



Early Presentation of Patients with Abnormal Origin of Left Coronary Artery from the Pulmonary Artery is a Predictor of Poor Mid-term Outcomes

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Abstract

Abnormal origin of left coronary artery from the pulmonary artery (ALCAPA) is one of the most common causes of myocardial ischemia and infarction in childhood. This study aimed to determine the correlation between age at clinical presentation, level of ventricular dysfunction, and post-repair outcomes. This is retrospective study from 1993 to 2018 including thirty-one patients. The study cohort was divided into two groups according to age (<6 months, >6 months). The significance level was set at $p < 0.05$. The median follow-up time was 72 [24–168] months. Median age was 4.7 [2.3–16] months. Median weight was 6.2 [4.3–9] kg. There was severe left ventricular (LV) dysfunction (ejection fraction <35%) in 64.5% of patients. Mitral regurgitation (MR) was moderate to severe in 13 patients (41.9%). Two patients (6.4%) required extracorporeal membrane oxygenation (ECMO) support before surgery and 6 (19.4%) after correction. Age <6 months was significantly associated with severe clinical presentation, severe LV dysfunction, delayed sternal closure, prolonged respiratory mechanical support, and prolonged length of ICU stay ($p = 0.024$, $p = 0.042$, $p = 0.002$, $p = 0.042$, $p = 0.022$, respectively). After surgery, ejection fraction improved to a median of 57% [50.7–60.5]. MR regressed in 12 patients (92.3%). Mortality rate after surgery was 9.7%. All patients were free from reoperation at the last follow-up. Young age at diagnosis was significantly associated with a more severe clinical presentation and poorer outcomes. After re-establishment of a two-coronary circulation, both ventricular function and MR tend to normalize over time regardless of age at repair.

Keywords ALCAPA · Left ventricular dysfunction · Mitral regurgitation

Introduction

Abnormal origin of coronary artery from the pulmonary artery (ALCAPA), also known as Bland-White-Garland syndrome, is one of the most common causes of myocardial ischemia and infarction in childhood. This rare congenital abnormality accounts for 0.25–0.5% of all congenital heart diseases [1].

The abnormal connection of left coronary artery to pulmonary artery leads to left-to-right shunt with abnormal myocardial perfusion. This phenomenon is classically referred as “coronary steal”. Mortality exceeds 90% within the 1st year of life, if left untreated [2]. Patients who reach adulthood can present myocardial infarction, left ventricular dysfunction and mitral regurgitation, or silent myocardial ischemia, with risk of sudden cardiac death [3].

Therefore, early diagnosis and immediate surgical correction with restoring a two-coronary-artery circulatory system

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can provide excellent results and lead to progressive myocardial recovery.

To categorize clinical differences, some authors oppose infant type to adult type [3]. We rather suggest to distinguish between early and late form according to physiopathology, presentation and outcomes.

This study aimed to determine the correlation between age at clinical presentation, level of ventricular dysfunction and post-repair outcomes.

Methods

Patients

A retrospective review of our clinical database from January 1993 to December 2018 was performed. Thirty-one children with ALCAPA were included. Patients older than 18 years old were excluded from the study.

The agreement of the local ethics committee was obtained. The retrospective nature of the study waived the need for individual consent.

The cohort was divided in two groups according to patient's age at diagnosis. Group 1 included patients younger than 6 months and Group 2 included patient older than 6 months.

Data Collection

Demographical characteristics (age, gender, weight), clinical data (ventilator requirement and inotropic support, arrhythmias, history of congestive heart failure, history of fatigue, retrosternal chest pain upon exertion and presence of an asymptomatic murmur), electrocardiographic (ECG) abnormalities, transthoracic echocardiography (TTE) findings focusing on left ventricular ejecting function (LVEF), and mitral valve function were collected.

Left ventricular function at presentation was assessed by left ventricular ejection fraction (LVEF) obtained from M-mode echocardiography in the parasternal short-axis view and by biplane Simpson methods in apical 4 and 2 chambers. LVEF greater than 55% was considered as normal. LVEF less than 35% was considered as severe dysfunction. The degree of mitral regurgitation (MR) was assessed by pulsed Doppler mapping of the atrial jet, color Doppler regurgitant area, retrograde pulmonary vein Doppler and mostly by the PISA using color Doppler echocardiography. The MR was categorized as absent, mild, moderate or severe.

