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Case Report

Serial cardiopulmonary exercise testing in an asymptomatic young female receiving percutaneous balloon dilatation for cor triatriatum sinistrum at an early age

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A young female was diagnosed as classic cor triatriatum sinistrum (CTS) at 38 months old incidentally and she received percutaneous catheter-based balloon dilatation twice at 41 and 48 months old. She took regular follow-up by echocardiography biannually with no re-stenosis of the orifice in the membrane between two chambers in the left atrium and she denied any cardiac-related symptoms. Serial cardiopulmonary exercise testing (CPET) by treadmill under Ramped-Bruce protocol was done at her 13, 19, and 23-year old. She could reach maximal effort and complete the three CPETs. No significant change of metabolic equivalent at anaerobic (MET) threshold, peak MET, and pulmonary function were noted in the serial CPETs and all of them were within normal limits comparing to the reference values of Chinese specific to her age. Our case report demonstrated that the concept of percutaneous catheter-based balloon dilatation of obstructive membrane for classic CTS without other associated congenital heart diseases is sound and feasible. The prognosis is well without re-obstruction and the cardiopulmonary fitness after that could be maintain as healthy peers for up to 18 years.

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Introduction

Cor triatriatum, a heart with three atrial chambers, is a rare condition with the incidence from 0.1% to 0.4% in patients with clinically diagnosed cardiomyopathy and congenital heart disease.[1] There is a mild male predominance in cor triatriatum with no genetic association (the male-to-female ratio of is about 1.5:1).[2] Approximately 83% of patients with cor triatriatum have cor triatriatum sinistrum (CTS) and 17% have cor triatriatum dextrum (CTD).[3]

Various anatomical variations exist in cor triatriatum and one of the most used classification is based on Lucas.[4] In this classification, accessory atrial chamber receiving all pulmonary veins in both type I and type II cor triatriatum while the accessory atrial chamber communicating with left atrium in type I but not in type II. Type III defines the subtotal cor triatriatum, where accessory atrial chamber receives only part of the pulmonary veins.[4] In the most common form, classic cor triatriatum, the atrium is divided into two distinct chambers by a thick fibro-muscular septum, which could be membranous with transverse or horizontal orientation, band-like or funnel shaped. The posterior-superior chamber receives blood from pulmonary veins, whereas the anterior-inferior chamber communicates with the left ventricle through the mitral valve.[5] Symptomatology of CTS typically mimics mitral stenosis. In addition, features of heart failure, atrial fibrillation, cyanosis, cardiac asthma, syncope, and even sudden cardiac arrest have been reported in the literature.[6]

Surgical treatment is usually indicated in symptomatic children and adults having a significant intra-atrial obstruction. The overall reported survival rate is above 90% at five years in well experienced centers and nearly all patients become asymptomatic after operation.[7,8] Successful percutaneous balloon dilatation of CTS has also been reported occasionally with the first case reported by Kerkar in 1996.[9] However, no studies discussing the aerobic fitness of patients with CTS after operation, not to mention studies with long-term follow-up by standard cardiopulmonary exercise testing (CPET). We reported results of serial CPET in an asymptomatic young female patient who receives operation for CTS in early childhood.

Case report

A 23-year-old Chinese female visited our tertiary rehabilitation center for regular CPET follow-up. She was admitted at 38 months old under the impression of bronchopneumonia with the presentation of productive cough and fever. Physical examination revealed no cyanosis or dyspnea at rest. There was left precordial prominence and a grade 2/6 apical mid diastolic murmur was heard. The electrocardiogram (ECG) revealed left atrial enlargement and right ventricular hypertrophy. A transthoracic echocardiography incidentally found a normal mitral valve with a fibrous membrane separating the left atrium into proximal and distal chambers. A 0.6 cm stenotic orifice in the membrane was observed and color flow mapping showed a high-velocity (2.2 m/s) turbulent jet through the defect directed toward the mitral valve (Supplement file Fig. 1-1). She was diagnosed as having CTS with obstruction of the orifice. Tracing back to her pre-intervention medical record and based on the statement of her parents, her baseline activity was good and there was no delay in her development milestones.

