Ultrasonic Diagnostic Strategy for the Causes of Coronary Artery Dilatation in Infants

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Research

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Abstract

Objective:

To explore a differential diagnosis strategy for the causes of coronary artery dilatation (CAD) in infants

Methods:

Clinical and echocardiography data for 243 infants with CAD from the Shengjing Hospital of China Medical University were analyzed retrospectively. The patients were divided into congenital and acquired groups according to the CAD causes.

Results:

The lesion detection rate for CAD in 22,925 infants who underwent echocardiography was 1.06% (243/22,925). The acquired group accounted for 84.77% (206/243) of participants, all of which had Kawasaki disease. The congenital group accounted for 15.23% (37/243) of patients, including coronary artery fistula [12.35% (30/243)], anomalous origin of the coronary artery [2.06% (5/243)], severe pulmonary stenosis [0.41% (1/243)], and moderate aortic stenosis [0.41% (1/243)]. There was no significant difference in the Z-score for CAD between the two groups of children ($P>0.05$). There were differences in the scope and shape of CAD between the two groups (all $P<0.05$). Acquired causes mainly manifested as segmental dilatation, while congenital causes manifested as tubular dilatation. The sensitivity and specificity of segmental dilatation in predicting acquired causes were 97.57% and 100%, respectively, and that of tubular dilatation in predicting congenital causes were 97.30% and 98.06%, respectively.

Conclusion:

It is particularly important to diagnose the cause of CAD because its treatment depends on its etiology. When an echocardiography examination identifies CAD in infants, comprehensive and systematic analysis can quickly and accurately determine the cause of CAD according to the diagnostic strategy process and evaluation of dilatation and cardiac structure characteristics.

Introduction

Coronary artery dilatation (CAD) refers to the localized or diffuse expansion of coronary artery under the visceral layer of the pericardium[1]. Different causes of CAD necessitate a variety of treatment options. If the diagnosis cannot be made in a timely fashion, it will have serious consequences and potentially endanger children's lives. CAD is observed using echocardiography, which is important to accurately determine the cause. Previous studies on coronary artery disease in children have mostly focused on a certain disease or several diseases at once. The present paper reviews recent echocardiography results and clinical data for children with CAD in Shengjing Hospital of China Medical University and discusses differential diagnosis strategies for the causes of CAD in children.

Patients

A total of 243 children with CAD admitted to the pediatrics department of the Shengjing Hospital of China Medical University between January 2018 and December 2020 were selected as the research subjects. Among them, there were 146 males and 97 females, with a male/female ratio of 1.5:1.0. The age ranged from two months to 12 years, with an average age of 2.3 ± 1.8 years. The children were divided into congenital (37 cases) and acquired (206 cases) groups according to the causes of CAD. The chief complaints (or surrogate complaints) of the congenital group were 23 cases of auscultation murmur, six cases of growth retardation, three cases of cyanosis, three cases of pneumonia, and two cases of feeding difficulties. The main complaints (or surrogate complaints) of the acquired group were 191 cases of fever, nine cases of skin rash, and six cases of diarrhea. The mean ages of the congenital and acquired groups were 2.6 ± 3.2 and 2.3 ± 1.9 years, respectively. This work was approved by the Ethics Committee of China Medical University. All of the examined children's families signed the informed consent form.

Instruments And Methods

GE VIVID E9 color Doppler ultrasound M5S probe and Philips iE33 color Doppler ultrasound X5 and S8 probes were used. The probe frequencies were ~1–5 and ~2–8 MHz. Children were asleep or in a quiet state and placed in a supine or left decubitus position for the examination. Xiphoid, apex, parasternal, and suprasternal fossa heart sections were examined and cardiac structure and hemodynamic changes were comprehensively evaluated.

When CAD was identified, the diastolic diameter was measured and the Z-score was calculated. First, the scope and shape of CAD were evaluated. Only a certain portion of CAD was defined as segmental dilatation, expansion from the opening to the end was defined as whole expansion. Dilated coronary arteries with uniform internal diameter were defined as tubular dilatation, inconsistent dilatation as fusiform, beaded, or tumor-like dilatation, respectively. Clinical data, including symptoms, signs, and laboratory examination results, were collected to determine whether they meet the criteria for Kawasaki disease (KD). A careful search for the origin, course, and blood flow direction of the coronary arteries and their branches was performed to detect whether they were combined with pericardial effusion, atrioventricular regurgitation, and cardiac insufficiency. Blood flow spectrum of the abnormal shunt and reflux were also analyzed. The data were measured at least three times and the average value was calculated.

