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Case Report

Diagnosis and treatment of 7 cases with anomalous left coronary artery from pulmonary artery

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Abstract: Anomalous left coronary artery from pulmonary artery (ALCAPA) is associated with high mortality. The aim of this study was to investigate the value of ALCAPA diagnosis using both clinical manifestation and imaging examination, and also the effect of surgery intervention on prognosis in ALCAPA patients. A retrospective review of seven patients with ages from 3 months to 51 years who had their ALCAPA repaired from February 2013 to January 2015 in our medical center was recruited in this study. The review focused on clinical manifestations, diagnostic features and surgical treatment effect. Echocardiogaphy showed right coronary artery dilation, left ventricular enlargement and decreased left ventricular systolic function such as left ventricular ejection fraction (LVEF) in all seven cases; mild to moderate mitral valve regurgitation (MR) in three cases and severe MR in one case. Enhanced CT indicated thickened and tortuous right coronary artery in all seven cases. Two cases underwent general aortic implantation, and the remaining 5 patients underwent a modified aortic implantation. For the three cases with severe MR, concurrent mitral valvuloplasty was performed. After surgical intervention, LVEF significantly increased and end-diastolic volume (EDV) decreased in all cases compared with their pre-surgery, states. Although one patient with severe mitral insufficiency still had moderate mitral insufficiency after surgery. There was no intraoperative or postoperative death. ALCAPA could be diagnosed by the combination of imaging examinations and = clinical manifestation. Beside, surgical intervention improved cardiac function which would potentially benefit the prognosis.

Keywords: ALCAPA, electrocardiogram, echocardiography, mitral regurgitation

Introduction

Anomalous left coronary artery from pulmonary artery (ALCAPA) is a congenital coronary abnormality associated with high mortality and adult sudden cardiac death in infant [1]. After birth, decreased pulmonary vascular resistance causes left to right shunting. Further, blood flow refluxes also exists in the anomalous coronary artery due to higher coronary artery resistance. If left untreated, the mortality rate of infants would reach 90% [2]. Patients suffered from ALCAPA usually have one major coronary artery (left anterior descending artery or left circumflex artery) or its branch (or two major coronary arteries arise from the proximal pulmonary trunk and in some rare cases, from the proximal right pulmonary artery. However, the coronary artery flow is usually normal in ALCAPA patients. ALCAPA has a low incidence rate, occurring in 1 per 30,000 live births and accounting for 0.5% of all congenital heart diseases [3], among which, anomalous right coronary artery from the pulmonary artery having the lowest incidence. However, infants who have two coronary arteries arising from the pulmonary artery usually die shortly after being delivered because of either myocardial ischemia or hypoxia. Therefore, little chance that surgeons usually have to investigate the pathogenesis of these patients or even had a chance to treat them. However, surgical treatment is the only way to cure the disease with satisfactory short- and long-term outcomes based on the development of advanced techniques recently [4]. The present study retrospectively analyzed the clinical features and treatment effect of seven cases with ALCAPA at our hospital from February 2013 to January 2015, and

we will systematically review the clinical diagnosis of and therapeutic approach for ALCAPA.

Materials and methods

General data

Seven cases of ALCAPA, four males and three females aging from 3 months to 51 years, were treated at our hospital from February 2013 to January 2015. Five of these patients are pediatric patients. Two patients received preoperative auxiliary respiration and positive inotropic action drug was used for 6 patients before operation. The protocol in this study was approved by the Ethics Committee of Henan Province People's Hospital, and all subjects gave their informed consent to participate.

Diagnosis and imaging methods

The diagnosis criteria for ALCAPA recruited in this study include (1) electrocardiogram (ECG) indicating Q wave depth >1/4 of the R wave in the same lead, (2) unipolar lead Q/R ≥0.15, with a Q wave duration of ≥30 ms; (3) downward shift in the ST segment was ≥0.05 mV.

Echocardiography was used to detect and the origin of the left coronary artery and right coronary artery on the aortic sinus and measure whether the diameter was enlarged. At the same time, parameters required for measuring left ventricular ejection fraction (LVEF) was measured and LVEF was calculated. Color Doppler ultrasound was used to detect the blood flow in the left and right coronary arteries, and a frequency spectrum analysis was conducted for the blood flow. The cardiac structure was identified as well [5].

