Journal of Rare Cardiovascular Diseases 2014; 1 (7): 24–28
www.jrcd.eu

Female patient after correction of tetralogy of Fallot with severe pulmonary regurgitation and significant left-to-right shunt at the ventricular septal level (RCD code: IV-5A2)

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Abstract

Tetralogy of Fallot (ToF) is the most common cyanotic congenital heart disease after 1 year of age. Less than 5% of all patients with uncorrected ToF live beyond the age of 40 years. Prognosis after surgical correction is good with a 32-year survival of 86% of the cases. Predictors of long-term mortality include older age at operation and postoperative right-to-left ventricular peak systolic pressure ratio of 0.5 or higher [1]. Surgery is performed to close ventricular septal defect (VSD) and relieve right ventricular outflow tract obstruction (RVOTO). Adult patients with surgical repair of tetralogy of Fallot in history often develop complications, which include severe pulmonary regurgitation, RVOTO, right ventricular dilation and dysfunction, residual VSD, aortic root dilation with aortic regurgitation, left ventricular dysfunction, endocarditis, atrial and ventricular tachycardia, and sudden cardiac death. We present a case of a female patient with several long-term complications after ToF repair. JRCD 2014; 1 (7): 24–28

Key words: Tetralogy of Fallot, residual ventricular septal defect, pulmonary regurgitation

Case presentation

A 40-year-old woman after surgical correction of tetralogy of Fallot (ToF) was admitted to the hospital due to deterioration in exercise tolerance (New York Heart Association functional class III). Correction of ToF was performed in 1974, and surgical closure of residual ventricular septal defect (rVSD) was performed in 2003. A dual-chamber pacemaker was implanted due to sick sinus syndrome associated with paroxysmal atrial fibrillation in 2005. Current treatment included warfarin and metoprolol CR. A physical examination revealed a holosystolic murmur with a thrill at the fourth left intercostal space. The patient's weight was 47 kg, height 159 cm, body mass index 18.6 kg/m^2, blood pressure 120/80 mm Hg, and heart rate 60 bpm. Regular normal breath sounds were heard and no cyanosis or peripheral edema was observed. The results of routine laboratory tests were within the normal limits except for elevated *N-terminal of the prohormone brain natriuretic peptide* level (1300 pg/mL; normal value, <125 pg/mL).

A resting electrocardiogram showed sequential atrial and ventricular pacing. Holter monitoring did not reveal cardiac arrhythmias or pacing disturbances. Cardiopulmonary exercise testing showed reduced exercise tolerance (workload of 8.4 metabolic equivalents) and maximal oxygen consumption (15.2 mL/kg/min; normal value, >43.1 mL/kg/min). The values of maximal oxygen consumption were significantly lower compared with the previous measurements (February 2011, 22 mL/kg/min and October 2010, 23 mL/kg/min).

Transthoracic echocardiography revealed numerous abnormalities (Figure 1.):

– enlargement of all heart chambers:

Conflict of interest: none declared.