Diagnostic criteria:

CAD was diagnosed when (1) coronary artery Z-score was ≥2.5 and <4 and (2) coronary artery diameter in one segment was larger than that in the adjacent proximal segment. Coronary aneurysm was diagnosed when the coronary artery was >1.5 times the inner diameter of the adjacent segment or when the Z-score was >4. The diagnostic criteria for KD has been previously described[2-3]. Coronary artery

fistula (CAF) and anomalous origin of the coronary artery were confirmed by computed tomographic angiography and surgery.

Statistical analysis:

Quantitative data were expressed as the mean±standard (x±s), while qualitative data were expressed as counts (n) and percentages (%). Quantitative outcome measures were compared using a t test if the outcome measure distribution met the normality criteria, or using a t' test if the distribution was abnormal. Comparisons between two qualitative outcome measures were performed using the X^2 test. $P<0.05$ was considered statistically significant.

Results

1. The causes of CAD: The causes of CAD include congenital dysplasia and acquired diseases. A total of 84.77% (206/243) were acquired diseases and all of them were KD, which were the main causes of infant CAD. Of these, 15.23% (37/243) were congenital causes, including CAF, anomalous origin of the coronary artery, severe pulmonary stenosis (PS), and moderate aortic stenosis (AS; Table 1).

2. The characteristics of CAD: There was no significant difference in the Z-scores between the two groups ($P>0.05$). There were statistically significant differences in the scope and shape of CAD (all $P<0. 05$). The sensitivity and specificity of segmental dilatation in predicting acquired causes were 97.57% and 100%, respectively, and that of tubular dilatation in predicting congenital causes were 97.30% and 98.06%, respectively (Table 2). Congenital causes also showed cardiac structure characteristics.

3. Flowchart for diagnosis of CAD in infants(Fig 1).

Discussion

Coronary heart disease is a common heart disease in adults. Infants can also experience heart problems caused by coronary arteries. CAD is a manifestation of coronary heart disease in infants. CAD lesion detection rate in the present study was as high as 1.06%. Therefore, bilateral coronary arteries should be carefully monitored during echocardiography. In the present study, the chief complaint (or surrogate chief complaint) in the congenital group was auscultation murmurs, while that of the acquired group was fever. Therefore, echocardiography should be routinely performed to screen for CAD in children with auscultation murmur and fever lasting for five days or more.

The present study showed that the causes of CAD include congenital dysplasia and acquired diseases. A total of 84.77% (206/243) were acquired diseases, all of which were KD, which was the main cause of infant CAD. Of these, 15.23% (37/243) were congenital causes, including CAF, anomalous origin of the coronary artery, severe pulmonary stenosis, and moderate aortic stenosis. Acquired diseases were medically treated, while congenital dysplasia was treated surgically. Therefore, it is very important to

quickly and accurately determine the cause of CAD. There was no significant difference in the CAD Z-score between the two groups of children, so it could not be used as a key point of identification.

The present study showed that the acquired causes were more likely to manifest as coronary artery segmental dilatation, while congenital causes were more likely to manifest as tubular coronary artery dilatation. By observing the scope and shape of CAD, the dilatation was first distinguished by its congenital and acquired causes. These data were combined with clinical symptoms and signs and a laboratory examination to compare with KD diagnostic criteria, where 2.43% (5/206) of children with KD were identified from the cases with tubular dilatation.

