

Anomalous origin of the left coronary artery from the pulmonary artery. Diagnosis and treatment in 3 pediatric patients

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Abstract

Anomalous origin of the left coronary artery (LCA) from the pulmonary artery (ALCAPA) syndrome is a potentially lethal and rare congenital cardiac anomaly (for approximately 1 in 300,000 live births). ALCAPA syndrome mostly presents in the first few months of life. Left untreated, the mortality rate in the first year of life is 90% secondary to myocardial ischemia or infarction and mitral valve insufficiency leading to congestive heart failure. When pulmonary arterial pressure decreases, it results in reversal of flow so that LCA drains from the right coronary artery through collateral vessels into the pulmonary artery. This phenomenon causes ischemia or eventually infarction of the anterolateral left ventricular wall. Sudden death may occur because of inadequate collateral circulation between LCA and the right coronary artery and/or development of arrhythmia. ALCAPA can be found both in infants and in older individuals, with the absence or presence of strong collateral circulation from the right coronary artery, with different clinical presentations. Clinical diagnosis of ALCAPA can be demanding. Findings can be similar to those in dilatative cardiomyopathy and the diagnosis of ALCAPA has to be excluded, principally in the presence of ischemic ECG findings. Currently, the prognosis for patients with ALCAPA syndrome is dramatically improved as a result of both early diagnosis and improvements in surgical techniques, including myocardial preservation. This paper presents 3 patients with ALCAPA syndrome as well as the variations in their age, clinical presentation, modality of treatment (pharmacological treatment, surgical correction and percutaneous coronary stent implantation after graft obstruction) and outcome.

Keywords

ALCAPA, heart failure, infant, older age, treatment.

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Introduction

Anomalous origin of the left coronary artery (LCA) from the pulmonary artery (ALCAPA) syndrome represents congenital anomaly of the coronary arteries. ALCAPA can be found in both infants and in older individuals, with the absence or presence of strong collateral circulation from the right coronary artery, with different clinical presentations. The 80% to 85% of patients without a satisfactory collateral provision typically demonstrates with congestive heart failure (CHF) secondary to ischemia within the first few months. If left untreated, the mortality rate in the first year of life reaches 90% secondary to myocardial ischemia or infarction and mitral valve insufficiency leading to heart failure [1].

The anomaly can emerge from either atypical partition of the conal trunk into the aorta and pulmonary artery (PA) or from perseverance of the pulmonary buds together with involution of the aortic buds that form the coronary arteries. In ALCAPA, the LCA usually arises from the posterior facing sinus of the PA close to where the normal origin of the LCA would be. Nevertheless, the LCA can arise from any part of the main PA or its branches, although seldom. Infrequently LCA originates from the juncture of the main PA and right PA or the right PA; it may have an intramural aortic route.

As a consequence of the decreasing PA pressure and resistance shortly after birth, the left ventricular myocardium being perfused by relatively desaturated blood under low pressure leads to a myocardial ischemia. This is followed by the development of collateral circulation between the right coronary artery and LCA. Pressure reduction in the PA is followed by the reversed flow. LCA drains from the right coronary system through collateral vessels into the PA. The steal phenomenon causes ischemia or

infarction of the anterolateral left ventricular wall [2, 3]. As an outcome, the combination of dysfunction of the left ventricle (LV) and serious mitral regurgitation can lead to symptoms of heart failure in the infant. The clinical diagnosis of ALCAPA can be challenging. Findings in ALCAPA resemble those of dilated cardiomyopathy and the diagnosis of ALCAPA must be excluded [4], especially in the presence of ischemic electrocardiography (ECG) findings. ALCAPA can be treated successfully by several types of operations with good prognosis [4]. When it comes to younger children with ALCAPA, restitution of a normal coronary system through reimplantation of the LCA to the aorta or by bypass grafting and ligation of proximal ALCAPA had good outcome [5]. Percutaneous coronary artery stent implantation in patients who develop acute coronary artery ischemia due to postoperative coronary artery obstruction is a rare procedure in the pediatric population. Obstacles to this procedure include small size of coronary arteries, related procedural difficulty, and risk of adverse events [6]. However, stent angioplasty remains the only reasonable option in those cases. Mitral valve surgery is indicated in cases of persistent refractory mitral regurgitation [7].