Cardiac catheterization was scheduled for hemodynamic study at her 41 months of age. It revealed normal coronary arteries without significant stenosis, and a marked increase in pulmonary capillary wedge pressure (PCWP, mean PCWP = 28 mmHg). Simultaneous pulmonary capillary wedge and retrograde left ventricular pressure were measured and revealed a mean transmembrane gradient (PCWP minus left ventricular end diastolic pressure) of 26 mmHg. Left atrial angiography was performed to delineate the restrictive orifice and the mitral annulus by inserting of the Inoue balloon catheter based on the standard technique as for balloon mitral valvuloplasty. Inflation of the balloon at the orifice was performed under fluoroscopy several times until the waist was abolished. After removal of the balloon, a significant fall in the transmembrane gradient from 26 to 4 mmHg and a mean PCWP from 28 to 15 mmHg were observed. Unfortunately, restenosis with a 0.6 cm stenotic orifice in the membrane and a 3.2 m/s continuous wave Doppler (CW Doppler) velocity of the orifice was observed during regular follow-up by echocardiography (Supplement file Fig. 1-2). She received another Inoue balloon dilatation at 48 months old. Mean transmembrane gradient reduced from 26 mmHg before and 5 mmHg after dilatation his time. A significant reduction of mean PCWP from 30 mmHg before and 15 mmHg after the dilatation was also found. Echocardiography after balloon dilatation showed an enlarged orifice of the diaphragm to 1.5 cm and no turbulent jet on color Doppler flow mapping (Supplement file Fig. 1-3). The CW Doppler velocity was down to 1.3 m/s (Table 1). She took regular out-patient follow-up at our pediatric cardiovascular department with routine echocardiography and cardiac catheterization after that and no further significant obstruction of the membrane between two chambers in left atrium was found up to her 6 years of age. After her 6 years of age, she took regular out-patient follow-up with echocardiography biannually and it showed no restenosis of the previous restrictive orifice with the resting CW Doppler velocity remained around 1.2—1.5 m/s. She also took once electrocardiogram-gated 64-detector-row computed tomography (MDCT) at 13 years old and it disclosed presence of CTS, with opening of 25 mm in the membrane and good

Table 1 Hemodynamic and echocardiographic data of pre- and post-balloon the first and the second dilatation of cor triatriatum sinistrum.

	Before 1st dilatation	After 1st dilatation	Before 2nd dilatation	After 2nd dilatation
Hemodynamic data				
PLA chamber pressure S/M (mmHg)	30/22	14/10	40/36	18/16
PCWP, A/V/mean (mmHg)	29/30/28	16/17/15	29/32/30	14/16/15
LVEDP (mmHg)	2	11	4	10
Resting mean gradient	26	4	26	5
Aorta S/D (mmHg)	118/73	120/81	117/79	122/84
PA S/M (mmHg)	75/52	60/33	70/51	56/29
Echocardiographic data				
Velocity of the jet[a] (m/s)	2.2	1.3	3.2	1.3
Orifice[b] diameter (cm)	0.6	1.4	0.6	1.5

PLA, proximal left atrial/left ventricular pressure; PCWP, Pulmonary capillary wedge pressure; A/V, a wave/v wave; LVEDP, left ventricular end diastolic pressure; S/D/M, systolic/diastolic/mean; PA, pulmonary artery.
[a] Turbulent jet of the orifice of the cor triatriatum sinistrum.
[b] Orifice of the cor triatriatum sinistrum.

motion, without mitral valve dysfunction, thickening, or calcification. Retrieving all her medical records in our hospital to nowadays, we found that she had only one hospitalization for 5 days after the second balloon dilatation due to bronchopneumonia at her 8 years of age. There were no medical records from the other department except for dental department, where she took regular tooth scaling and for dental filling.

