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# The outcome of surgical repair of anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) in infants

Leena Moshref[1*], Rana Moshref[1], Mazen Faden[2] and Osman Al-Radi[1,3]

## Abstract

**Background:** Anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) is a rare congenital malformation in infants presenting with angina, dyspnea, and excessive perspiration invoked by crying and feeding. The aim of this study was to evaluate the factors affecting morbidity and the use of extracorporeal membrane oxygenation (ECMO) and to assess the quality of life post-repair.

**Methods:** In this retrospective study, information about five infants who underwent ALCAPA repair was collected from the databases of two tertiary referral cardiac centers (King Abdulaziz University Hospital and King Faisal Specialist Hospital & Research Center, Jeddah, Saudi Arabia) from 2011 to 2018. The patients were diagnosed using echocardiography, and data including mitral insufficiency and ejection fraction were assessed preoperatively and postoperatively. Quality of life was assessed using a questionnaire-based interview.

**Results:** The median (range) age at the time of repair was 95 (34–144) days, and the median weight was 4.9 (3–5.7) kg. Two patients underwent the Takeuchi procedure, and three patients underwent left coronary artery reimplantation and translocation to the aorta. The median preoperative ejection fraction was 25 (12.5–45)%, and at the last follow-up, the median EF of the three survivors was 59 (50–70)%. There was no significant change in mitral insufficiency grade postoperatively. Two patients had ECMO support and died postoperatively. The infants who died were younger (< 75 days) and had lower weight (< 4.5 kg) at the time of intervention. Patients who survived showed good quality of life were asymptomatic and had heart function within the normal range.

**Conclusion:** Echocardiography and CT angiogram are effective tools for ALCAPA diagnosis in pediatric patients. Low weight at time or repair was associated with increased morbidity and ECMO did not increase survival.

**Keywords:** Anomalous left coronary artery from the pulmonary artery, Mitral regurgitation, Ejection fraction, Extracorporeal membrane oxygenation

## Background

Bland and colleagues defined a symptom complex in infants presenting with angina, dyspnea, excessive perspiration, dizziness, and paleness invoked by crying and feeding, which they named Bland-White-Garland syndrome [1]. It mimics heart failure and often accompanies significant mitral valve regurgitation (MR) and might be mistaken as colic, reflux, or bronchiolitis [2, 3]. Bland-White-Garland syndrome or anomalous origin of the left coronary artery from the pulmonary artery (ALCAPA) is a rare congenital malformation that accounts for 0.25–0.5% of all congenital cardiac anomalies [3, 4]. It is classified into two types: infantile or adult. The infantile variety is associated with a poor prognosis if not treated surgically because of the lack of coronary collaterals. In the adult variety, collaterals are present or have developed; thus, adequate blood supply to the myocardium is present [4].

* Correspondence: leenahatem0987@gmail.com
[1]Department of Surgery, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia
Full list of author information is available at the end of the article

This syndrome is usually diagnosed by echocardiography (ECHO) and CT scan [5]. Few patients survive past childhood without surgical repair, and up to 90% of the survivors die suddenly at a mean age of 35 years [6]. In patients who survive until adulthood, the coronary steal phenomenon and retrograde left-sided coronary flow are the bases of developing chronic subendocardial ischemia, which may lead to left ventricular dysfunction, ischemic mitral regurgitation, malignant ventricular arrhythmias, and sudden cardiac death. The average age for sudden cardiac death is 31 years, and that for a life-threatening presentation is 33 years [7]. The common origin of the carotid arteries (COCA) is a frequent pattern of aortic arch vessels and is the single most common cause of tracheobronchial compression by a congenital cardiovascular anomaly [8].

To our knowledge, there have been no recent studies conducted in the western region of Saudi Arabia regarding the prevalence of ALCAPA, its associated anomalies, and surgical interventions. In this study, we attempted to determine the factors affecting the use of extracorporeal membrane oxygenation (ECMO) and the mortality and to assess the quality of life after ALCAPA repair. Quality of life was assessed in terms of mental and physical development.