In this report, we present 3 patients with ALCAPA syndrome as well as the variations in their age, clinical presentation, modality of treatment and outcome.

Case presentation

Case 1

This 4-month-old female patient was admitted to the Pediatric Intensive Care Unit (PICU) with a history of poor feeding, seizures and irritability for 4 weeks prior to admission. During the examination, the child was dyspnoic, tachycardic and had II/VI ejection systolic murmur at the left lower border of the sternum. The liver was found to be 3 cm below the right costal margin. The child was hemodynamically compromised and required mechanical ventilation and inotropic support. Chest X-ray (**Fig. 1**) showed cardiomegaly with plethoric lungs and ECG revealed anterolateral ST-segment depression. On echocardiogram, dilated LV with poor function was present, fractional shortening of 22%, moderate mitral insufficiency, akinetic midventricular septum and echogenic left ventricular papillary muscles. The origin of the LCA from the aortic root on 2D option was not

visible, while color Doppler was revealing blood flow to PA in the parasternal short-axis view. The diagnosis of ALCAPA was strongly suspected, without other proved congenital heart defects. Heart catheterization (**Fig. 2**) was performed and coronary artery angiogram with 3D reconstruction confirmed the diagnosis of ALCAPA.



Figure 1. Antero-posterior radiograph of the chest. It shows massive cardiomegaly, involving mainly the ventricles and the right atrium. Perihilar alveolar opacification is present.

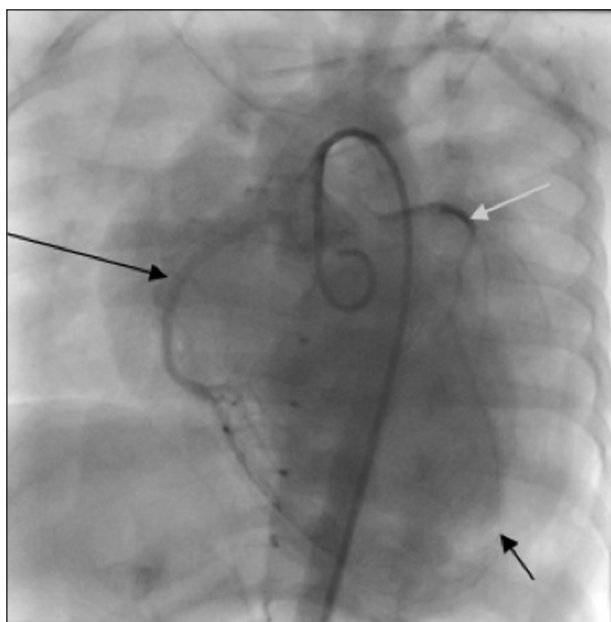


Figure 2. Catheter in the ascending aorta. The angiogram is showing right coronary artery (arrow to the right of the catheter) with collateral vessels (the smallest arrow) flowing into left coronary artery (LCA). The LCA (white arrow) and then the pulmonary artery (PA) are filled by the right coronary artery retrogradely.

The patient underwent surgery where ALCAPA was reimplemented to the aortic root. Postoperative echocardiography shows good flow via the newly transpositioned artery. In postoperative management, the child has developed atelectasis due to obstruction of the left main bronchus, caused by the pressure of the enlarged heart. Depressed ST segments could still be observed in V5, V6 leads in ECG, but drop in pro-brain natriuretic peptide (proBNP) values has been noted. The child was, in stable clinical condition, discharged home on digoxin, diuretics and salicylate therapy for further follow-up.

Case 2

The 4-month-old male patient was admitted to the hospital with signs of CHF, dyspnea and feeding difficulties. A systolic murmur was noted. ECG showed signs of anterolateral myocardial infarction. Echocardiography showed dilatative cardiomyopathy and fractional shortening of 13%. The right coronary artery normally arose from the aorta, whilst the LCA could not be visualized arising from the aortic root. The patient was suspected with ALCAPA and heart catheterization was indicated. After the catheterization was performed, coronary angiogram showed an anomalous LCA arising from the posterior aspect of the PA.

