CASE REPORT

Neonatal ventricular fibrillation and an elusive ALCAPA: things are not always as they seem

Tracie C Walker,¹ Markus S Renno,² David A Parra,² Scott O Guthrie^{1,3}

¹Mildred Stahlman Division of Neonatology, Vanderbilt University, Nashville, Tennessee, USA

²Thomas P Graham Jr Division of Pediatric Cardiology, Vanderbilt University, Nashville, Tennessee, USA

³Department of Neonatology, Ayers Children's Medical Center, Jackson, Tennessee, USA

Correspondence to

Dr Scott O Guthrie,
scott.o.guthrie@vanderbilt.edu

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SUMMARY

An anomalous left coronary artery from the pulmonary artery (ALCAPA) is a rare congenital cardiac condition that typically presents with poor feeding and failure to thrive from progressive myocardial ischaemia. Previous reports of ALCAPA presenting with ventricular fibrillation (VF) have suggested a causative relationship. In this case, we present a neonate with VF without apparent cause after an extensive evaluation. Following implantable cardioverter-defibrillator placement for presumed idiopathic VF, at which time she also underwent surgical ligation of a patent ductus arteriosus (PDA), the neonate developed haemodynamic instability that ultimately was found to be due to ALCAPA.

Numerous echocardiograms had missed the ALCAPA in the setting of mildly elevated pulmonary artery pressure. We discuss the limitations of current ultrasound technology in diagnosing ALCAPA in the setting of pulmonary hypertension and explain why the relationship between this patient's diagnosis of ALCAPA and her episode of VF is not clearly causative.

BACKGROUND

Ventricular fibrillation (VF) and an anomalous left coronary artery from the pulmonary artery (ALCAPA) are both exceptionally rare cardiac conditions in neonates.^{1 2} Survivors of VF are usually found to have an underlying diagnosis that causes structural or functional cardiac dysfunction. The most common causes include channelopathies, cardiac tumours, metabolic disorders, or cardiac ischaemia from acidosis.³ The diagnosis of idiopathic VF can only be made after an extensive work up for an underlying aetiology yields no answer.⁴

ALCAPA is an infrequent but potentially lethal congenital anomaly. The reported incidence is 1 in 300 000 live-births. Untreated it has a mortality of up to 90% in the first year of life.⁵ ALCAPA typically presents in infants with failure to thrive due to angina during feeding, dyspnoea secondary to congestive heart failure and an abnormal ECG consistent with myocardial ischaemia. These develop over the course of weeks to months as the pulmonary vascular resistance and pulmonary artery pressure drop. Often, the chronic ischaemia in the distribution of the left coronary artery system results in the development of collateral coronary arteries from the right coronary artery. These collateral arteries can form fistulae from the right to the left coronary artery system, resulting in retrograde flow from the left main coronary artery (LMCA) into the pulmonary artery on echocardiography.

VF has previously been described as the presenting manifestation of ALCAPA.^{6–9} These reports have been in teenagers, adults and in two neonates after surgical ligation of a patent ductus arteriosus (PDA). All cases suggested that myocardial ischaemia caused by the ALCAPA resulted in VF. We present a unique case of a neonate who presented with VF, in whom the subsequent finding of ALCAPA may not explain the episode of VF. The case also highlights the limitations of echocardiographic diagnosis of ALCAPA in neonates with pulmonary hypertension.

CASE PRESENTATION

A 7-day-old female infant was transferred to our hospital after cardiac arrest. She was born at 35 2/7 weeks by spontaneous vaginal delivery. Pregnancy had been complicated by maternal pyelonephritis, positive group B streptococcus status and prolonged rupture of membranes. Delivery was complicated by respiratory distress necessitating admission to the neonatal intensive care unit. The baby's laboratory findings of an elevated C reactive protein and I:T ratio were concerning for sepsis, and she was started on antibiotics. Her blood culture remained negative, possibly due to her mother having received antibiotics during labour. The baby weaned off of respiratory support on day four of life and was completing treatment for clinical sepsis with ampicillin and gentamicin.

On day seven of life, the planned day of discharge, she became limp and apnoeic immediately prior to a feed. VF was noted on cardiac monitoring. The airway was secured and resuscitation per PALS cardiac arrest algorithm initiated.¹⁰ During the course of the resuscitation, she received 22 min of chest compressions, three intravenous doses of epinephrine, two doses of calcium gluconate and one dose of sodium bicarbonate. Unsynchronised defibrillation was performed three times (2 J/kg each), with return to normal sinus rhythm after the third shock was delivered. Review of telemetry preceding the event demonstrated sinus rhythm with single ventricular ectopic beats, followed by ventricular tachycardia that rapidly degenerated to VF within 30 s (figure 1).