Congenital causes also showed cardiac structure characteristics. CAF is present in 1–2% of the general population[4–5]. In the early embryonic period, the sinusoid space of the myocardium communicates with the heart cavity and epicardial blood vessels. As the heart develops, blood vessels are distributed on the surface of the heart from the root of the aorta. The growth and development of the myocardium gradually compress the sinusoid spaces into small channels, which become coronary arteries and capillaries in the myocardium. If the development is impaired, the sinusoid space of the myocardium is not degraded, leading to abnormal communication between the coronary arteries and the heart chambers and forming a CAF. The clinical symptoms of this disease are related to the size of the fistula shunt. A small shunt may have no obvious symptoms. Only a continuous murmur on the left or right parasternal border can be identified during a physical examination. With age, some patients will experience palpitations, shortness of breath, cyanosis, angina, and heart failure after physical activity. CAF should be considered when right or left proximal coronary artery broadening is found via transthoracic ultrasonography. More than 90% of coronary fistulas are single artery fistulas, of which right coronary artery is the most common, accounting for ~ 50% of cases, followed by left coronary artery at ~ 30–40%, and bilateral coronary fistulas at ~ 10%. The most common sites of termination are the pulmonary artery, right ventricle, and right atrium. Drainage into the left side of the heart is unusual. In the 30 CAF patients in the present study, 26 patients had a right coronary artery pulmonary fistula (Fig. 2) and four patients had a right coronary artery right ventricular fistula. It is thus key to identify diseased coronary arteries and search for fistulas and other associated malformations. The parasternal long- and short-axis sections of the great blood vessels are very important. In addition, several non-standard sections are also used to explore the location of coronary artery dislocations and fistulas.

There were five anomalous origin coronary artery patients in the present study. Among them, four had a left coronary artery from the pulmonary artery (ALCAPA) (Fig. 3) and one had a right coronary artery from the left coronary sinus. Anomalous origin of the coronary arteries is mainly due to the error in the process of coronary artery fusion to the aortic sinus during embryonic development. It is a serious congenital coronary artery malformation. ALCAPA is relatively more common. As the pulmonary circulatory resistance decreases after birth, the effective myocardial perfusion depends on the collateral circulation formed between the right coronary artery of normal origin and the left coronary artery of abnormal origin. The collateral circulation is not well developed and the left ventricular myocardial blood supply is reduced, resulting in left ventricular dysfunction and mitral regurgitation. Anomalous origin of the

coronary artery from the pulmonary artery may be asymptomatic at birth, then manifest as sweating, pale face, and crying, and often present along with congestive heart failure. The parasternal long-axis section, short-axis section of the great blood vessels, and the apical five-chamber heart section are all important sections of the coronary arteries, focusing on the position of the coronary artery ostium and the proximal shape. When the initial segment of the left or right coronary artery is thickened and there is no coronary artery ostium in the aortic sinus, it is important to observe whether there is coronary artery ostium in the right medial side and the posterior side of the main pulmonary artery. About 90% of the children died before reaching one year of age, mainly due to congestive heart failure. Early diagnosis and treatment can significantly improve their prognosis.

Acquired etiologies include KD, acute stage of myocarditis, polyarteritis nodosa, Takayasu disease, scleroderma, and Noonan syndrome[6–9]. Of these, KD is the most frequent CAD etiology in children and is defined as vasculitis involving medium and small blood vessels. In patients with KD, risk factors for coronary artery injury include male gender, younger age at diagnosis, persistent fever longer than 14 days, anemia, increased white blood cell count, neutrophil percentage, platelet count, alanine transaminase, hypersensitive C-reactive protein, erythrocyte sedimentation rate, and decreased hemoglobin and albumin[10–17].

Study limitations include the fact that all of the acquired causes are KD, which do not cover all of the acquired CAD characteristics. In addition, study sample size needs to be expanded for further investigations.

Conclusions

Different causes of CAD have different manifestations. It is particularly important to diagnose the cause of CAD because its treatment depends on its etiology. When an echocardiography examination identifies CAD in infants, comprehensive and systematic analysis can quickly and accurately determine the cause of CAD according to the diagnostic strategy process and evaluation of dilatation and cardiac structure characteristics.

Declarations

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Conflicts of interest: The authors have no financial conflict of interest to report.

Statement regarding the patient consent: This study is a retrospective study, and it was approved and reviewed by the Ethics Committee of China Medical University.(2021PS537K)

Impact: Different causes of Coronary artery dilatation (CAD) necessitate a variety of treatment options. If the diagnosis cannot be made in a timely fashion, it will have serious consequences and potentially endanger children's lives. CAD is observed using echocardiography, which is important to accurately

determine the cause. Previous studies on coronary artery disease in children have mostly focused on a certain disease or several diseases at once. The present paper reviews recent echocardiography results and clinical data for children with CAD and discusses differential diagnosis strategies for the causes of CAD in children.

Authors' contributions: Jinling Hu wrote the manuscript and prepared the figure. All authors reviewed the manuscript.