She took three serial follow-ups of CPET at our rehabilitation center at 13, 19, and 23 years old, respectively. Table 1 presented the results of the three CPETs. A symptom-limited exercise testing by a treadmill was used to measure her exercise capacity. The criteria of CPET termination was as indicated by the American College of Sports Medicine.[10] The anaerobic threshold (AT) was determined by the minute ventilation (VE)/oxygen consumption (VO_2) and VE/carbon dioxide production (VCO_2) methods.[11] VO_2 peak was the maximum oxygen uptake measured at peak exercise. VO_2 peak to predicted value was the percentage of measured peak MET to predicted peak MET after comparing to the normal standards for cardiopulmonary responses to exercise in Taiwan.[12] Pulmonary function test was performed by the spirometry at rest. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and maximal voluntary ventilation (MVV) were measured. The percentage of predicted FVC (FVCP), FEV1 (FEV1P), and MVV (MVVP) was the percentage of measured data to predicted data by reference values for spirometry in Chinese.[13] Overall, she could complete all the three serial CPETs and the exercise testing was terminated since she reached maximal effort in both respiratory exchange ratio (RER) and predicted HR maximum criterion. All data in the serial CPETs were within normal limits comparing to the reference values of Chinese (Table 2).

Discussion

We reported data of serial CPETs done in adolescence of a young female who received percutaneous balloon dilatation of CTS twice in her early childhood. To our knowledge, no available studies about CPET in patients with CTS after percutaneous balloon dilatation presented before. We found that patient with classic CTS could maintain aerobic fitness without cardiac symptoms years after intervention.

CTS may demonstrate variability with regard to the location and the orientation of the obstructing membrane; the position, size, and number of defects in the membrane; and the pulmonary venous connections.[9] The case we reported was diagnosed accidentally though mild obstruction of the membrane in the left atrium had presented at the diagnosis. Theoretically, it is logical that a patient with an obstructive CTS membrane has delayed presentation if he/she has an atrial-level shunt in the proximal chamber, as the shunt could provide decompression of the pulmonary venous chamber.

Limited studies about the outcomes of CTS due to its rarity. One Canadian study analyzed 82 pediatric patients with CTS retrospectively in one pediatric center. It observed that 70% of the patients underwent resection of the fibromuscular membrane with median age of presentation at 8 months old and 17% of them did not require surgery with median age of presentation at 2.5 years old. The patient we reported here received only catheterization and was found to have CTS incidentally at 38 months old.[14] Most of the survival patients of the above were completely asymptomatic at the time of the last follow-up at a median of three years although the remaining 13% of the children did not survive the time to intervention.[14] Arda et al. did a retrospective study of 15 pediatric patients with CTS after surgical correction in Turkey and found no any late mortality after a mean follow-up of 64 months in the 14 survived patients while early postoperative mortality was encountered in one patient with ventricular septal defect and CTS.[15] In one recent larger retrospective study performed by Mayo clinic, only 27 in the 57 patients underwent surgical intervention during the study period and more than half of them had associated congenital heart lesions while the rest 30 patients were managed conservatively.[16] What's more, they observed that no any significant temporal increase in the severity of obstruction was noted in those

Table 2 Results of cardiopulmonary exercise testing at each visit.

	Visit 1 (in 2010/08)	Visit 2 (in 2016/08)	Visit 3 (in 2020/03)
Age (yr)	13	19	23
Height (cm)	163.9	165.2	166.6
Weight (kg)	48.1	52.1	54.9
BMI (kg/m^2)	17.8	19.1	19.8
Resting SBP (mmHg)	112	128	130
Resting DBP (mmHg)	65	70	70
Resting HR (bpm)	75	68	76
FVC (L)	3.17	3.20	3.28
FVCP (%)	105.2	92.6	94.5
FEV1 (L)	3.14	3.17	3.17
FEV1P (%)	120.2	110.2	103.4
FEV1/FVC (%)	98.9	99.1	96.6
MVV (L)	58.7	73.3	70.8
MVVP (%)	106.4	100.6	96.2
AT MET	6.0	6.2	6.3
AT HR (bpm)	146	133	132
Peak HR (bpm)	176	174	182
Peak VE (L)	51.2	54.3	55.7
Peak RER	1.36	1.21	1.34
Peak SBP (mmHg)	190	194	189
Peak DBP (mmHg)	101	80	82
Peak MET	9.8	9.6	9.7
Peak PD	91.05	88.75	87.95
Reason of termination	Attaining maximal effort	Attaining maximal effort	Attaining maximal effort

BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HR: heart rate, FVC: functional vital capacity, FVCP: percentage of predicted forced vital capacity, FEV1: force expiratory volume at 1 min, FEV1P: percentage of predicted forced expiratory volume at 1 min, MVV: maximal voluntary ventilation, MVVP: percentage of predicted maximal voluntary ventilation, MET = metabolic equivalent, AT MET = MET at the point of anaerobic threshold, VE = minute ventilation, RER = respiratory exchange ratio, peak MET = maximal MET during whole exercise testing, peak PD = percentage of predicted peak MET.[12]

treated conservatively by serial echocardiography during the whole follow-up period.[16] The patient we reported presented the similar results after the second balloon dilatation for CTS without recurrent obstruction during the biannual follow-up so far.

Successful percutaneous balloon dilatation of cor triatriatum has been reported occasionally in children[9,17] and young adults[18,19] with shorter period of follow-up (with 12 months as the longest reported period[17]). All the patients in these reports had either type Ia (where an accessory atrial chamber receives all pulmonary veins and connects with the left atrium)[9,17,19] or type IIIA1 (subtotal cor triatriatum with an accessory atrial chamber receiving part of the pulmonary veins and communicates with the left atrium, with the remaining pulmonary veins connecting normally)[18] CTS. In other words, only isolated forms of cor triatriatum where all pulmonary veins ultimately drain into the left atrium can be recommended for percutaneous strategies.[20] Operative therapy naturally remains the treatment of choice when CTS is associated with other cardiac abnormalities requiring surgical intervention.[16] Moreover, when it comes to the use of trans-septal left heart catheterization, some potential complications, including mitral valve damage,[21,22] inadvertent dilatation of the interatrial septum or left atrial appendage, cardiac perforation,[17,23] should be aware of. Performers should always keep in mind that the large sheath inserted during catheterization might cause venous thrombosis and even obstruction, in small children.[17]

No available studies about the CPET in patients with CTS after surgical or percutaneous catheter-based intervention before this report was submitted. Limited results of CPET in patients with cor triatriatum before intervention were reported. Santos el al. reported a 46-year-old female who was diagnosed as type Ia CTS accompanied with atrial septal defect (ASD) incidentally and she could reach maximal heart rate at peak exertion with 5.13 METs in CPET by Bruce protocol before catheterization. She did not receive any intervention for CTS due to no obstructive signs.[24] Eckersly et al. presented a 14-year-old boy with exercise-induced hypoxia secondary to an atrial septal defect and CTD. Pre-intervention CPET of the boy demonstrated low peak VO_2, significant desaturation but a normal cardiovascular and ventilator response to exercise. He received percutaneous catheterization only for occlusion of ASD. The CPET he took one week after the occlusion showed significant improvement of peak VO_2.[25] We observed that our case could achieve maximal effort during the exercise testing with adequate peak oxygen consumption comparing to the healthy peers in all the three CPETs. The results of the CPET is reasonable and predictable since the patient presented no cardiac-related symptoms and no evidence of obstruction or pulmonary hypertension which might impede the aerobic fitness at each follow-up.

Although our case reported a significant reduction of transmembrane gradient and increasing of orifice diameter in the membrane after balloon dilatation, we can't tell for sure whether the normal CPETs is the result of catheter intervention or just a nature course given that the activity of our case was good without cardiac symptoms before intervention and current evidences are limited.

In conclusion, our reported case demonstrated that the concept of percutaneous catheter-based balloon dilatation of obstructive membrane for classic CTS without other associated congenital heart diseases is sound and feasible. The prognosis is well without re-obstruction and the cardiopulmonary fitness after dilatation could be maintain as healthy peers for up to 18 years. Relating to the small case numbers available for review, the natural history of classic CTS has previously been poorly documented. Given that this article was just a case report, efficacy of this therapy remains to be confirmed with studies with larger numbers.

Declaration of competing interest

The results of the present study do not constitute endorsement and this work disclosed no financial support from any foundation. All authors declared that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jfma.2020.10.011.

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