The baby was transported to our hospital endotracheally intubated and in normal sinus rhythm. Echocardiogram on admission showed normal segmental anatomy, mildly depressed biventricular function, a large PDA and antegrade diastolic flow through a normal appearing origin of the LMCA (figure 2). Her ECG showed normal sinus rhythm with no ST-segment changes and no lateral

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Figure 1 Continuous telemetry from cardiac arrest showing sinus rhythm, with premature ventricular beats, then ventricular tachycardia that rapidly degenerated to ventricular fibrillation.

Q-waves concerning for ALCAPA, and a normal QT interval (QTc 420 ms). There were no characteristic ECG signs of Brugada syndrome, a genetic disorder with increased risk for ventricular tachyarrhythmias and sudden cardiac death, with standard lead positions and high V1 and V2 (figure 3).¹¹

The patient's family history was notable for Sudden Infant Death Syndrome (SIDS) in a paternal uncle and one of the patient's male cousins, who died without explanation at ages

Figure 2 Parasternal short axis of the aortic root (A) by two-dimensional (left) and colour Doppler (right) echocardiogram, demonstrating the illusion of a normal left main coronary artery origin with antegrade flow (B).

6 weeks and 5 months, respectively. The patient's mother and father had normal screening ECGs. A comprehensive arrhythmia panel in our patient was negative for 30 known arrhythmia-causing mutations, deletions and duplications.¹² Urine organic acids, plasma amino acids, acylcarnitine profile and the Tennessee state newborn screen¹³ did not reveal any metabolic aetiology for VF. Cardiac MRI, performed on day 11 of life, was significant for mild left ventricular dilation and demonstrated no myocardial enhancement suggestive of ischaemia or fibrosis, but did not have resolution high enough to delineate a coronary artery anatomy.

The patient experienced no further episodes of VF during her hospitalisation. Numerous follow-up echocardiograms demonstrated normalisation of biventricular function and continued to suggest normal coronary artery origins by two-dimensional imaging and colour Doppler. Mild mitral insufficiency and increased echogenicity of the papillary muscle were noted and attributed to ischaemia associated with the initial arrest and resuscitation. Doppler interrogation of the residual PDA suggested a mildly elevated pulmonary artery pressure, ranging from normal to half systemic on serial echocardiograms. With no apparent structural or metabolic disease and no evidence of a channelopathy, the working diagnosis was idiopathic VF. After extensive discussion of risks and benefits, the decision was made to place an implantable cardioverter-defibrillator (ICD).

On day 48 of life, after reaching a weight of 4 kg, an epicardial ICD system was placed and surgical PDA ligation performed. While still anaesthetised in the operating room, a provocative drug challenge with procainamide (15 mg/kg) revealed no ECG changes consistent with Brugada syndrome, and epinephrine (up to 0.2 µg/kg/min) revealed normal QT shortening and no ventricular ectopy that would be concerning for catecholaminergic polymorphic ventricular tachycardia.¹⁴

Within 2 h postoperative, the baby became progressively haemodynamically unstable. An echocardiogram revealed severely depressed left ventricular wall motion, worsening mitral regurgitation, echogenicity of the left ventricular myocardium, and to-fro flow in the left coronary system. She developed diffuse ST-segment changes, consistent with myocardial ischaemia (figure 4). She underwent emergent cardiac catheterisation and was found to have ALCAPA with a sharp turn of the proximal LMCA from its origin at the bifurcation of the pulmonary arteries and coursing immediately past its normal insertion to the aortic root (figure 5). She returned to the operating room that evening for translocation of the left coronary artery.

OUTCOME AND FOLLOW-UP

The baby subsequently recovered well. By the time of her discharge on day 63 of life, her ventricular function had almost normalised. She is now 12 months old, developing normally, and has had no recurrent VF and no arrhythmias. Although our tests were negative for genetic mutations known to cause VF, the family was counselled that this could still be a hereditary condition.

DISCUSSION

VF in neonates has been reported as a cause of sudden infant death and, therefore, finding a treatable or underlying aetiology is important.¹ The evaluation for the cause of neonatal VF is extensive and includes echocardiographic interrogation of cardiac structure and function, testing for channelopathies and a detailed metabolic work up. Given this patient's strong family history of SIDS, we were especially concerned for a heritable aetiology. However, despite a thorough evaluation for

Figure 3 Normal 12-lead ECG hours after the initial cardiac arrest.

identifiable causes of VF, no specific aetiology was found, leading us to the presumed diagnosis of idiopathic VF. There has been one previous report of three unrelated infants with idiopathic VF, who each had multiple recurrences with ST segment changes and QRS widening prior to arrhythmia onset, features that were absent in our patient.⁴

While there have been two previous reports of infants with VF as the first manifestation of ALCAPA,^{6,7} there have been multiple reports of this phenomenon in adolescents and adults.^{8,9} In all of these cases, myocardial ischaemia was hypothesised to be the precipitating cause of VF. After the diagnosis of ALCAPA was made in our patient, there was significant discussion of whether her VF was truly idiopathic or if the ALCAPA could have been the underlying cause of her initial cardiac arrest. We cannot rule out a causative relationship between the two conditions, namely that ALCAPA precipitated the VF arrest; however, multiple factors suggest otherwise for our patient.