## Methods

In this retrospective study, patients were recruited from the databases of two tertiary referral cardiac centers (King Abdulaziz University Hospital and King Faisal Specialist Hospital & Research Center, Jeddah, Saudi Arabia) from 2011 to 2018. Patients aged less than 1 year and who underwent repair of the anomalous left coronary artery from the pulmonary artery were included. The study was approved by the ethics review committee of King Abdulaziz University Hospital, reference number (179-18). The study was conducted according to the ethical guidelines conforming to the declaration of Helsinki, and patients' parents/guardians consented to participate; therefore, a written consent was obtained.

The patients' parameters including age at surgery, associated anomalies, type of surgery, and duration were recorded. The postoperative parameters included complications, duration of ventilation, the need for extracorporeal membrane oxygenation (ECMO), length of intensive care unit (ICU) stay, and inotropic use and duration. Additionally, hospital stay and follow-up (durations, complications, and interventions) were assessed. ECHOs of patients were documented pre- and postoperatively and included the degree of mitral regurgitation, ejection fraction, and fractional shortening.

### Surgical technique

The surgical approach was through a median sternotomy. The pericardium was opened and suspended, followed by excision of the thymus. Cardiopulmonary bypass was started and immediately the branched pulmonary arteries were snuck down.

#### *Takeuchi procedure (cases 1 and 5)*

The main pulmonary artery was transversely cut, and the left anomalous coronary artery was identified arising from the non-facing sinus very close to the commissure of the pulmonary valve. A large button was harvested from the left anomalous coronary artery, and adequate mobilization of the vessel was achieved. There was insufficient distance or tissue for that vessel to reach the ascending aorta; therefore, pericardial tissue was taken and was formulated into a tube-like structure that was anastomosed to the ostium of this anomalous left coronary artery and the ascending aorta after creating a window in the left inferior border of the ascending aorta. The anastomosis was performed using the 7-0 Proline continuous suture. Then, the posterior wall of the main pulmonary artery was augmented, and re-anastomosis of the pulmonary arteries was completed. The patients were weaned off bypass successfully. Chest tube and pacer wire were inserted. In case 1, peritoneal dialysis lines were inserted, and the chest was closed using a patch. In case 5, the chest was closed by sternal wires.

#### *Left coronary artery reimplantation (cases 2, 3, and 4)*

Single left coronary was re-implanted onto the aorta, and patch pulmonary artery repair was performed. Chest tube and pacer wire were inserted. The chest was closed using a patch. In case 3, a direct ventricular septal defect (VSD) closure was performed, and case 4 underwent mitral valve (MV) repair.

### Postoperative follow-up

Patients were followed up by echocardiography at 1 day, 1 and 4 months, and 1, 2, and 3 years postoperatively. The follow-up was conducted by pediatric cardiologists and included echocardiography (EF, MR, and FS), and the parameters were measured on the M-mode.

The quality of life was assessed using a questionnaire-based interview. The questionnaire was validated by two consultants. The questionnaire was telephone based and consisted of open-ended and multiple-choice questions. It aimed to assess the quality of life postoperatively, and it recorded the following data: the achievement of milestones, medications, symptoms, and complications.

### Statistical analysis

Data were analyzed in SPSS version 20 (IBM Corporation, Chicago, IL, USA). Continuous data were presented as median, and range and categorical data as number and percentage. Categorical data were compared using Fisher's exact test and numerical data by Mann-Whitney test. Paired $t$ test was used to compare preoperative and postoperative parameters. Kaplan-Meier method was used to assess the survival rate at the latest follow-up.

**Table 1** Preoperative patients' characteristic

| Case | Gender | Age (days) | Weight (kg) | Height (cm) | Associated anomalies | Mitral valve | EF (%) | FS (%) | Admitting Diagnosis |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Female | 95 | 4.9 | 60 | – | Mild MR | 25 | 12.5 | Referred with depressed LV systolic function |
| 2 | Male | 109 | 4.9 | 60 | – | Mild to moderate MR with 2 jets | 12.5 | 12.1 | Cardiogenic shock and severe LV dysfunction |
| 3 | Male | 34 | 3 | 52 | Perimembranous VSD<br>Biventricular dilatation<br>Thickened pulmonary valve | Mild MR | 28 | 14 | Referred with heart failure and severe LV dysfunction |
| 4 | Female | 75 | 4.5 | 44 | Mild TR<br>Dilated LV | Severe MR with 2 jets | 45 | 25 | Sepsis |
| 5 | Female | 144 | 5.7 | 62 | Severely dilated LV | Moderate MR | 22 | 10 | Respiratory distress<br>Suspected myocarditis |

