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ORIGINAL ARTICLE

Myocardial scarring after repair of anomalous origin of the left coronary artery from pulmonary artery

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Abstract

OBJECTIVES: Prognosis of patients with anomalous origin of the left coronary artery from pulmonary artery has dramatically improved as a result of both, early diagnosis and improvements in surgical techniques. Post surgical complications are rare and most patients show quick improvement of the left ventricular performance after repair with complete functional recovery within one year after surgery. Exercise-induced electrocardiographic changes have been found in patients postoperatively and scars and perfusion deficits of the left ventricle may not be detected by standard echocardiographic evaluation.

METHODS: Authors present 6 cases of anomalous origin of the left coronary artery from pulmonary artery observed at Martin Univesity Hospital and Pediatric Cardiology Clinic over the last eight-year period. In order to assess the presence of myocardial injury, cardiovascular magnetic resonance imaging with late gadolinium enhancement technique was performed in all 6 cases one year after surgical correction.

RESULTS: One patient died 1.5 year after surgical treatment. One year after surgery, the heart size and myocardial functions returned to normal in all patients. Cardiovascular magnetic resonance imaging demonstrated subendocardial late gadolinium enhancement in varios segments of the left ventricle, representing myocardial fibrosis in all patients one year after surgical correction.

CONCLUSION: Because of the presence of scarr tissue, the long term prognosis of these patients remains unclear. The damaged tissue may have arrhythmogenic potential, therefore close follow-up, excercise testing and avoidance of high-level sport activities may be needed.

INTRODUCTION

Anomalous origin of the left coronary artery from pulmonary artery is a rare but serious congenital anomaly first time described in 1866 and it accounts for approximately 0.25–0.5% of all congenital heart diseases (Bland *et al.* 1993; Fierens *et al.* 2000). Presently, the prognosis of these patients has dramatically improved as a result of both, early diagnosis using echocardiography with color flow mapping and improvements in surgical techniques including myocardial preservation. Post-surgical complications are rare and most patients show quick improvement of left ventricular performance with complete functional recovery within 1 year after surgery. Despite preserved ventricular function after repair, the long-term prognosis remains unclear (Latus *et al.* 2014). Exercise-induced electrocardiographic changes have been found in patients postoperatively and scars and perfusion deficits of the left ventricle may not be detected by standard echocardiographic evaluation of the global left ventricular function and therefore may be underestimated (Alexi-Meskishvili *et al.* 2011; Paridon *et al.* 1990). Late gadolinium enhancement is an established cardiovascular magnetic resonance technique that allows reliable detection of myocardial scarring, including exact scar localization and determination of the size of necrosis/fibrosis (Schuster *et al.* 2012). Using this technique, myocardial scars have been documented in majority of patients after surgical correction (Latus *et al.* 2014; Alexi-Meskishvili *et al.* 2011; Kazmierczak *et al.* 2013; Secinaro *et al.* 2011; Shivalkar *et al.* 1994; Browne *et al.* 2010). Cardiovascular magnetic resonance seems to be an important modality in surveillance of these patients by providing important clinical information.

MATERIAL AND METHODS

Authors present 6 cases of anomalous origin of the left coronary artery from pulmonary artery patients observed at Martin Univesity Hospital and Pediatric Cardiology Clinic over the last eight–year period. Study was approved by Institutional Ethical Committee. The diagnosis was established by physical examination, chest x-ray, electrocardiography and two-dimensional and color Doppler echocardiography in all patiens. Surgical correction was done in all patients by direct reimplantation of coronary artery to aortic wall. Postoperatively, patients have been regularly followed-up at cardiologic clinic with ECG and echocardiography. In order to assess the presence of myocardial injury, cardiovascular magnetic resonance imaging with late gadolinium enhancement technique was performed in all 6 cases one year after surgical correction.

RESULTS

There were 6 cases of anomalous origin of the left coronary artery from pulmonary artery cases diagnosed and followed-up at Martin University Hospital and Pediatric Cardiology Clinic between 2008 and 2015 (Table 1). The most common clinical presentation was congestive heart failure. The age at diagnosis varied from 4 months to 6 years of age. Surgical correction was undertaken in all cases.