The patient was operated and ALCAPA was reimplemented to the aortic root. The patient was transferred to PICU with delayed sternal closure and a high dose of inotropic agents. The sternum was closed on postoperative day (POD) 2. *Enterobacter cloacae* was cultured on POD 6 from the tracheal aspiration (taken on POD 1). Daily echocardiographic examinations revealed minimal improvement of myocardial functions. The patient was extubated on POD 8 but shortly after had to be re-intubated. Due to continued myocardial dysfunction and dysrhythmia problem, coronary angiography was performed on POD 13. Coronary artery angiogram showed no antegrade flow in the left main coronary artery (LMCA), aortic anastomosis of LMCA was obstructed, the tube graft was occluded. Circumflex artery and left anterior descending artery were filling by collateral arteries. Balloon angioplasty and stent implantation were performed inside the coronary tube graft which was created during the operation (4-4.5 mm in size): after one drug-eluting stent (XIENCE PRIME 3.5 mm x 8 mm) was implanted in LMCA, distal LMCA stenosis was absent on angiogram, but residual stenosis in the proximal portion of LMCA was present so that the second drug-eluting stent

(XIENCE PRIME 4 mm x 9 mm) was implanted. LMCA flow was shown to be normal after the procedure. Following stent implantation, sinus rhythm was maintained and daily echocardiographic examinations revealed improvement of the myocardial functions. The patient was extubated on POD 15 and re-intubated on POD 16 due to respiratory distress. Tracheostomy cannula was implanted on POD 17. The patient was transferred to the ward on POD 27 after removing tracheostomy cannula with satisfying myocardial and respiratory functions. The patient was discharged at POD 36 on salicylate, clopidogrel, digoxin, diuretics and angiotensin converting enzyme inhibitors (ACEI) therapy.

Two years after the procedure, the patient experienced a few episodes of transient loss of consciousness, but apart from that clinical condition was satisfying and stable.

The most recent echocardiogram performed as an outpatient 28 months after the procedure shows normal LV function (fractional shortening – 35%; ejection fraction – 66%). The latest electrocardiogram shows no changes within the ST segment.

Twenty-eight months after surgical correction and stent placement, heart catheterization was performed and coronary artery angiogram showed normalization of the left coronary vasculature

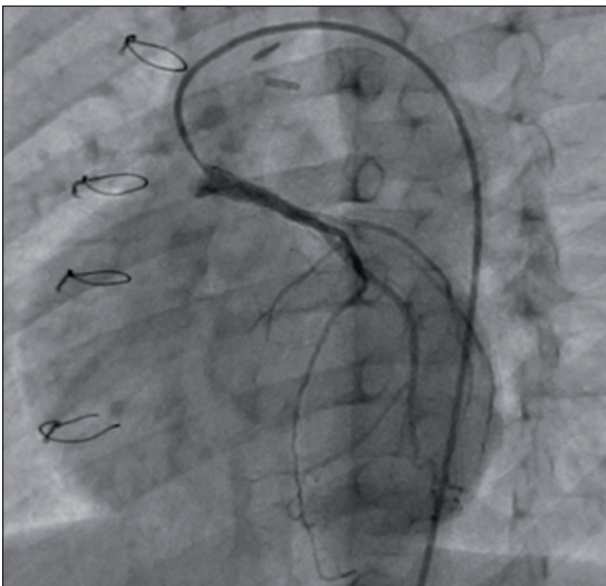


Figure 3. Coronary angiogram shows the left coronary artery (LCA) 28 months after the reimplantation of anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) to the aortic root and stent placement in the left main coronary artery (LMCA). The complete resolution of flow in the LCA is accomplished and no signs of in-stent stenosis are present.

and no sign of in-stent stenosis (**Fig. 3**). After the catheterization, the patient was discharged home on continuation of the salicylate and ACEI therapy and clopidogrel was excluded, more than 2 years after stent placement.