*EF* ejection fraction, *FS* fraction shortening, *LV* left ventricle, *MR* mitral regurgitation, *TR* tricuspid regurgitation, *VSD* ventricular septal defect

## Results

### Preoperative assessment

Five infants (less than 1 year), with a male to female ratio 2:3, who underwent ALCAPA repair, were included in this study. The median age was 95 days (range, 34 to 144 days) . The median weight was 4.9 kg (range, 3 to 5.7 kg). The patients were diagnosed based on echocardiography (ECHO) findings and CT angiogram. The median of the preoperative ejection fraction was 25% (range, 12.5–45%). Mitral regurgitation degree was mild in 2 patients, mild-to-moderate in 1 patient, moderate in 1 patient, and severe in 1 patient. Echocardiography measurements along with patients' height and weight are illustrated in Table 1.

### Surgical intervention

Cardiopulmonary bypass median time was 118 min (range, 52 to 157 min), and ischemic time was 50 min (range, 24 to 111 min) (Table 2).

### Postoperative assessment

Postoperatively, inotropes (milrinone and epinephrine) were administered to all the patients. Furosemide and spironolactone were administered to 60% (3/5) of patients, who survived eventually. Two patients (cases 1 and 2) had delayed closure due to severe left ventricular dysfunction. ECMO was used in two patients who died eventually. The median duration of ventilation was 3 days (range, 2 to 5 days), and the median duration of ICU stay was 8 days (range, 2 to 12 days). The median postoperative hospital stay was 11 days (range, 2 to 15 days). The mortality rate was 40% (2/5) in patients who had ECMO support. Postoperative details are shown in Table 3.

### Follow-up assessment

Median follow-up was 10 months. The infants who died were younger and had lower weight at the time of intervention ($p = 0.08$ and 0.07, respectively), and they had multiple congenital anomalies (ventricular septal defect, tricuspid regurgitation, and pulmonary valve thickening).

Survival rate was 60% (3/5) at 3 years' follow-up. Ejection fraction improved during follow-up compared to the preoperative value ($p$ value = 0.02) (Fig. 1). Mitral regurgitation degree preoperatively was mild in 1 patient, mild to moderate in 1 patient, and moderate in 1

**Table 2** Operative details of patients who underwent ALCAPA repair

| Case | Operation procedure | Surgery time (min) | CPB time (min) | Ischemic time (min) | Operative events |
|---|---|---|---|---|---|
| 1 | Takeuchi procedure (LCA augmentation by bovine pericardium graft then anastomosed to the aorta) | 260 | 157 | 111 | – |
| 2 | LCA reimplantation to aorta, patch PA repair | 100 | 52 | 27 | – |
| 3 | LCA reimplantation to the aorta, patch PA repair, and direct VSD closure | 176 | 129 | 70 | Arrested for 8 min.<br>Hemodynamic instability with high lactate<br>High doses of inotropes (dobutamine and epinephrine) |
| 4 | LCA reimplantation to the aorta, patch PA repair, and MV repair | 180 | 118 | 50 | Hypotension, bradycardia, and bleeding<br>Blood transfusion<br>Arrested and CPR was done for 2 min |
| 5 | Takeuchi procedure | 101 | 73 | 24 | – |

*ALCAPA* anomalous left coronary artery from the pulmonary artery, *CPB* cardiopulmonary bypass, *CPR* cardiopulmonary resuscitation, *LCA* left coronary artery, *MV* mitral valve, *PA* pulmonary artery, *VSD* ventricular septal defect

**Table 3** Postoperative outcomes after ALCAPA repair

| Case | MV duration (days) | ECMO | Inotropes and (duration; days) | ICU stay (days) | Time to sternal closure (days) | Postoperative complications | Mortality | Hospital stay (days) | Follow-up duration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | No | Milrinone (15), epinephrine (4) | 9 | 1 | Severe left ventricular dysfunction<br>Sternal reopening | Alive | 15 | 10 months |
| 2 | 5 | No | Epinephrine (2), milrinone (12) | 12 | 1 | Severe ventricular dysfunction<br>Sternal reopening<br>Upper chest wall abscess (1 month) | Alive | 12 | 53 months |
| 3 | 2 | Yes | Milrinone (2) | 2 | 2 | Bleeding<br>Surgical reexploration<br>Pacemaker inserted<br>Multiorgan failure | Dead | 2 | 2 days |
| 4 | 4 | Yes | Epinephrine (4), norepinephrine (4), milrinone (3) | 5 | 5 | Bleeding<br>Cardiac catheterization showed dissection of coronary arteries.<br>Surgical re-exploration, anastomosis revision, and LIMA to LAD<br>Multiorgan failure | Dead | 5 | 5 days |
| 5 | 3 | No | Milrinone (6), epinephrine (6) | 8 | None | Left lower lung collapse. | Alive | 11 | 28 months |