A Siemens 64-slice spiral CT machine was performed in all patients and the original images were transmitted to an AW4.3 workstation, where volume reconstruction (VR), maximum intensity projection (MIP) and multi-plane projection (MPR) were analyze and calculated. Afterwards, images with diagnostic value were obtained and reported [6].

Cardiac catheterization and angiography were also performed. The right femoral artery and vein were punctured under local anesthesia. Left and right cardiac catheterizations were both performed to evaluate the hemodynamics. Angiography focusing on the root of the ascending coronary artery and late-phase development were carried out to determine the origin of the coronary artery and the direction of blood flow, respectively.

Surgical approaches

All seven cases received surgical treatment. Briefly, following a median thoracotomy and aortic cannulation, cardiopulmonary bypass was established with vena cava cannulation. While administering mild hypothermic therapy, the aorta and pulmonary artery were blocked with cold blood cardioplegia. The tube for left ventricular decompression was inserted into the right superior pulmonary vein. Two cases were treated with direct aortic implantation, and the remaining five cases underwent modified aortic implantation using autologous blood vessels to achieve transplantation of the coronary artery. All cases were reexamined postoperatively using ECG and echocardiography to monitor the origin and blood flow of the right coronary artery and ensure and early detection of myocardial ischemia and left ventricular systolic function change.

We would like to further demonstrate the two different types of surgery. In patients with LCA/LAD opening at the right sinus of pulmonary artery (2 cases), a direct aorta implantation surgery was performed. Briefly, abnormal left coronary artery opening was localized after open up the lumen of pulmonary artery around right sinus during the surgery. A U-shape tissue flap was dissected from the pulmonary artery with the abnormal left coronary artery opening. Next, the lumen of aortic artery sinus where the normal left coronary artery opening should be located was opened, and the U-shape tissue flap was implanted directly into the dissected aortic artery. The U-shape tissue gap in pulmonary artery where the abnormal opening was taken out was repaired using artificial repairmen tissue. On the other hand, patients whose abnormal openings of left coronary artery were at the left sinus or non-facing sinus of pulmonary artery received an alternative surgical approach which was a modified aortic implantation. Briefly, pulmonary artery tissue which was distal and proximal to the abnormal opening of LCA was cut into a rectangle shape tissue, which was further folded into a canal-shape tube. The lumen of aortic artery sinus where the normal left coronary artery opening

Table 1. Clinical characteristics and features of imaging examination

Case number	Age (yr)	Gender	Height (cm)	Body weight (kg)	Symptoms and signs	EKC	Echo	CT	Angiography
1	51	Male	178	82	Angina, shortness of breath	Left axis deviation, Abnormal Q wave, ST depression	RCA dilation, LV enlargement, moderate MR	RCA dilation, LAD origins from right sinus of pulmonary trunk	LAD opens at pulmonary artery
2	25	Female	162	58	Angina, shortness of breath	Left axis deviation, Abnormal Q wave, ST depression	RCA dilation, LV enlargement,	RCA dilation, LCA origins from right sinus of pulmonary trunk	LCA opens at pulmonary artery
3	7	Male	116	21	Angina, shortness of breath	Left axis deviation, Abnormal Q wave, LRBBB	RCA dilation, LV enlargement, mild MR, ASD	RCA dilation, LCA origins from non-facing sinus of pulmonary artery	
4	3	Female	89	16	Shortness of breath, anxiety, facial pale	Left axis deviation, Abnormal Q wave, ST depression, premature ventricular beat	RCA dilation, LV enlargement, severe MR, endocardium fibrosis	RCA dilation, LCA origins from right sinus of pulmonary trunk	
5	2	Male	79	12	Shortness of breath, sweating, pale of extremities	Left axis deviation	RCA dilation, endocardium fibrosis, VSD	RCA dilation, LCA origins from right sinus of pulmonary trunk	
6	1	Male	70	9	Facial pale, shortness of breath, sweating	Left axis deviation, Abnormal Q wave, CLBBB	RCA dilation, mild MR, endocardium fibrosis, ASD	RCA dilation, LCA origins from left sinus of pulmonary trunk	
7	0.25	Female	56	6	Facial pale, shortness of breath, sweating	Left axis deviation	RCA dilation, LV enlargement, PDA	LCA origins from left sinus of pulmonary trunk	

Abbreviations: ASD, atrial septal defect; VSD, ventricular septal defect; PAD, patent ductus arteriosus. LCA, left coronary artery; RCA, right coronary artery; LAD, left descending coronary artery; CLBBB, complete left bundle branch block; MR, mitral valve regurgitation.