Preoperative electrocardiographic findings in all patients showed normal sinus rhythm without abnormalities in atrioventricular conduction. Five patients exhibited an abnormal Q wave with inverted T-wave and ST depression in leads I, aVL and V5. The chest x-rays in anteroposterior projection uniformly revealed cardiac enlargement predominantly affecting the left atrium and the left ventricle. Two-dimensional echocardiograms showed left ventricular and left atrial dilatation in all patiens (Figure 1). Echocardiographic imaging of the anomalous left coronary artery from pulmonary artery was achieved in five cases, in one case coronary angiography had to be used to confirm the diagnosis (Figure 2).

A markedly enlarged right coronary artery was found in five patients. The direction of flow in the left coronary system was determined by Doppler color flow mapping. In all five patients it demonstrated an abnormal jet from the left coronary artery into the pulmonary trunk. The left ventricular ejection fraction was below 50% in 5 patients and was normal in one. Mitral regurgitation was found preoperatively in all 6 patients (mild form in 3 and moderate in 3 patients).

Tab. 1. Patient characteristics and left ventricular fibrosis location.

Patient	Sex	Age at presentation	Clinical presentation	Age at surgery	Surgical techniques	LV fibrosis location
1	M	8 mo	Symptoms of CHF	4 yr	Reimplantation	Anterior segment
2	F	10 mo	Symptoms of CHF	5 yr	Reimplantation	Anteroseptal and anterolateral segment
3	F	3 mo	Symptoms of CHF	4 mo	Reimplantation	Apical and interventricular
4	F	5 mo	Symptoms of CHF	6 mo	Reimplantation	Anteroseptal and anterolateral segment
5	F	6 yr	Asymptomatic	6 yr	Reimplantation	Anterior segment
6	M	5 mo	Symptoms of CHF	5 yr	Reimplantation	Anteroseptal and anterolateral segment

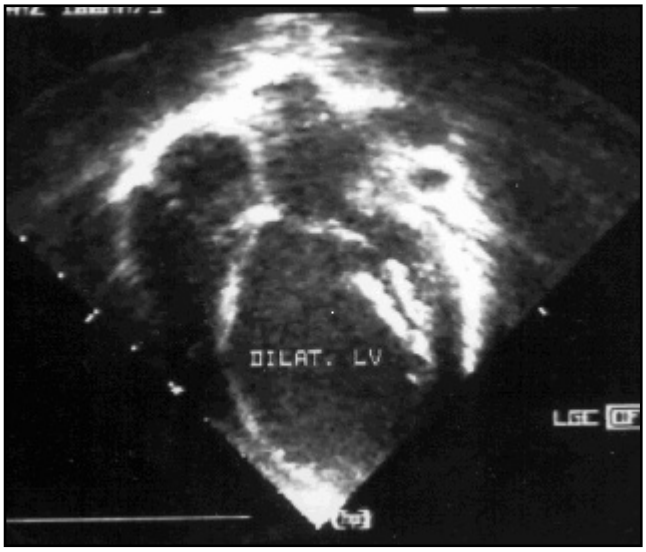

Fig. 1. Echocardiography revealing left ventricular dilatation.

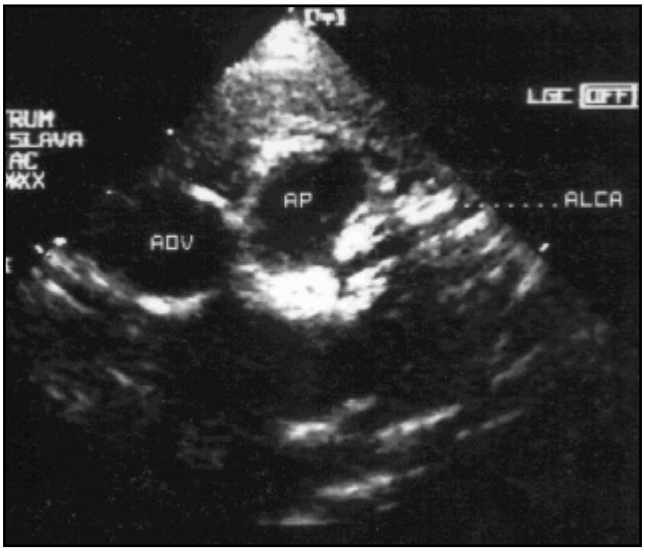

Fig. 2. Anomalous left coronary artery origin from pulmonary artery.