In some cases, computed tomodensitometry (CT) or cardiac catheterization with angiograms completed the diagnosis.

Clinical status and TTE were reassessed six months after surgery and at the last follow-up.

Endpoints

The primary endpoint was in-hospital mortality. Secondary outcomes included ECMO requirement, delayed sternal closure, length of mechanical ventilatory support and length of ICU stay.

Statistical Analysis

Continuous variables were expressed as means with standard deviation (SD) or median with interquartile ranges (IQR) when appropriate. The normality of continuous data was verified by using Kolmogorov-Smirnov test. Categorical variables were presented as frequencies with percentages.

Univariate analysis was made to compare the two groups according to age (> 6 months vs < 6 months). Chi-square test (or Fisher's exact test when appropriate) was used to compare categorical data, and Student's tests (or Mann-Whitney *U* test when appropriate) was used for independent continuous variables. Estimates of time-related survival after surgical repair were calculated using the Kaplan-Meier method.

All analyses were performed using IBM SPSS statistics (Version 24.0. Armonk, NY: IBM Corp). A *p* less than 0.05 was set as the level of statistical significance.

Results

Pre-repair Findings

The median age at diagnosis was 4.7 months (extremes: 7 days–10 years), with a median weight of 6.2 kg (extremes: 2.9–27 kg). Preoperative characteristics of our cohort are summarized Table 1.

At the time of diagnosis, 24 patients (77.4%) had moderate to severe signs of heart failure with failure to thrive ($n = 13$, 42%) and dyspnea ($n = 20$, 64.5%). Ten patients (32.2%) were admitted with severe heart failure requiring immediate ventilatory and inotropic support.

ECG abnormalities (ST depression and pathological Q-wave), as well as cardiomegaly at chest XR were found in all patients.

Before surgical repair, median LVEF was 30% [20–50]. The lowest LVEF (10%) were found in 2 children who were, respectively, 3 and 7.5 months. The highest LVEF (62%) was found in the oldest patient (10 years old).

Ten patients (32.2%) underwent surgical repair with diagnosed based only on clinical, electrical, and echocardiographical data. Twelve patients (38.7%) needed a cardiac catheterization to confirm diagnosis (Fig. 1). Eight patients

Table 1 Demographic and clinical characteristics at diagnosis

Preoperative data	Median [quartils]	Cases (percentage)
Age (months)	4.7 [2.3–16]	
Weight (Kgs)	6.2 [4.3–9]	
Male gender (%)	–	15 (48.4%)
Inotropic support (%)	–	10 (32.2%)
Ejection fraction (%)		
< 35%	–	20 (64.5%)
35–50%	–	4 (12.9%)
> 50%	–	7 (22.6%)
Preoperative EF (%)	30[20–50]	
Mitral regurgitation (%)		
Mild	–	7 (22.6%)
Moderate	–	11 (35.5%)
Severe	–	13 (41.9%)