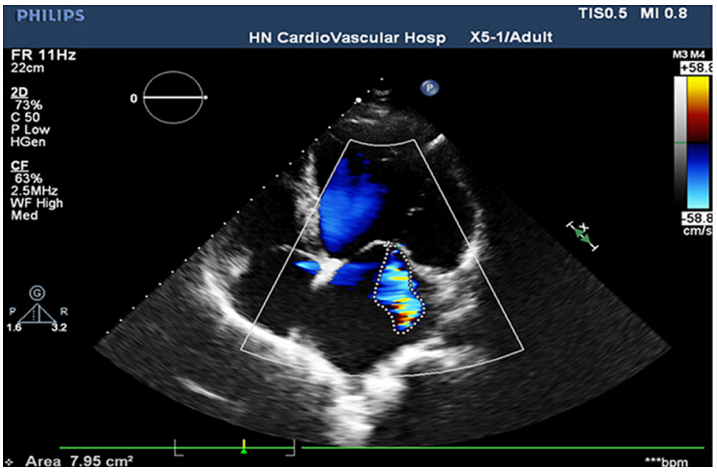

Figure 1. A two-dimensional echocardiography indicated a shunt from the left anterior descending artery (LAD) to the main pulmonary artery (PA).

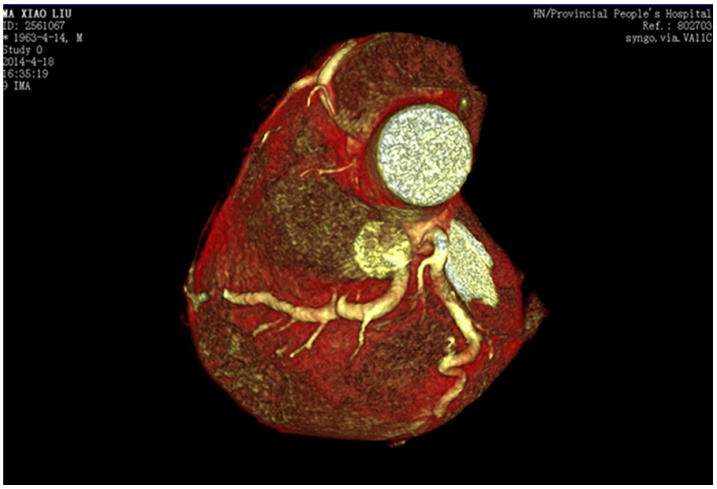

Figure 2. CTA showed that the left anterior descending artery (LAD) rised from the left sinus of Valsalva of the main pulmonary artery (PA).

should be located was also opened as stated in the direct aorta implantation patients mentioned above. The canal-shape pulmonary artery with abnormal LCA opening was then implanted into the aortic artery. End-to-end anastomosis was performed in the pulmonary artery section where the rectangle tissue flap with abnormal LCA opening was taken off.

Statistical analysis

Results are reported as mean ± standard deviation (SD) for each group. Statistical analysis was performed by the pair t test for pre- and post-operation comparison using SPSS 16.0 software. A two tail $P<0.05$ was considered as statistically significant.

Results

Clinical and ECG characteristics

The five pediatric cases with ALCAPA experienced shortness of breath, agitation, pale complexion, pale extremities, and hyperhidrosis. Meanwhile, the two adult cases experienced less severe symptoms of shortness of breath and angina after exertion (**Table 1**). Left axis deviation was observed on EKG from six cases. Abnormal Q wave was detected in leads I, aVL, V5, and V6 in five cases, with depression of ST segment and an inverted T wave. In addition, one patient presented with a complete left bundle branch block, and one had a ventricular premature beat. Detailed clinical and ECG characteristic of each patient is summarized in **Table 1**.