Case 3

A 3-year-old male patient suspected with postvaccinal myocardial lesion was admitted for cardiologic evaluation. Ten days after receiving an MMR vaccine, morbilliform rash and dysrhythmia occurred. On admission, the patient was eupnoic, eucardic, without signs of hepatomegaly as well as without fatigue or limitations in physical activity. IV/VI ejection systolic murmur at the left lower sternal border was revealed during the examination. Laboratory tests showed that proBNP was elevated – 1,334 pg/ml. Chest X-ray showed cardiomegaly, as well as increased pulmonary vascularity. ECG showed no significant changes within the Q wave; negative T waves in left precordial leads were noted, without ST segment elevation. Echocardiogram showed dilated LV with ejection fraction of 44%, fractional shortening of 22%, mild mitral regurgitation. Color Doppler revealed a vascular structure that extends vertically over the anterior wall of the right ventricle. Right coronary artery imposed as prominent and arised normally from the aorta. LCA arose from the PA (**Fig. 4**). The diagnosis of ALCAPA was suspected. Magnetic resonance angiography (MRA) confirmed the diagnosis (**Fig. 5**).

The patient was operated for reimplantation of ALCAPA to the aortic root. During the postoperative period, the child was in general in stable clinical condition with episodes of hypotension and monomorphic extrasystoles in ECG monitoring (1.15% of all heartbeats). At discharge, the patient was hemodynamically stable and without extrasystoles. The child was discharged home on salicylate, diuretics, ACEI and beta-blocker therapy. The most recent postoperative echocardiography (2 months after the procedure) shows good flow via the newly transpositioned artery as well as better ejection fraction – 51% and fractional shortening – 26%. On the latest postoperative ECG finding neither the extrasystoles or the signs of ischemia were noted. The most recent postoperative proBNP test was performed 8 weeks after the operation and showed a significant decrease in its value – 345 pg/ml.

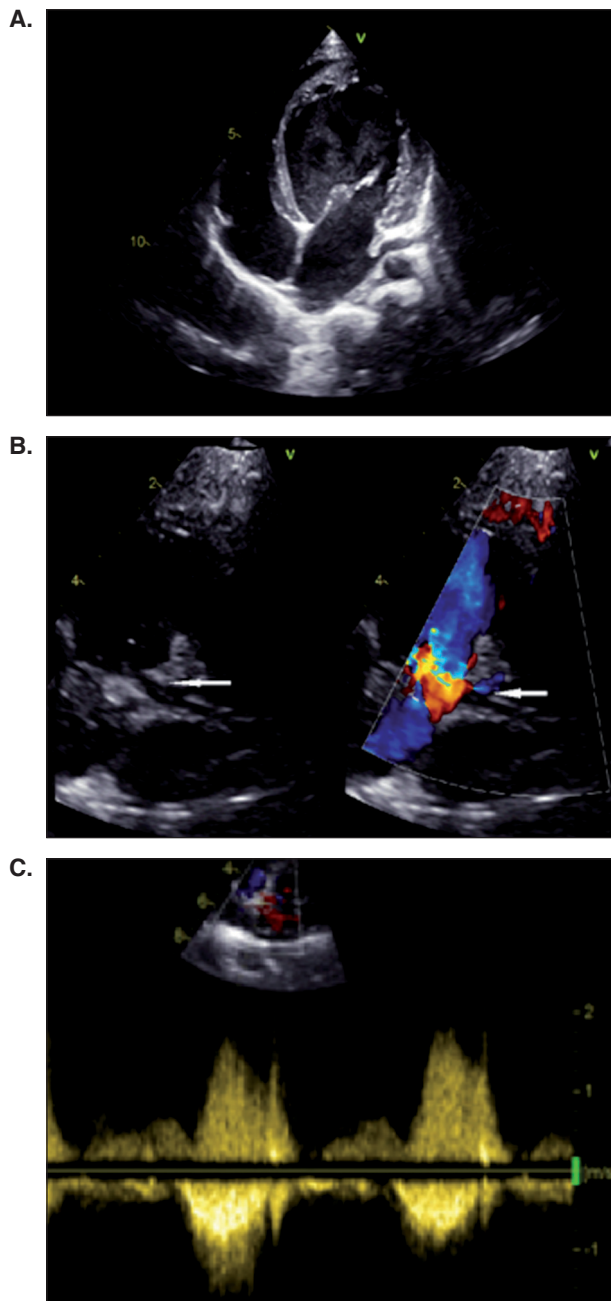


Figure 4. A. Apical four-chamber view shows dilated left heart cavities. B, C. The parasternal long-axis view shows the origin of left coronary artery (LCA) with retrograde diastolic flow.