EF ejection fraction

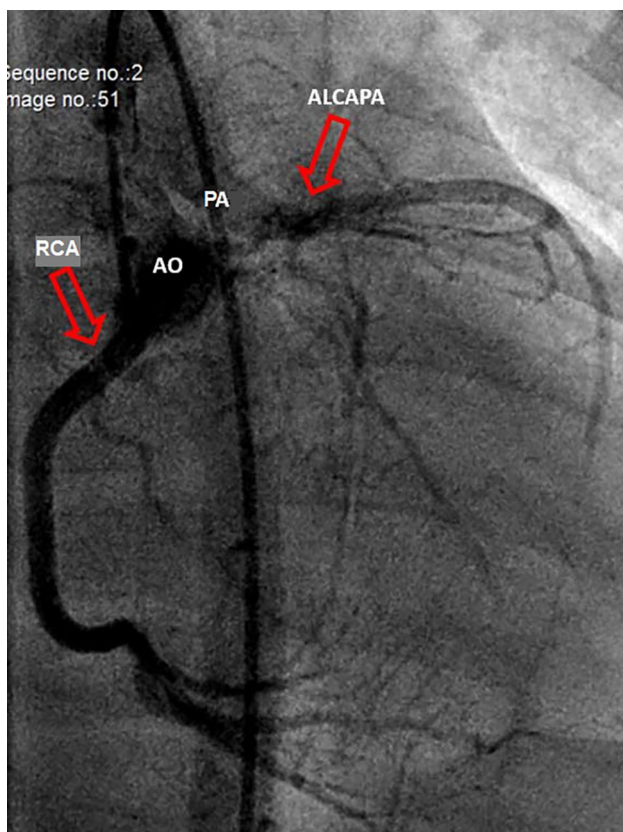


Fig. 1 Angiographic view showing abnormal origin of left coronary artery from pulmonary trunk and dilated right coronary artery. AO aorta, PA pulmonary artery, RCA right coronary artery, ALCAPA abnormal origin of left coronary artery from the pulmonary artery

(25.8%) had a CT coronary angiography (Fig. 2). These data correspond to the evolution of the practices in our center. Cardiac catheterization was used as a first resort until 1990

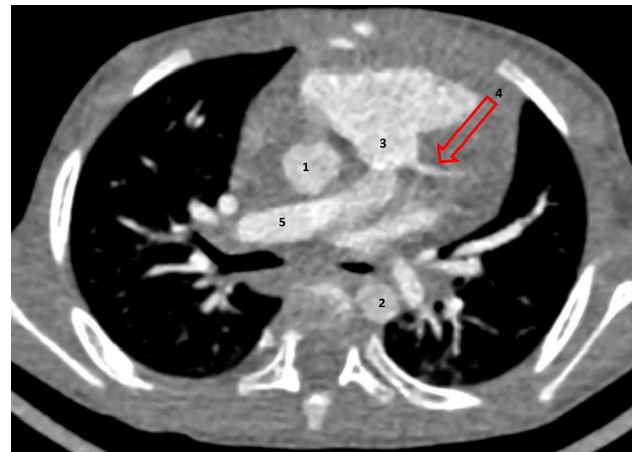


Fig. 2 Axial enhanced CT scan showing abnormal origin of left coronary artery from pulmonary artery. 1: ascending aorta; 2: descending aorta; 3: pulmonary artery; 4: ALCAPA; and 5: Right pulmonary artery

and from 2005, CT angio is used in first line for diagnostic confirmation if necessary.

Two patients (6.4%) had an associated congenital heart disease: the first one had Tetralogy of Fallot operated at 16 months of life, in whom ALCAPA was discovered at the time of surgery. The second was a 7-year-old patient with pulmonary artery stenosis associated with an atrial septal defect and persistent arterial duct, in which the diagnosis was made incidentally during an interventional cardiac catheterization.

Preoperative Data

All symptomatic patients were operated within 24 h to 48 h after diagnosis. The other asymptomatic patients were repaired within the week following diagnosis. The surgical technique consisted of standard direct re-implantation of the left coronary artery on the corresponding Valsalva sinus. Pulmonary artery was repaired with treated autologous pericardium. Mean cardiopulmonary bypass time was 157 ± 43 min and mean aortic cross clamp time 78 ± 24 min. Concomitant mitral valvuloplasty was performed in 2 patients (6.4%). Preoperative data are detailed in Table 2.

Left Ventricular Assistance

In our cohort, two patients (6.4%) needed extracorporeal life support before surgical repair, because of severely decreased LVEF and circulatory failure. ECMO was maintained during postoperative course. Four additional patients (12.9%) were supported by ECMO in the postoperative period. The median length of post-repair ECMO support was 7 days [4–14 days].

Table 2 Preoperative and postoperative data

Preoperative and postoperative data	Median [quartils]	Cases (percentage)
Mitral valve plasty		2 (6.4)
ECMO requirement		6 (19.4)
Open chest		15 (48.4)
Length of CPB (min)	150 [117–192]	
Length of Clamping (min)	81 [61–96]	
Reanimation length of stay (days)	11 [6–22]	
Length of mechanical ventilation support (days)	7[1.5–13]	
Postoperative EF (%)	65 [60–70]	
Mortality		3 (9.7)

ECMO extracorporeal membrane oxygenation, CPB cardiopulmonary bypass, EF ejection fraction

Postoperative Outcomes

Evolution of LVEF and mitral regurgitation in the postoperative period was favorable. Among the twenty children who had LVEF below 35% at admission, 15 (75%) recovered a LVEF greater than 50% six months after surgery.