Features on echocardiography

The results of echocardiography showed that all seven cases had typical manifestations of ALCAPA including right coronary artery dilation, left ventricular enlargement, and impaired left ventricular systolic cardiac function. Three patients had mild to moderate mitral valve regurgitation (MR) and one had severe MR. Besides, three patients had fibrosis and elastic fiber hyperplasia of the papillary muscles and left ventricular endocardium, one of whom had the left anterior descending artery arising from the pulmonary artery with a thickened right coronary artery, enlarged left ventricle and impaired systolic function (**Figure 1**). Detailed feature of echocardiography of each patient is summarized in **Table 1**.

Features on enhanced CT

Enhanced CT images in all cases confirmed that left coronary artery did not arise from aortic root but from pulmonary artery. The right coronary artery was tortuous and dilated. The coronary artery of those five pediatric patients had fewer collateral vessels, while the adult cases had abundant collateral blood supply.

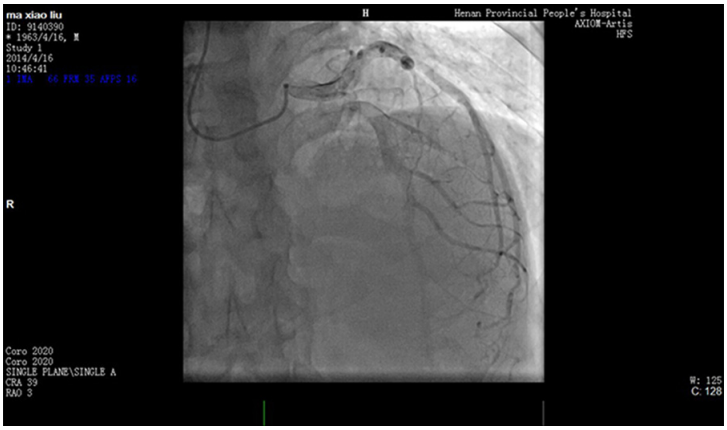

Figure 3. Coronary angiography performed in the left anterior oblique view (LAO) showed a dilated left circumflex artery (LCA) with an anomalous origin of the left anterior descending artery (LAD) that developed from and was connected to the main pulmonary artery (PA) with multiple collateral vessels.

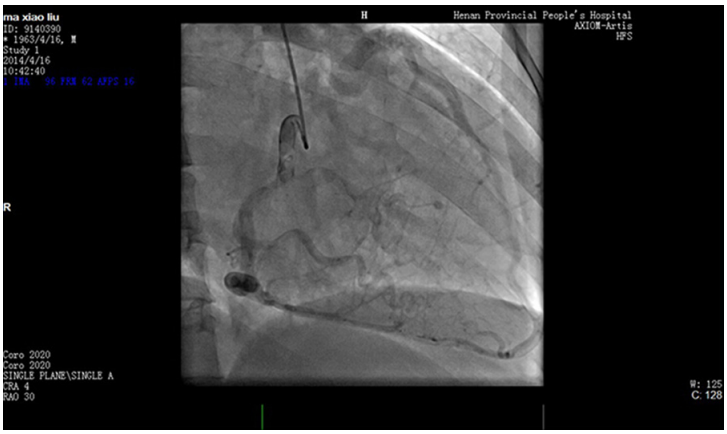

Figure 4. Coronary angiography performed in the right anterior oblique view (RAO) showed a dilated right coronary artery with an anomalous origin of the left anterior descending artery (LAD) that developed from and was connected to the main pulmonary artery (PA) with multiple collateral vessels.

One case had left anterior descending artery arising from the pulmonary artery (**Figure 2**). Detailed feature of CT angiography of each patient is summarized in **Table 1**.

Findings on cardiac catheterization and angiography

Two adult cases received cardiac catheterization in which an obvious dilation of the right coronary artery was observed (**Table 1**). Contrast agent quickly flowed into the pulmonary artery from the left coronary artery via collateral circulation after injection. Left ventricular enlargement with weakened motion of the left ventricular anterolateral wall and mitral valve insufficiency were clearly observed. One adult patient who had left coronary artery arising from the pulmonary artery had left circumflex artery and right coronary artery thickening with abundant collateral blood supply. As a result, there was a left-to-right shunt from the right coronary artery to the pulmonary artery via the left anterior descending artery (**Figures 3**, **4**).

