary artery [10]. An atrial switch operation needs to be performed within the first month of life to prevent the left ventricle from becoming too weak.

Knowing the pathophysiology of TGA also explains the physical exam findings of TGA. On physical exam TGA may present with a normal precordium and a no murmur. There may be other physical exam findings, such as a murmur, depending on the presence and size of other cardiac defects such as a pulmonary stenosis or left ventricular outflow tract obstruction.

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.

Conclusion:

Now that we have reviewed the pathophysiology of TGA and how it is treated, let's finish our case. John remains stable after the infusion of prostaglandins and arrives safely at the Stollery Children's Hospital for surgery. John's parents are very worried about the surgery and about how John will do in the future. As part of your counselling, you tell them that patients at the Stollery Children's Hospital have been shown to have a 98.9% survival at 4 years, however, delays in neurological development are a concern [11]. The 15-25 year survival from an atrial switch operation has been found to be greater than 95% by multiple institutions [12,13].

Summary

To conclude this podcast, we'd like to leave you with the top four clinical take home points:

1. Central cyanosis has a broad differential; therefore, it is very important to consider both cardiac and pulmonary causes. A physical exam for both systems should always be completed and the hyperoxia test may help you differentiate between them. If the patient's oxygen saturation does not increase when given 100% oxygen, this is a failed hyperoxia test and suggests a cardiac cause of the cyanosis.
2. Transposition of the great arteries (TGA) usually presents within hours to the first couple of weeks after birth
3. If you suspect TGA in an infant, or any cyanotic heart lesion, prostaglandins should be delivered immediately to maintain the ductus arteriosus. The prostaglandins should be administered in communication with the neonatal intensive care or pediatric cardiology teams. The definitive treatment for TGA is an arterial switch operation.
4. An echocardiogram is the gold standard to diagnosis congenital heart defects. An ECG and CXR can be very useful prior to echo assessment to and narrow down the differential diagnosis.

That brings us to the end of this podcast. Thank-you so much for listening to PedsCases.

References

[1] Steppan J, Maxwell BG. Congenital Heart Disease. In: *Stoelting's Anesthesia and Co-Existing Disease*. 7th ed. Philadelphia: Elsevier; 2018:129-147. https://www-clinicalkey-com. Accessed September 23, 2018. https://www-clinicalkey-com.login.ezproxy.library.ualberta.ca/#!/content/book/3-s2.0-B9780323401371000077

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.

[2] Heron M. Deaths: Leading Causes for 2014. *National Vital Statistics Report.* 2016;65(5):1-96. https://www.ncbi.nlm.nih.gov/pubmed?term=27376998

[3] Horeczko T, Inaba AS. Cardiac Disorders. In: *Rosen's Emergency Medicine: Concepts and Clinical Practice.* 9th ed. Philadelphia: Elsevier; 2018:2099-2125. https://www-clinicalkey-com. Accessed September 23, 2018. https://www-clinicalkey-com.login.ezproxy.library.ualberta.ca/#!/content/book/3-s2.0-B9780323354790001707?scrollTo=%23hl0001300

[4] Kemper AR, Mahle WT, Martin GR, et al. Strategies for Implementing Screening for Critical Congenital Heart Disease. *Pediatrics.* 2011;128(5):1259-1267. doi:10.1542/peds.2011.10.10. https://pediatrics.aappublication.org/content/128/5/e1259

[5] Nevo O, Brown R, Glanc P, Lim K. No. 352 - Technical update: the role for early comprehensive fetal anatomy ultrasound examination. *Journal of Obstetrics and Gynecology Canada.* 2017;39(12):1203-1211. https://www.jogc.com/article/S1701-2163(17)30699-0/pdf

[6] Archer JM. Evaluation of the infant for congenital heart disease (CHD). DynaMed Plus. http://www.dynamed.com. Published August 9, 2018. Accessed September 23, 2018. http://www.dynamed.com/topics/dmp~AN~T566082/Evaluation-of-the-infant-for-congenital-heart-disease-CHD#Common-syndromes

[7] Donofrio MT, Moon-Grady AJ, Hornberger LK, Copel JA, Sklansky MS, Abuhamad A. Diagnosis and treatment of fetal cardiac disease: a scientific statement from the American Heart Association. *American Heart Association*. April 2014. https://www.ncbi.nlm.nih.gov/pubmed. Accessed September 23, 2018. https://www.ncbi.nlm.nih.gov/pubmed?term=24763516

[8] Lee W, Allan L, Carcalho R, et al. ISUOG consensus statement: what constitutes a fetal echocardiogram. *Ultrasound in Obstetrics and Gynecology.* 2008;32:239-242. https://obgyn.onlinelibrary.wiley.com/doi/epdf/10.1002/uog.6115

[9] Baffa J. Tetralogy of Fallot - Pediatrics. MSD Manual Professional Edition. https://www.msdmanuals.com/professional/pediatrics/congenital-cardiovascular-anomalies/tetralogy-of-fallot. Published November 2016. Accessed September 23, 2018.

[10] Jantene AD, Fontes VF, Paulista PP. Anatomic correction of transposition of the great vessels. *The Journal of Thoracic and Cardiovascular Surgery*. 1976;72(3):364-370. https://www.ncbi.nlm.nih.gov/pubmed. Accessed September 23, 2018. https://www.ncbi.nlm.nih.gov/pubmed?term=957754

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.

[11] Freed DH, Robertson CM, Sauve RS, et al. Intermediate-term outcomes of the arterial switch operation for transposition of great arteries in neonates: Alive but well? *The Journal of Thoracic and Cardiovascular Surgery*. 2006;132(4):845-852. doi:10.1016/j.jtcvs.2006.05.046.
https://www.sciencedirect.com/science/article/pii/S0022522306010907

[12] Choi BS, Kwon BS, Kim GB, et al. Long-Term Outcomes After an Arterial Switch Operation for Simple Complete Transposition of the Great Arteries. *Korean Circulation Journal*. 2010;40(1):23. doi:10.4070/kcj.2010.40.1.23.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2812794/

[13] Fricke TA, Dudekem Y, Richardson M, et al. Outcomes of the Arterial Switch Operation for Transposition of the Great Arteries: 25 Years of Experience. *The Annals of Thoracic Surgery*. 2012;94(1):139-145. doi:10.1016/j.athoracsur.2012.03.019.
https://www.ncbi.nlm.nih.gov/pubmed/22607787

Developed by Shealynn Carpenter, Brie Cawston-Grant, Dr. Jessica Foulds and Dr. Lily Lin for PedsCases.com.
August 29, 2019.