Discussion

Prognosis in patients with ALCAPA has improved with the progress in diagnosis, surgical techniques and postoperative care. It is of great importance to diagnose ALCAPA early because of the irreparable ischemic injury that develops as time goes by. Early recognition and surgical intervention with the aim of restoring a two-coronary-artery circulatory system had outstanding outcome and led to gradual myocardial recovery.

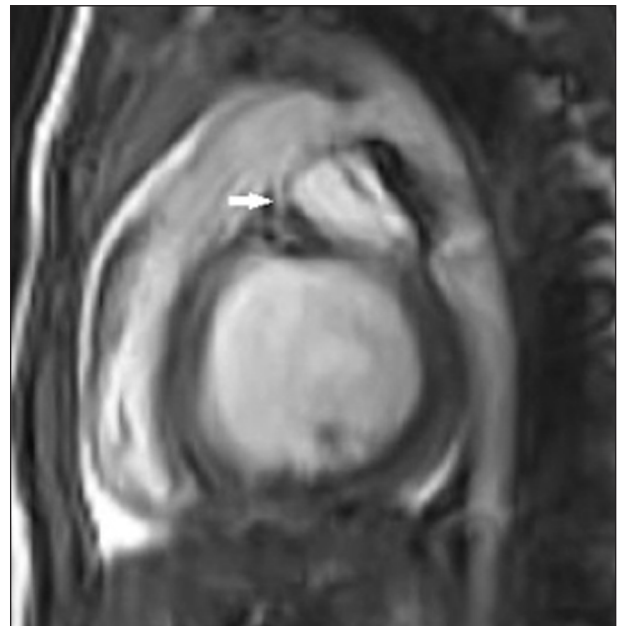


Figure 5. Magnetic resonance angiography (MRA) shows the left coronary artery (LCA) arising from the posterior aspect of the pulmonary trunk.

This report presents 3 patients with ALCAPA and their different clinical, electrocardiographic and echocardiographic findings as well as the modalities of treatment and the postoperative period.

Inadequate myocardial perfusion likely causes significant chest pain and these symptoms of myocardial ischemia may be misinterpreted as routine infantile colic [8]. In 85% of these patients, symptoms appear between 2 to 3 months of age as recurring episodes of distress, marked cardiomegaly and heart failure. In unusual cases, the clinical presentation with symptoms of myocardial ischemia may be delayed into early childhood, or even adulthood. A significant heart murmur is usually absent, with a rare exception of a heart murmur of mitral regurgitation secondary to myocardial infarction.

Rodriguez-Gonzalez et al. describe in their case series the difference in clinical presentation among the patients with ALCAPA between the infants and the older children. It is described that the chief symptom in infants was irritability elicited by only slight effort, such as feeding, and that this feature started within 2 months of birth. At the same time, a substantial reduction in pulmonary vascular resistance occurs and results in coronary steal from the anterolateral aspect of the LV. It is also reported that the older children were asymptomatic probably because of the strong collateral vessels [9].

Two of our patients were 4-month-old infants and both had clinical symptoms that included

dyspnea and poor-feeding as a result of CHF. The onset of the disease was typical for the syndrome. After pulmonary arterial pressure had decreased, patients demonstrated distress after feeding and irritability. These were caused by the coronary steal from the LCA into the pulmonary trunk. This coronary steal resulted in diminished perfusion of the left ventricular muscle, extensive myocardial ischemia and finally myocardial infarction.

The third patient was 3 years old and asymptomatic – he was eupnoic and eucardic on admission and had no limitations in physical activity.