This patient did not have the characteristic ECG changes associated with ischaemia before or after her VF arrest as seen in previously reported patients with ALCAPA and VF.⁶⁻⁹ It was not until the sudden drop in her pulmonary artery pressure at the time of PDA ligation that she began demonstrating abnormal to-fro coronary flow on echocardiogram, raising concern for a coronary anomaly. This sudden change in haemodynamics corresponded with new ECG evidence of myocardial ischaemia that had not previously been present around the time of her arrest. It is also noteworthy that she had no arrhythmias despite severe ischaemia after her PDA ligation. In animal models, when ischaemic VF is observed, the arrhythmia is generally very reproducible.¹⁵ Another factor suggesting that the VF may be

unrelated to her ALCAPA is the family history of sudden death in two paternal relatives. ALCAPA is not a familial disease, while most channelopathies, including idiopathic VF, have familial forms.¹⁶

This case also illustrates the limitations of echocardiography for the diagnosis of ALCAPA in the setting of elevated pulmonary artery pressure. It is well recognised that two-dimensional imaging can suggest a normal origin of the left coronary artery from the aortic root in ALCAPA, particularly when the course of the anomalous coronary passes near the normal site of origin.¹⁷ Colour flow mapping of all segments of the left coronary artery is recommended to detect abnormal retrograde flow into the pulmonary artery.¹⁸ In the case of this patient, she had five echocardiograms that demonstrated antegrade flow in all three proximal segments of the left coronary artery. Multiple experienced paediatric cardiologists, many with training in advanced imaging, initially interpreted these echocardiograms. Later review of the images, even with perfect hindsight, still suggested a normal LMCA origin.

The studies prior to PDA ligation did demonstrate mild mitral regurgitation and echobrightness of the papillary muscles, potential signs of myocardial ischaemia. This should have raised concern for ALCAPA and was instead attributed to the prior myocardial injury during cardiac arrest. The mild pulmonary hypertension present in the setting of the PDA was associated with antegrade LMCA flow and masked the abnormality until ductal ligation. Though echocardiography with colour flow mapping is associated with few false positive and false negative diagnoses, coronary angiography may be required in the setting of elevated pulmonary artery pressures and was essential to the diagnosis in this case. Cardiac CT and MRI may be appropriate

Figure 4 ST segment depression on 12-lead ECG after PDA ligation.

Figure 5 Cardiac catheterisation revealing a normal origin to the right coronary artery (A) from the aorta but an anomalous origin to the left main coronary artery (B) from the pulmonary artery.

for older children; however, traditional angiography remains the gold standard for neonatal diagnoses in which high heart rates may lead to incomplete or inaccurate data with CT and MRI.

Had this infant not required treatment for clinical sepsis through the seventh day of life, this would in all likelihood have been a case of SIDS, either from VF arrest or myocardial ischaemia from ALCAPA. Instead, this unusual case and rare diagnosis in an infant admitted for the routine evaluation and treatment of sepsis should serve as a reminder for the clinician that things are not always as they seem.

Patient's perspective

As I sit and try to put into words how it felt for us to have our little one go through all that she has, the unexplained episode of ventricular fibrillation, the ICD placement, the ALCAPA diagnosis, the repair surgery, the reality of it sets in again. The sights, sounds, and smells of the hospital never really leave you. During the actual hospital stay, the feelings we felt are indescribable. It was a constant flood of changing emotions. I would find myself praying and pleading with all my heart for them to save my baby, and then the next minute I would catch myself thinking she is fighting so hard it's best to just let her pass peacefully. On the good days it felt like we were in every moment. However, looking back at the bad days, it was as if we were watching a movie because that could not be our baby, our life. I found myself searching for any and all information I could find about anything that was mentioned during the doctors' rounds. Thinking maybe if I knew just a little more we could somehow manage to love on her one more day, but no matter how much I read I still felt helpless. That would be the single word I would pick to describe how it feels to be in our shoes: helpless. There was nothing we could do except trust in her doctors to care for her to the best of their abilities. Thank goodness she had the amazing doctors that she did.

Learning points

- Neonatal ventricular fibrillation (VF) has been reported as a cause of sudden infant death and, therefore, finding a treatable or underlying aetiology is important. The evaluation for the cause of neonatal VF is extensive and includes echocardiographic interrogation of cardiac structure and function, testing for channelopathies and a detailed metabolic work up.

- Current ultrasound technology has limitations in accurately diagnosing an anomalous left coronary artery from the pulmonary artery (ALCAPA) in the setting of pulmonary hypertension from any cause, including a patent ductus arteriosus. In these cases, angiography remains the gold standard for diagnosis.
- While prior reports have described VF that resulted from myocardial ischaemia in the setting of ALCAPA, this is a case of a neonate in whom the relationship between ALCAPA and VF may not have been causative.

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