*ECMO* extracorporeal membrane oxygenation, *ICU* intensive care unit, *LAD* left anterior descending artery, *LIMA* left internal mammary artery, *MV* mechanical ventilation

patient, compared to postoperatively 2 patients were mild and 1 patient was moderate degree ($p > 0.99$).

One patient (case 2) had postoperative cardiac MRI to assess the coronary arteries and function and revealed subendocardial infarction of the mid- and distal anterolateral wall with poor function. Ten months postoperatively, the patient had a cardiac CT which showed normal coronaries with no stenosis. No other complications or admissions were noted after that.

### Quality of life assessment

Quality of life questionnaire was assessed in three patients. As shown in Table 4, all patients were asymptomatic, with 1–2 medications and normal milestones.

## Discussion

ALCAPA is a rare congenital disease associated with poor prognosis in infants [4]. There are different surgical techniques for repair. The coronary transfer is the current technique of choice for the repair of ALCAPA [9], and it has an acceptable survival rate [10]. In this study, two patients underwent the Takeuchi procedure, and three patients had LCA reimplantation to the aorta and patch PA repair. The patients who underwent Takeuchi procedure survived while two patients who underwent LCA reimplantation had ECMO support and could not survive.

Surgeries were usually undertaken in acute settings as the most common presentation was acute heart failure and depressed LV function [11]. In addition, three

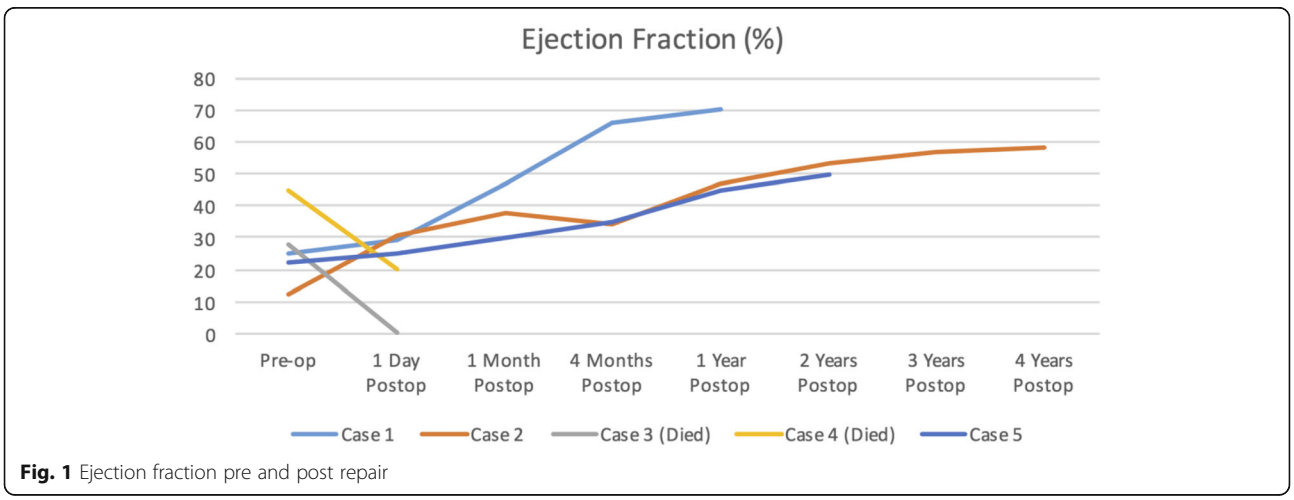


**Fig. 1** Ejection fraction pre and post repair

**Table 4** Quality of life assessment

| Case | Age (years) | Alive Yes/no | Symptomatic Yes/no | Yes, what are symptoms | Medication Yes/no | What medications | Milestones | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Social and emotional | Language/ communication | Cognitive | Movement/physical development |
| 1 | 5.3 | Yes | No | – | Yes | Aspirin | Up to age. | Normal and up to age. | Up to age in school | Fully active and no restriction of movement. |
| 2 | 6.3 | Yes | No | – | Yes | Digoxin | Up to age. | Normal and up to age. | Up to age in school | Fully active and no restriction of movement. |
| 5 | 3.2 | Yes | No | – | Yes | Captopril and aspirin | Up to age. | Normal and up to age. | Up to age. | Fully active and no restriction of movement. |