One patient died 1.5 year after surgical treatment. One year after surgery, the heart size and myocardial functions returned to normal in all patients and they became clinically asymptomatic. The findings on electrocardiogram have considerably improved but the T-wave remained flat with depresion of ST-segments in the left precordial leads in all children. One child continued having negative T-wave in the left chest leads. In three patients with mild preoperative mitral regurgitation it remained postoperatively mild in two and resolved in one. Moderate preoperative mitral regurgitation remained postoperatively moderate in one patient and improved to mild in two.

Cardiovascular magnetic resonance imaging demonstrated subendocardial late gadolinium enhancement in the various segments of left ventricle representing myocardial fibrosis in all patients one year after surgical correction (Table 1, Figure 3).

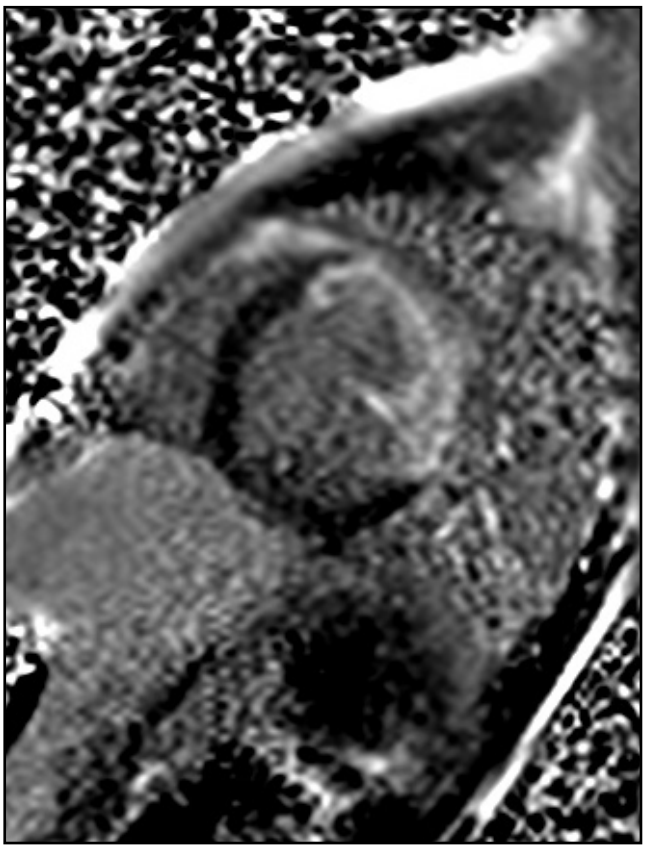

Fig. 3. Magnetic resonance imaging with positive subendocardial late gadolinium enhancement in the anteroseptal and in anterolateral parts of left venticle.

DISCUSSION

Anomalous origin of the left coronary artery from pulmonary artery is usually an isolated cardiac anomaly but in 5% of cases, the coarctation of the aorta, atrial or ventricular septal defects have been described (Takimura *et al.* 2005). In fetal life, this anomaly is well tolerated because of both, systemic and pulmonary arterial pressures and oxygen saturation are equal. After birth from the second month of life, as pulmonary pressure and saturation fall, the left ventricular oxygen demands no longer can be accommodated by the left coronary artery and leads to myocardial ischemia. Subendocardial ischemia can occur even in the presence of well-established coronary collateral vessels between the right and left coronary arteries because of preferential coronary blood flow into the low-pressure pulmonary circulation, instead of high-resistance myocardial blood vessel (coronary steal) (Barbetakis *et al.* 2005; Lardhi 2010). This condition has been suggested to represent a concept of hibernating myocardium, in which chronic hypoperfusion results in a dysfunctional but viable myocardium, with variable degree of fibrosis. This unique condition with ischemic but yet viable

myocardium has been accounted for the dramatic improvement in left ventricular function after successful coronary reimplantation (Latus *et al.* 2014).

During infancy, anomalous origin of the left coronary artery from pulmonary artery syndrome can be fatal and patients have symptoms of myocardial infarction, left ventricular dysfunction, mitral regurgitation or silent myocardial ischemia which can lead to sudden cardiac death (Johnsrude *et al.* 1995). Those without associated cardiac defects may present with heart murmur, congestive heart failure, sudden cardiac death or may remain asymptomatic and be detected incidentally during evaluation of other problems (e.g. coronary angiography in the older age group) (Bansal *et al.* 2009).