Cardiac enzyme changes probably occur, but the relatively slow development of myocardial infarction and the uncertainty of the exact time of infarction may make it difficult to interpret laboratory data.

The ECG in 2 of our patients, who were infants, showed an anterolateral myocardial infarction pattern. The third, the 3-year-old patient, did not have changes within the ST segment and had no typical signs of myocardial infarction on ECG.

Color-flow Doppler echocardiography is today considered to be the best diagnostic option for ALCAPA patients. Its value also depends on the ability and experience of the doctor who performs it. Some recommendations even promote not performing coronary angiography at all, principally not in critically ill patients. Color-flow Doppler echocardiography can show that the LCA does not arise from the aorta and that it has either retrograde flow or none. Retrograde flow correlates with blood that the LCA receives from the collateral vessels. Recognition of a dilated right coronary artery and retrograde flow in the PA near the suspected origin of the anomalous LCA is another strong suggestion towards the ALCAPA. It should be noted that a large coronary artery can impose and be misidentified as persistent ductus arteriosus.

Common ultrasound findings are mild to moderate mitral valve regurgitation (caused by ischemia of the papillary muscles), echogenic left ventricular papillary muscles, some degree of LV dilatation/dysfunction and, as previously mentioned, prominent right coronary artery with collaterals that present as diastolic or continuous flow within the interventricular septum and then towards the PA. This flow should not be misidentified as the ventricular septal defect.

LV dilatation, retrograde diastolic flow in the LCA and main PA, as well as the mild to moderate mitral regurgitation, were present in all of our 3

patients. Hyperechogenic papillary muscles were found in 2 of our patients, who were infants. Severe right coronary artery dilatation along with the intraseptal collateral vessels was present only in our 3-year-old patient. Even in this age of advanced imaging techniques, echocardiography still allows diagnosing coronary arteries abnormalities, before confirming it by angiography, computed tomography (CT), MRA and so on [10].

Cardiac catheterization or CT/MRA may be indicated to confirm the diagnosis [1] and to exclude other potential diagnoses [11]. The most important differential diagnosis in this age group is dilatative cardiomyopathy, and others are congenital mitral valve disorder, coronary artery fistula, mitral valve insufficiency and viral myocarditis. Coronary angiography is a simple and quick invasive diagnostic modality in the centers where CT/MRA facilities are not fully established.

When the collateral circulation is not well-developed, aortograms can fail in revealing of the LCA. However, only one coronary artery on angiogram should suspect ALCAPA. In this case, it is necessary to perform pulmonary arteriography. Angiography is the gold standard for the confirmation of ALCAPA, although coronary angiography in critically ill infants has been doubted by some authors.

Chang and Allada have presented a scoring system in which the diagnosis of ALCAPA can be both suspected and confirmed as well as differentiated from the dilatative cardiomyopathy with use of echocardiography and ECG and without the use of coronary angiography.

This system has a sensitivity of 100% and a specificity of 91%. MRA and CT are alternatives for the confirmation of ALCAPA when the diagnosis is not clear [12].

All of our patients were suspected with ALCAPA after the findings on echocardiographic assessment. Two of our patients had their diagnoses confirmed with coronary angiography and one had diagnosis confirmed with MRA.

Initial management of the anomalous LCA from the PA is both supportive and temporary. Treatment of CHF includes careful use of diuretics, afterload reduction medications and inotropic drugs. Once the patient is stabilized, the surgical revascularization is performed in order to create a two-coronary artery system including coronary button transfer, the Takeuchi procedure (creation of an aortopulmonary window and an intrapulmonary tunnel extending from the anomalous ostium to the window) and

placement of a coronary artery bypass graft combined with ligation of the origin of the LCA. Of these options, coronary button transfer, as the preferred method of treatment in infants, is considered to be the best anatomic correction and it has excellent long-term results. Once revascularization to a two-coronary artery system is accomplished, most patients experience normalization of left ventricular systolic function, decreased mitral valve insufficiency and resolution of heart failure symptom, thereby improving long-term survival [13]. In many cases, the classic myocardial infarct pattern on ECG eventually disappears following normalization of left coronary blood flow. The need for simultaneous mitral valve reconstruction, in the presence of severe insufficiency, is controversial because spontaneous improvement of mitral valve function often occurs following surgical revascularization. A study of 23 infants with anomalous LCA from the PA proved that aortic reimplantation of the anomalous coronary artery is effective in improving myocardial function but is a less effective tool for treating severe mitral valve regurgitation [14].