patients had associated anomalies preoperatively; one patient had VSD with a mildly thickened pulmonary valve and the other two patients had dilated LV, and one of them had tricuspid regurgitation. In a study conducted by Laux and colleagues, the most encountered cardiac anomaly associated with this condition was coarctation of the aorta, followed by tetralogy of Fallot with or without pulmonary atresia [12]. One patient had simultaneous mitral valve repair, and several researchers recommend performing simultaneous mitral annuloplasty in patients who have moderate and severe mitral regurgitation at the time of ALCAPA repair [13].

Younger and low weight patients did not survive the repair even though they were on ECMO during the postoperative period. Joshi and colleagues reported their experience in the off-pump repair of ALCAPA [14] as an alternative to the conventional repair that avoids the use of the circulatory support and its associated morbidity. On the other hand, the use of mechanical circulatory support in patients with difficult weaning from cardiopulmonary bypass achieved a high survival rate with good long-term recovery in another study [15]. The poor ECMO outcome in our study could be attributed to the small patient's number and the associated patients' related factors. Younger age at presentation indicates a severe form of the disease.

Among the survived patients, the EF improved markedly in the last follow-up compared to the preoperative value. This finding was consistent with a study conducted over 40 years in patients aged less than 1 year and showed a preoperative EF < 35% in 71% patients, and the last follow-up EF > 50% in 84% [16]. Infants with ALCAPA presents with depressed myocardial function due to poor collaterals and restoring myocardial blood flow improved the function markedly.

All living patients were asymptomatic with no late sequelae, which was consistent with other studies [17, 18]. In our study, the survival rate of patients was 60% at the 3-year follow-up. A better survival rate of 98% at the 20-year follow-up was reported in another study [19]. Survival varies widely in the literature, and this could be attributed to different baseline characteristics and the volume of the centers.

## Limitations of the study

The number of participants included in the study is small, and multiple surgical techniques were utilized. The follow-up period was not fixed. Moreover, the authors found difficulty in finding an assessment of the quality of life questionnaire in infants and toddlers because the available questionnaires were validated and are applicable to pediatric and adult patients and, thus, were not relevant for this study.

## Conclusion

Echocardiography and CT angiography are effective diagnostic tools for ALCAPA in pediatric patients. Morbidity occurred more frequently in low weight infants, and ECMO use did not increase survival. Patients who survived had a good quality of life and were asymptomatic with a normal range of heart function. Quality of life is rarely assessed in ALCAPA cases which are usually discovered in infants, so we recommend further studies in this area.

### Abbreviations

ALCAPA: Anomalous left coronary artery from the pulmonary artery; ECMO: Extracorporeal membrane oxygenation; EF: Ejection fraction; MR: Mitral regurgitation

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### Authors' contributions

LM carried out the drafting of the manuscript and carried out the statistical analysis. RM participated in writing the manuscript and collecting the data. MF helped to draft the manuscript. OR came out with the idea and helped in editing the manuscript. All authors read and approved the final manuscript.

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### Availability of data and materials

Data and materials are available to readers.

### Ethics approval and consent to participate

The study was approved by the ethics review committee of King Abdulaziz University Hospital, reference number (179-18), its Chairman Prof. Hassan Alzahrani. The study was conducted according to the ethical guidelines conforming to the declaration of Helsinki, and patients' parents/guardians consented to participate; therefore, a written consent was obtained.

**Consent for publication**
Not applicable

**Competing interests**
The authors declare that they have no competing interests.

**Author details**
[1]Department of Surgery, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. [2]Department of Anesthesia and Critical Care, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. [3]Cardiovascular Department, King Faisal Specialist Hospital & Research Center-General Organization, Jeddah, Kingdom of Saudi Arabia.

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## Publisher's Note