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Tables

Table 1 CAD etiology and composition ratio

Cause	Number of cases	Composition ratio/%
Acquired group	206	84.77
KD	206	84.77
Congenital group	37	15.23
CAF	30	12.35
Anomalous origin of the coronary arteries	5	2.06
PS	1	0.41
AS	1	0.41
Total	243	100.00

Table 2 Comparison of the scope and shape of CAD between the congenital group and the acquired group [N (%)]

	Number of cases	scope		shape	
		whole	segmental	fusiform, beaded, or tumor-like	tubular
Acquired group	206	5(2.43)	201(97.57)	202(98.06)	4[a](1.94)
Congenital group	37	37(100)	0	1[b](2.70)	36(97.30)
X^2		208.88		207.40	
p		< 0. 05		< 0. 05	

a:4 patients had left main coronary artery or right coronary artery with tubular dilatation.

b:1 patient had a right coronary artery right ventricular fistula with beaded dilatation of the right coronary artery.

Figures

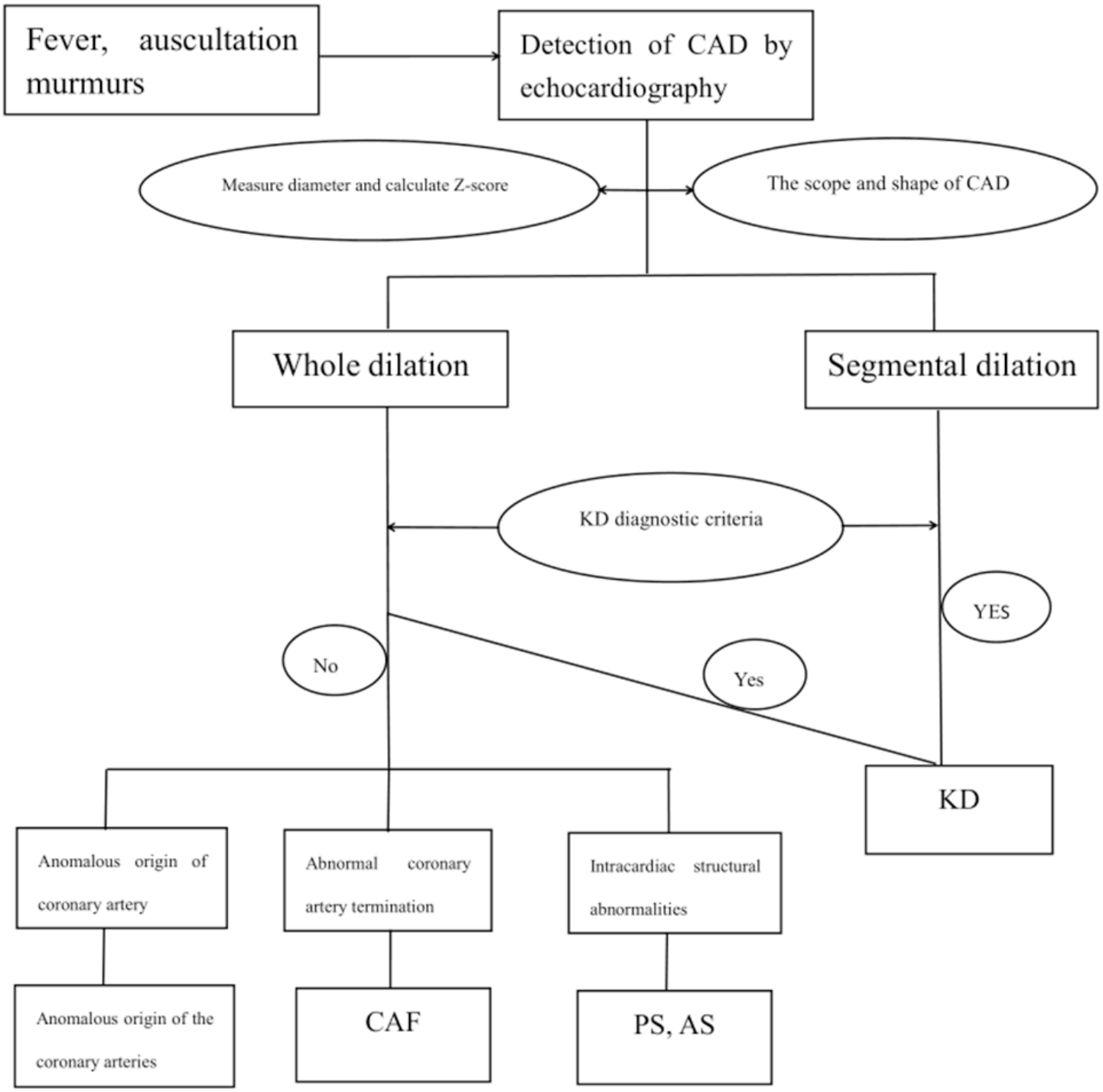

Figure 1

Flowchart for diagnosis of CAD

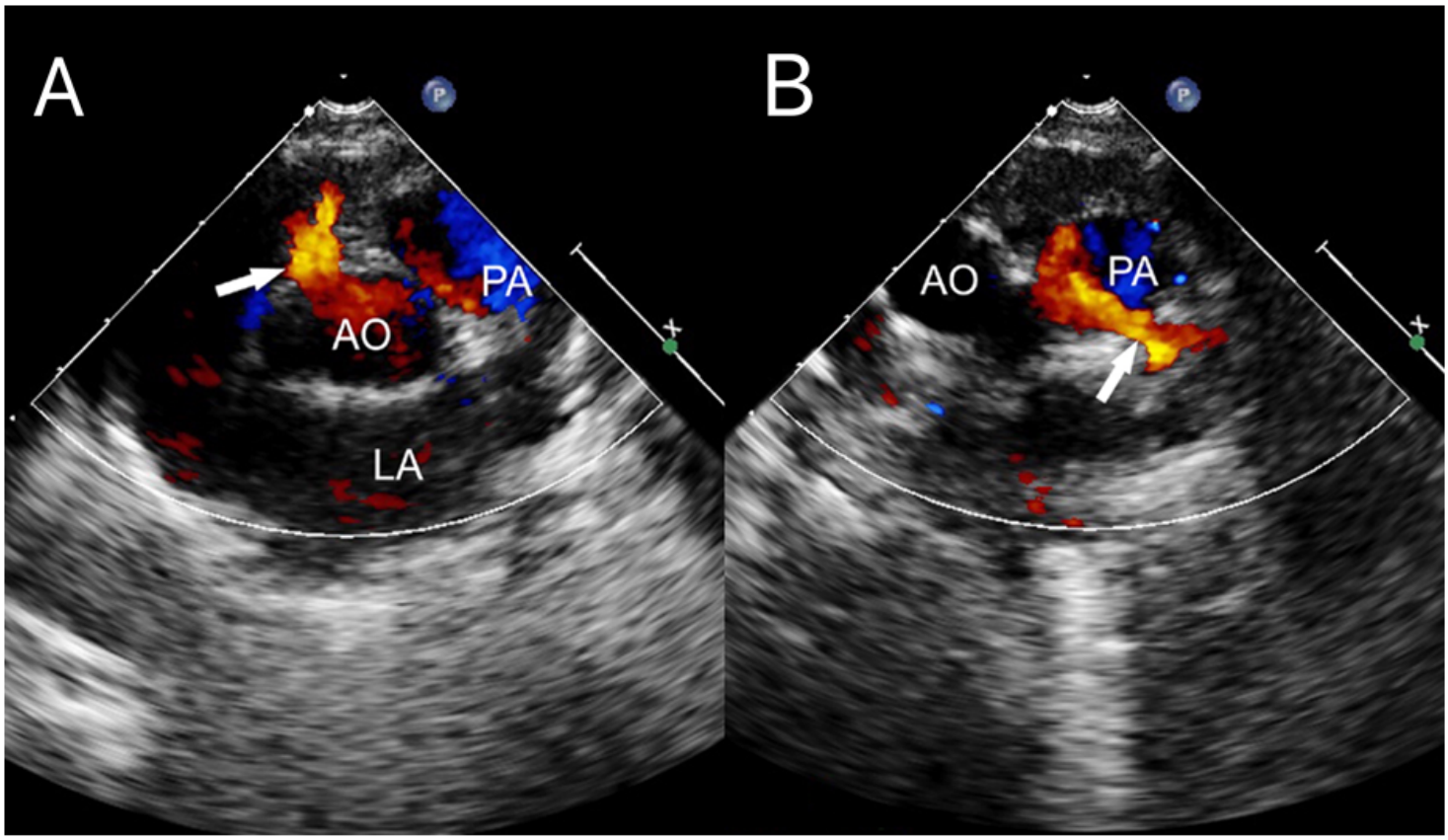

Figure 2

Right coronary artery pulmonary fistula. A. Color Doppler showed widening of the right coronary artery (arrow). B. Color Doppler showed the fistula located on the pulmonary valve (arrow).