One year after surgery, only 1 patient maintained an abnormal LVEF. This patient was diagnosed and operated at 18 months of life. His initial LVEF was 15% and MR was severe. He needed post-repair ECMO support during 14 days. LVEF normalized after 3 years.

Mitral regurgitation regressed in all patients. The evolution of mitral regurgitation and ejection fraction is illustrated in Fig. 3.

At latest follow-up (median 65 months), the median LVEF was 65% [60–70]. All patients were in class NYHA I or II. EKG showed dimmed disturbances of repolarization.

In our cohort, 6 patients (19.3%) underwent myocardial scintigraphy (5 with MIBI and 1 with Thallium), 12 patients (38.7%) underwent a control CT coronary angiography, 1 patient had a cardiac magnetic resonance imaging (MRI), and 15 (48.4%) patients underwent a stress test either isolated or associated with one of the previous exams.

There were no sign of ischemia. In 4 patients (12.9%), the myocardial scintigraphy found a discrete perfusion anomaly (less than 5%), partially reversible and located in the apical anterior segment. Post-repair CT coronary angiography and MRI were satisfactory, showing no stenosis of reimplanted coronary. No necrotic sequelae were highlighted by those investigations.

Comparison Between Group 1 and 2

Young age at diagnosis (Group 1) was significantly associated with severe clinical presentation, severe LV dysfunction, delayed sternal closure, prolonged mechanical ventilatory support and prolonged length of stay in ICU. Table 3 details the comparison of the two groups. Kaplan–Meier survival curve is presented in Fig. 4.

Death and Reoperation

Three patients did not survive (9.8%). Two of them required surgical revision (6.4%). For the three patients, the clinical conditions were not favorable for a heart transplant project.

The first one, three and half months old, needed a mitral valvuloplasty at postoperative day 43 and 50. He died on day 61. The second patient, four and half months old, underwent a left ventriculoplasty with resection of necrotic myocardial tissue at postoperative day 92. This patient died 120 days after repair with a terminal heart failure and ventricular arrhythmias.

Fig. 3 Evolution of echocardiographic parameters during follow-up. **A** Mitral regurgitation grading. **B** Ejection Fraction