Surgical outcomes

All cases underwent surgical treatment in this study. For the two adult cases, we observed thin coronary arteries walls and rich collateral vessels during the surgery. The opening of the right coronary artery was enlarged, and the vessels of the entire coronary artery system were tortuous and dilated, consistent with enhanced CT scan results. In three pediatric cases, gross morphology showed stiffness or fibrosis of left ventricular wall with grayish-white myocardium. One case with severe MR had significantly enlarged four chambers of the heart. Finally, two cases underwent aortic implantation and five underwent modified aortic implantation artery using autologous blood vessels to achieve reversing the blood flow from the pulmonary artery to aortic root. Concurrent mitral valvuloplasty was performed in the case with severe MR.

All cases received follow-up for 2-24 months after surgery (**Table 2**). LVEF was monitored by echocardiography and significantly increased during the follow-ups. End-diastolic volume (EDV) also decreased in all cases after surgery (**Table 3**). Three cases with mild to moderate mitral insufficiency had considerable improved after surgery. However, one case with severe mitral insufficiency still had moderate mitral insufficiency after surgery. There were no intraoperative or postoperative deaths reported in all cases.

Table 2. Detailed follow-up information of all seven patients

Case	Surgery type	Additional procedures	Extracorporeal circulation time (minutes)	Aorta cross-clamp time (minutes)	Ventilation time (days)	Length of ICU admission (days)	Length of in-patient admission time (days)	Post-surgery complications	Length of follow-up	Complications during follow-up
1	Modified aortic implantation	None	165	92	12	25	45	Congestive heart failure, pulmonary infection, arrhythmia	13	Congestive heart failure
2	Modified aortic implantation	None	132	69	6	9	15	None	17	None
3	Modified aortic implantation	ASD repair	112	53	3	5	13	Arrhythmia	24	Mild MR
4	Modified aortic implantation	Mitral valvuloplasty	152	83	3	5	25	Pulmonary infection, arrhythmia	2	Occasional premature ventricular beat, moderate MR
5	Modified aortic implantation	VSD repair	130	75	4	7	18	Arrhythmia	10	Premature atrial beat
6	Aortic implantation	ASD repair	157	102	6	13	30	Sepsis, pulmonary infection	8	Mild MR
7	Aortic implantation	PDA ligation	163	112	8	20	42	Congestive heart failure, pulmonary infection	6	None

Abbreviations: ASD, atrial septal defect; VSD, ventricualr septal defect; PAD, patent ductus arteriosus; MR, mitral valve regurgitation.

Table 3. Surgical outcomes of seven cases with anomalous left coronary artery from pulmonary artery (ALCAPA)

	Pre-operation	Post-operation	Follow-up
LVEF	40.6±7.9	48.6±6.2*	50.9±6.4*
EDV	55.8±19.3	36.5±14.5*	33.0±14.3*

Means ± standard deviations (SD). *: P<0.05 compared with pre-operation.

Discussion

ALCAPA is characterized by chronic ischemia due to the abnormal blood flow between coronary artery and pulmonary artery which is associated with impaired cardiac function at an early stage and possibly cardiac arrest due to myocardium ischemia and histological feature of necrosis in the late stage [7]. The degree of myocardial necrosis of the left ventricle is determined by the balance between timing of closure of the ductus arteriosus, changes in pulmonary vascular resistance, and speed of development of preexisting collateral circulation between the right and left coronary arteries [8]. This study investigated the value of t combined application of clinical examination methodologies and clinical manifestations of patients in ALCAPA diagnosis, and the effect of early surgical treatment on the prognosis of ALCAPA patients.