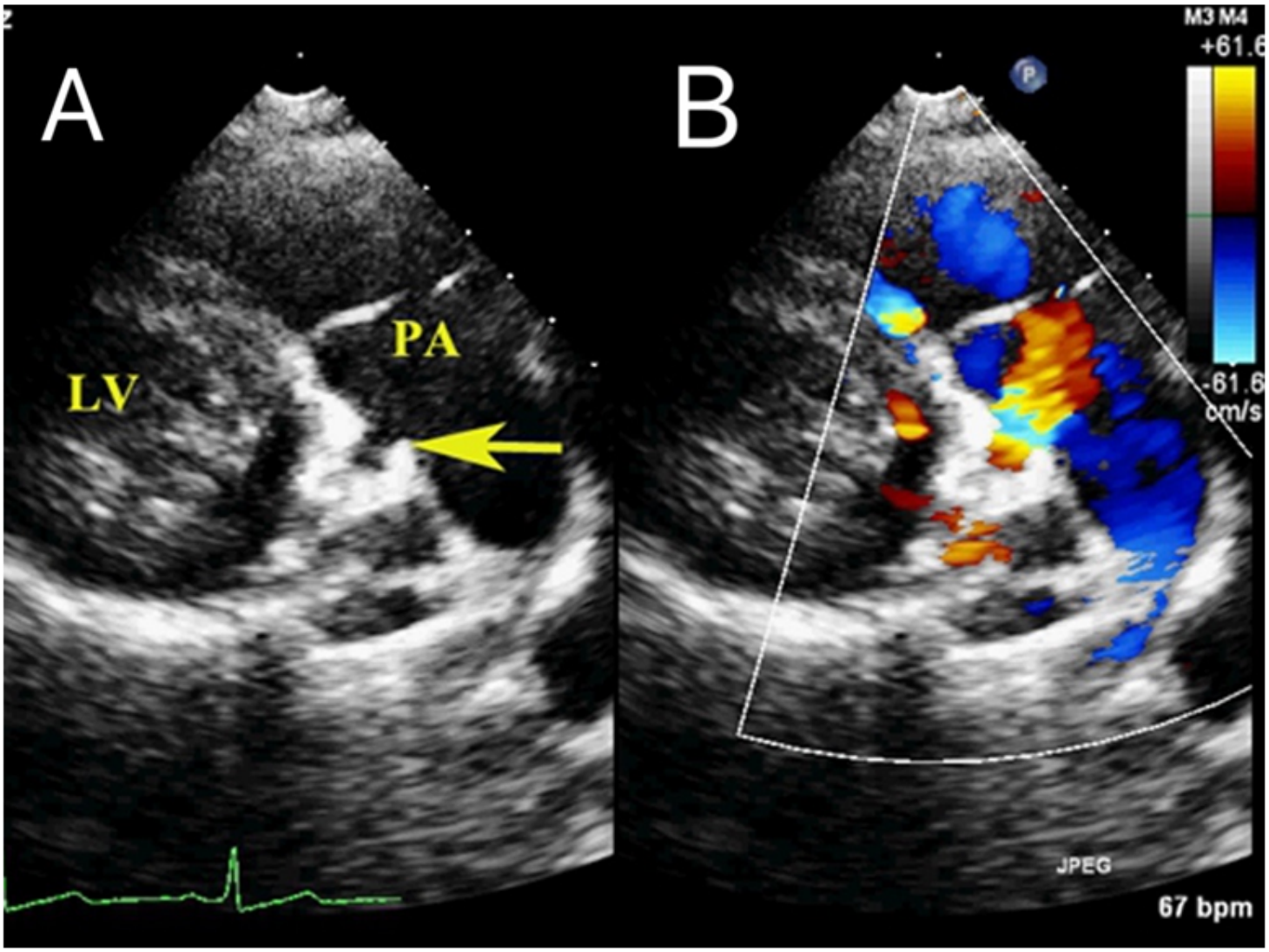

Figure 3

Left coronary artery from the pulmonary artery. A. On the non-standard long-axis view of the pulmonary artery, the left coronary artery originated from the posterior medial side of the pulmonary artery (arrow). B. Color Doppler showed that the left coronary artery "steals blood" from the pulmonary artery.