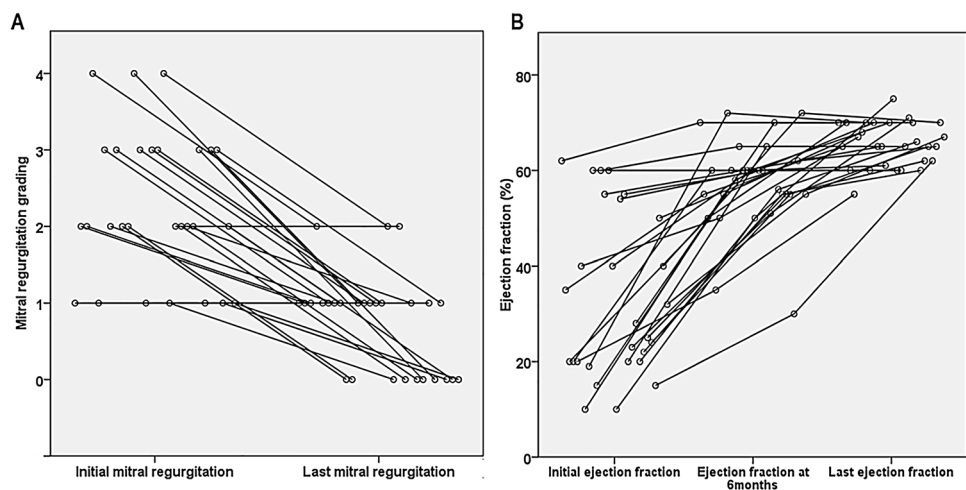


Table 3 Comparison of Group 1 and Group 2 in univariate analysis

Data	Group 1 < 6 months n = 20	Group 2 > 6 months n = 11	p
Male gender (n, %)	9 (45%)	6(54.5%)	0.61
Severe clinical presentation (n, %)	18 (80%)	6 (54.5%)	0.024
Open chest (n, %)	14 (70%)	1 (9.1%)	0.002
ECMO requirement (n, %)	5 (25%)	1 (9.1%)	0.28
Mitral valve plasty (n, %)	1 (5%)	1 (9.1%)	0.41
Length of CPB (min)	155.6 ± 41.7	160.3 ± 47.4	0.78
Length of Clamping (min)	77.5 ± 21.8	78.8 ± 28.7	0.89
Reanimation length of stay (days)	15 [10–36]	5 [2–8]	0.022
Length of mechanical ventilation support (days)	8.5 [7–18]	1 [0.5–5]	0.042
Preoperative EF (%)	28.8 ± 12.7	41.2 ± 19.6	0.042
Postoperative EF (%)	62.3 ± 10.4	65.1 ± 5.1	0.35
Mortality (n, %)	3 (15%)	0 (0%)	0.25

ECMO extracorporeal membrane oxygenation, CPB cardiopulmonary bypass, EF ejection fraction

Bold correspond to parameters with significant difference between the two groups

The third deceased patient was a newborn with antenatal diagnosis of pericardial effusion and left ventricular

dysfunction. He required ECMO support immediately after pericardial drainage at the age of 7 days. ALCAPA was diagnosed and repaired on day 8. The patient required postoperative ECMO, but died on day 7 post surgery because of an intracranial hemorrhage.

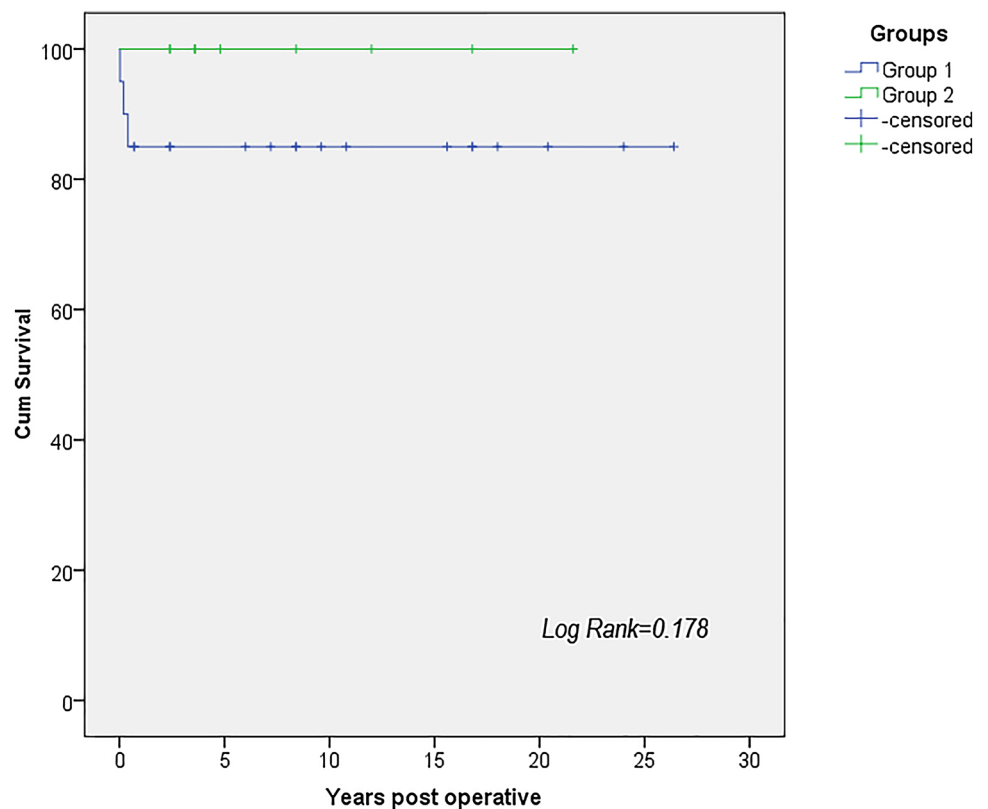
None of our surviving patients needed revision of the left coronary artery re-implantation, neither by surgical nor percutaneous approach.

Discussion

Technical Feature

Several surgical techniques have been performed for ALCAPA such as placement of a coronary artery bypass graft (CABG) combined with ligation of the origin of the LCA [4]; intra pulmonary tunnel (Takeuchi Technique) [5], and the anatomical correction with direct re-implantation of the left coronary artery on the aorta [6]. When feasible, direct re-implantation has greatly evolved and emerged as the technique of choice in many centers [7–10]. It is the preferred method of treatment in infants [11].