The objective of surgical treatment is to restore a normal coronary circulation and improve myocardial perfusion by surgical reimplantation the left coronary artery into aorta. Reported surgical results are very good, with little or no mortality in most series. Ventricular function and electrocariographic changes either completely normalize or significantly improve and the majority of children become asymptomatic (Latus *et al.* 2014; Kazmierczak *et al.* 2013; Fratz *et al.* 2011). In our series one patient died. We did not find postoperative pulmonary stenosis, as has been described after direct left coronary artery reimplantation (Alsuofi *et al.* 2008; Ben Ali *et al.* 2009). Mild and moderate mitral regurgitation improved concomitantly with normalization of the left ventricular function in all patients.

Despite excellent results, there is still concern about long term prognosis and outcome of these patients and possibility of develoment of permanent myocardial damage, which may cause problems in their future life or limit their physical performance.

Cardiovascular magnetic resonance with late gadolinium enhancement allows detection of myocardial scarring, including exact scar localization and determination of the size of necrosis/fibrosis. This method also has a potential to identify abnormal hibernating myocardium, defined as an absence of the scar in areas with hypokinesia at rest and distinguishing it from irreversibly damaged necrotic tissue (Schuster *et al.* 2012).

We have demonstrated, that even after restoration of global myocardial function, cardiovasculr magnetic resonance showed presence of necrotic/fibrotic tissue in anterior, anterio-lateral and anterio-septal segments of the left ventricle one year after surgery in all our patients.

Perfusion deficits in anomalous origin of the left coronary artery from pulmonary artery patients were initialy documented by myocardial perfusion assessed by scintigraphy with thalium 201 under dipyridamole stress (Stern *et al.* 1993). Using magnetic resonance imaging at rest later study revealed the wall motion abnormalities in 67%, perfusion deficits in 28% and myocardial scars in 67% of children. These authors recommended lifelong surveillance including magnetic resonance imaging, because the scar tissue can potentially serve as a substrate for cardiac arrhythmia later in life (Alexi-Meskishvili *et al.* 2011). The presence of myocardial fibrosis despite normal left ventricular function in the postoperative follow-up has been reported by several other authors (Latus *et al.* 2014; Kazmierczak *et al.* 2013; Secinaro *et al.* 2011; Browne *et al.* 2010; Fratz *et al.* 2011).

Important questions to ask are what is the timing of the scar tissue formation and what are its possible long-term consequences. Preoperative histological findings from the region perfused by the anomalous artery showed a variable degree of fibrosis. The ultrastructure of the remaining myocytes revealed viable characteristics but a substantial percentage showed markedly reduced fraction of contractile material (Shivalkar *et al.* 1994) .

The first study assessing myocardial function and viability using cardiovascular magnetic resonance prior surgery and in the short-term follow-up was published recently. The authors concluded, that despite diminished myocardial perfusion and consecutively often severely compromised left ventricular function, myocardial scarring was preoperatively present only in 2 of 8 of patients. Improvement of myocardial function was independent of preoperative and new-onset myocardial scarring (Latus *et al.* 2014).

Although we have documented normal global left ventricular function under resting conditions, possible abnormalities on the cellular level may still exist because significant electrocardiographic abnormalities persited in two of our children and there was only partial improvement of the ST-segment changes in the left precordial leads of the other four patients. Our observation is in accordance with other authors, who found that after surgical correction residual ischemic changes may persist and some patients may develope exercise-induced electrocardiographic changes (Paridon *et al.* 1990; Finley *et al.* 1978).

It seems, that some patients with anomalous origin of the left coronary artery from pulmonary artery may develop myocardial fibrosis before surgical correction but in majority of them, the myocardium might be in a hibernating but viable condition. Majority of patients have full recovery of the left ventricular function after surgery but variable degree of myocardial scaring develops in most of them within one year. Small number of patients continue having a delayed left ventricular recovery or have persitent electrocardiographic changes, however the relationship to the presence of preoperative fibrosis is not clear.

After the recovery of the left ventricular function children are asymptomatic and echocardiography is unable to detect myocardial scar development. Late gadolinium enhancement cardiovascular magnetic resonance imaging seems to be the method of choice for scarr tissue detection (pre- and postoperatively), for distinguishing of hibernation myocardium and also for diagnosis of coronary artery obstruction after reimplantation.

Because of the presence of scarr tissue, the long term prognosis of these patietns remains unclear. The damaged tissue may have arrhythmogenic potential, therefore close follow-up, excercice testing and avoidance of high level sport activities may be needed.

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