One of our patients developed acute coronary artery ischemia due to postoperative coronary artery obstruction. Percutaneous coronary artery stent implantation in LMCA was performed and the result was complete restitution of flow in the previously stenotic artery. Although coronary artery stenting is a rare procedure in the pediatric population and carries the risk of adverse events, it was life-saving in the case of our patient. The patient was discharged home with dual antiplatelet therapy. Control coronary angiogram 28 months after the procedure showed normal flow in LMCA without the signs of in-stent re-stenosis. Clopidogrel was excluded because it was believed that its therapeutic activity has ended and the

patient was discharged with single antiplatelet therapy. Long-term acetylsalicylic acid therapy is required as the vessels grow and the size mismatch occurs causing shear stress. Other limitations to this procedure include small size of coronary arteries and related procedural difficulty. Also, the long-term outcome of coronary stent implantation in infants is still not known [6]. Current guidelines recommend that dual antiplatelet therapy with aspirin and an adenosine-diphosphate receptor antagonist be continued for a minimum of 12 months following drug-eluting stent percutaneous coronary intervention. The optimal duration, however, remains unclear [15].

Tab. 1 presents clinical, electrocardiographic and echocardiographic findings in the above-presented cases.

Clinical significance of the presented cases is to emphasize the importance of early diagnosis and treatment of ALCAPA syndrome, with awareness of the significant difficulties and possible errors throughout.

Perspectives for research in this field are determination of the long-term outcome after palliation of the syndrome as well as lifelong care in a center experienced with caring for adults with congenital heart disease.

Conclusion

Our paper presented three patients with ALCAPA that had different clinical presentation preoperatively and different postoperative course. Patients who were infants presented with symptoms of CHF. Their ECG showed signs of myocardial infarction, which was the consequence of the coronary steal from the LCA into the pulmonary trunk as well as of the absence of strong collateral vessels. On the other hand, the older child was

Table 1. Clinical, electrocardiographic and echocardiographic findings in presented cases.

Findings	Case 1	Case 2	Case 3
Clinical	Dyspnea, poor feeding, seizures and irritability	Dyspnea and poor feeding	No symptoms
ECG	Anterolateral MI	Anterolateral MI	Normal results
Mitral regurgitation	Moderate	Moderate	Mild
Retrograde diastolic flow in LCA and main PA	Present	Present	Present
Right coronary artery dilatation	Slight	Slight	Severe
Intraseptal collateral vessels	None	None	Present
LV dilatation or dysfunction	Present	Present	Present
Hyperechogenic papillary muscles	Present	Present	None

ECG: electrocardiography; MI: myocardial infarction; LCA: left coronary artery; PA: pulmonary artery; LV: left ventricle.

asymptomatic, without signs of myocardial infarction in ECG and with good collateral system that arose from the right coronary artery. Two patients had in general uncomplicated postoperative course, while 1 patient underwent the life-saving stent implantation in LMCA due to its postoperative obstruction.

Although ALCAPA syndrome is a rare condition, it is potentially lethal and thus should be considered in every clinical finding of severe heart failure, cardiomyopathy and presence of ischemic ECG findings in infants. Diagnosis in older children can be much more challenging regarding the absence of typical clinical symptoms and borderline ECG findings. In these patients, detailed assessment through echocardiography has a determining role. Early diagnosis and prompt surgical intervention have excellent results, leading to gradual myocardial recovery and better prognosis for these children.

Critically ill patients should undergo treatment in clinic centers that are able to provide mechanical ventricular assist devices, ECMO, and the possibility of heart transplantation.

Declaration of interest

The Authors declare no conflict of interest.

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