Fig. 4 Kaplan–Meier Survival curve comparing Group 1 and Group 2



Mortality and Risk Factors

In most of the studies, the mortality reported rate after surgical repair varies from 0 to 16% [12–18]. In our study, hospital mortality rate was 9.7%.

These results are consistent with similar studies. Some studies assumed that the young age at corrective surgery was a risk factor of mortality [14, 19]. Other studies demonstrated that LVEF < 30% [10, 20] was a predictor of mortality.

In the work of Lambert et al. age at surgery, mitral valve regurgitation and the delay between symptom onset and surgery did not appear to be predictive factors of mortality [10].

For Sauer and al. the mortality was primarily determined by the severity of myocardial ischemia, which is related to the dominance of the left coronary artery the extent of inter-arterial collateralization [19].

Increased support (inotropic agents and ECMO) was reported by some authors in younger patients. Their hypothesis was that young patients had less hibernating myocardium and less development of coronary collaterals than older patients [18, 21].

In our work, young age was associated with worse clinical condition and poorer outcomes. Our hypothesis is the lack of coronary supply by collaterals in some patients. This is related to two phenomenon, firstly the ability to develop collaterals and secondly the time required for pulmonary resistance to reach normalization. Indeed, this drop in pulmonary vascular resistance varies between newborns. A longer duration with more gradual decrease might favor collateralization and angiogenesis. The extent of acquired collateral circulation between right and left coronary artery will condition the extent of ischemia and in consequence the clinical presentation (early or late) of ALCAPA.

All of our deceased patients cumulated young age at diagnosis (7 days, 3.5 months and 4 months), severe LV dysfunction (> 35%) and moderate to severe mitral regurgitation. Although not statistically significant, these results are consistent with the data of published literature.

Management of the Mitral Valve

The management of mitral regurgitation at the time of the ALCAPA repair is variable and raises many divergent opinions. The mechanism of mitral regurgitation is dual: dilatation of the mitral annulus and ischemia of the papillary muscles.

Some centers do not recommend to routinely perform surgical repair of mitral valve during the initial surgery [14–16, 18, 22], whereas other centers do [17, 23]. Mitral valvuloplasty can be very challenging in small children. Even if mitral annuloplasty is a technique of choice in the ischemic

mitral valve disease, its feasibility in infants is arduous. Moreover, repair of the mitral valve extends the operative time and myocardial ischemia time.

The rate of mitral valvuloplasty reached 4.8% in the study of Ben ali et al. [20], 0% in Muzaffar et al.'s report [24] and 8.7% in Kazmierczak et al.'s report [25]. In our study, 2 patients underwent mitral valvuloplasty (6.4%).

Recovery

Surgical repair has excellent results at all ages with improvement in left ventricular function and regression of mitral regurgitation [3, 20, 26].

In our work all surviving patients, improved their cardiac function over time with regression of mitral regurgitation. The improvement of LV and MV function was independent of patient's age at the time of the initial repair. Interestingly, functional exploration showed that small ischemic sequelae persisted. Even discrete, these lesions probably maintain a persistent a risk of arrhythmia and sudden death [27]. Long-term rhythmic follow-up and screening is required in addition to LV and MV function analysis.

For patients with severe cardiac dysfunction and significant ischemic sequelae, promising methods such as cell based therapy may represent a possible treatment [28].

Limitations of Our Study

This is a retrospective study over a long period concerning a limited number of patients. Furthermore, the retrospective nature of the study did not allow the application of techniques more adequate and adapted to the evaluation of the ventricular function such as the global strain analysis.

Preoperative evaluation of collateralization was not available for all patients.

In this work, we only present median follow-up. Further studies are needed to assess long-term follow-up.

Conclusions

ALCAPA is a severe disease and young age is significantly associated with a more severe presentation and more ECMO requirement. This may be explained by lesser development of coronary collateral circulation. After establishment of a two-coronary circulation, both LVEF and MR tend to rapidly normalize over time in most patients.

Declarations

Conflict of interest All authors declare that they have no conflict of interest.

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