ALCAPA is classified into two major categories, pediatric type and adult type [9]. Usually, fewer collateral blood supply develop to connect the left coronary artery and right coronary artery in pediatric type. As pulmonary artery pressure decreases after birth, blood perfusion from the pulmonary artery to the left coronary artery decreases accordingly, the process of which will finally stop when the pressure difference between pulmonary and coronary system is balanced. As a result, pulmonary artery pressure is lower than coronary artery pressure, leading to a phenomenon called coronary steal. With reduced blood supply to the left ventricle, consequences of ALCAPA include an cardiac hypertrophy or enlarged heart, endocardium fibrosis, ischemic papillary muscles, atrophic papillary muscles, and mitral insufficiency. Cardiac function impairment or heart failure usually happens at an early stage of the disease. Severe cases may experience a myocardial infarction or post-myocardial infarction ventricular aneurysm. The present study showed that all five pediatric cases had the clinical manifestations of cardiac dysfunction including shortness of breath, agitation, pale complexion, pale extremities, and hyperhidrosis. In the adult type, the right coronary artery is the dominant artery that is involved in the pathophysiology of ALCAPA, and rich collateral vessels usually form between the right coronary artery with a normal origin and the left coronary artery with an anomalous origin. Right coronary artery is thickened and left coronary artery connected to the low-pressure pulmonary artery. Collateral circulation blood flows into the pulmonary artery, instead of perfusion to the high-resistance coronary arteries, leading to coronary steal. The clinical symptoms include shortness of breath, syncope, angina on exertion, arrhythmia and heart failure. In the current study, both adult cases experienced difficulty in breathing and angina on exertion.

In the aspect of treatment, surgery is the only choice that could cure the disease. In the last several decades, the surgical choices for ALCAPA patients have had developed and changed a lot. Simple ligation of the coronary artery arising from the pulmonary artery was one of the first surgical choices for ALCAPA patients long time ago. About thirty years ago, anastomosis of the left common carotid artery or left subclavian artery to the left coronary artery which could completely excised coronary artery from the pulmonary circulation became popular [4]. Afterwards, vessels like great saphenous vein [10] or internal mammary artery became other vessel course for ALCAPA patients. Takeuchi's method is another surgical approach that is favored by surgeons in treating ALCAPA [11, 12]. However, all these surgical methods have been gradually phased out because of a high incidence of complications and unsatisfactory long-term outcomes.

The main objective for surgical treatment of ALCAPA is to reconstruct the coronary artery system to ensure normal blood flow in the coronary artery. Turley et al. reported that aortic implantation is the treatment of choice for ALCAPA. Using this method, either direct transfer and in situ transfer, they treated a total of eleven patients regardless of the site of coronary origin of ALCAPA [13]. Laks published seven cases all of whom underwent a modified aortic implantation, with no early- or late-stage deaths, and blood flow in the implanted aorta was completely normal, suggesting this should be a good and proper surgical approach in

treating ALCAPA patients [14]. Neches also presented two cases of aortic implantation with a good short-term outcome [15]. Antonio et al. reported that excellent outcomes could even be achieved in repairing ALCAPA without mechanical circulatory support and with low reintervention rates in a total of 34 patients [1]. These studies suggested that aortic implantation is the preferred choice for ALCAPA with or without concurrent mitral valvuloplasty and resection of ventricular aneurysms. In the present study, two cases underwent aortic implantation, and five cases underwent modified aortic implantation using autologous blood vessels. Posy surgery echocardiography showed that the impaired LVEF significantly increased and EDV decreased in all cases. Relocation of the coronary artery arising from the pulmonary artery to the aortic root was achieved.

There are several studies that have reported the infant cases of ALCAA, while the similar reports in adult patients have been extremely limited. Here in our study, we have reported two adult cases of ALCAPA. We believe that this study could provide more information particularly in adult ALCAPA clinical manifestation, diagnosis and treatment to physicians. Besides, most published studies or reported cases studies of ALCAPA recruited patients with various surgery types, while in our study, aortic implantation was used in both pediatric and adult patients. Based on the fact that fewer adult ALCAPA cases have been reported and little experience of surgeons to deal with adult form of ALCAPA, our study could be valuable in demonstrating that aortic implantation is also a proper and effective surgical approach for adult ALCAPA.

Conclusion

In summary, ALCAPA could be confirmed by the combination of imaging examinations and the careful assessment of clinical manifestation of patients. Beside, surgical intervention improved cardiac function which would potentially benefit the prognosis.

Disclosure of conflict of interest

None.

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