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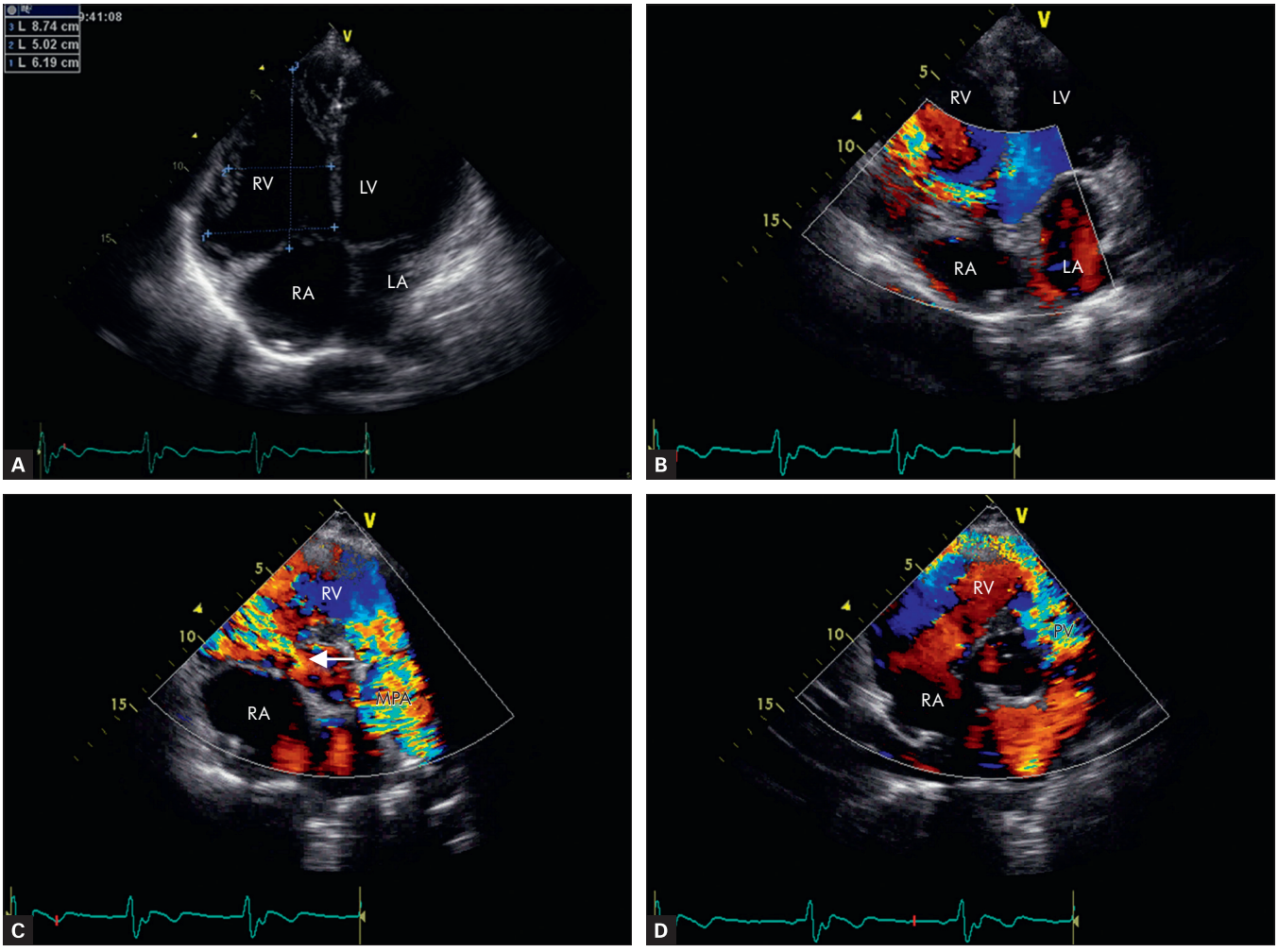

Figure 1. Transthoracic echocardiography. A. Apical four-chamber view, diastole: enlarged right ventricle, dilated tricuspid valve annulus. B. Apical five-chamber view: residual perimembraneous ventricular septal defect with left-to-right shunt. C. Parasternal short-axis view at the base of the heart: residual perimembraneous ventricular septal defect with left-to-right shunt, turbulent flow pattern in pulmonary trunk (white arrow). D. Parasternal short-axis view at the base of the heart: severe pulmonary regurgitation. RV-right ventricle, LV-left vetricle, RA-left atrium, RA – left atrium, MPA-main pulmonary artery

- right ventricular (RV) diameters in apical four-chamber view: basal 62 mm (normal value, <42 mm); mid-cavity 50 mm (< 35 mm); longitudinal 88 mm (< 86 mm), end-diastolic area, 48 cm^2 (<25 cm^2)
- left ventricular (LV) in parasternal longaxis view: end-diastolic diameter, 58 mm; 36 mm/m^2 (normal value, <31 mm/m^2)
- left atrial area at ventricular end-systole, 24 cm^2 (normal value, <20 cm^2), right atrial area at ventricular end-systole, 32 cm^2 (<18 cm^2)
- impaired RV systolic function: fractional area change, 31% (normal value, >35%), tricuspid annular plane systolic excursion, 14 mm (>16 mm)
- preserved LV ejection fraction, 62% (normal range, >55%)
- paradoxical septal motion
- rVSD with left-to-right shunting
- severe pulmonary regurgitation (PR) assessed by dense/steep jet deceleration, early termination of diastolic flow, shortened pressure half-time of 68 ms, and wide origin of regurgitant jet exceeding 50% annular width
- dilated pulmonary trunk and branches of the pulmonary artery
- mild aortic regurgitation
- moderate-to-severe tricuspid regurgitation (TR) assessed by vena contracta width (6 mm); tricuspid early diastolic wave velocity (0.9 m/s)
- dilated tricuspid annulus: four-chamber diameter (56 mm; normal range, 20–40 mm)
- elevated RV systolic pressure (normal value, <31mm Hg). **It was calculated as: 1) the difference between LV peak systolic pressure and interventricular pressure gradient through residual VSD (120 – 60 = 60 mmHg), 2) sum of tricuspid regurgitation gradient (40 mm Hg, Vmax 3.2m/s) and right atrial pressure (40 +15 = 55 mm Hg)".**

Considering that cardiovascular magnetic resonance imaging (CMR) is not suitable for patients with pacemakers, we performed computed tomography (CT) as an alternative. A CT scan confirmed

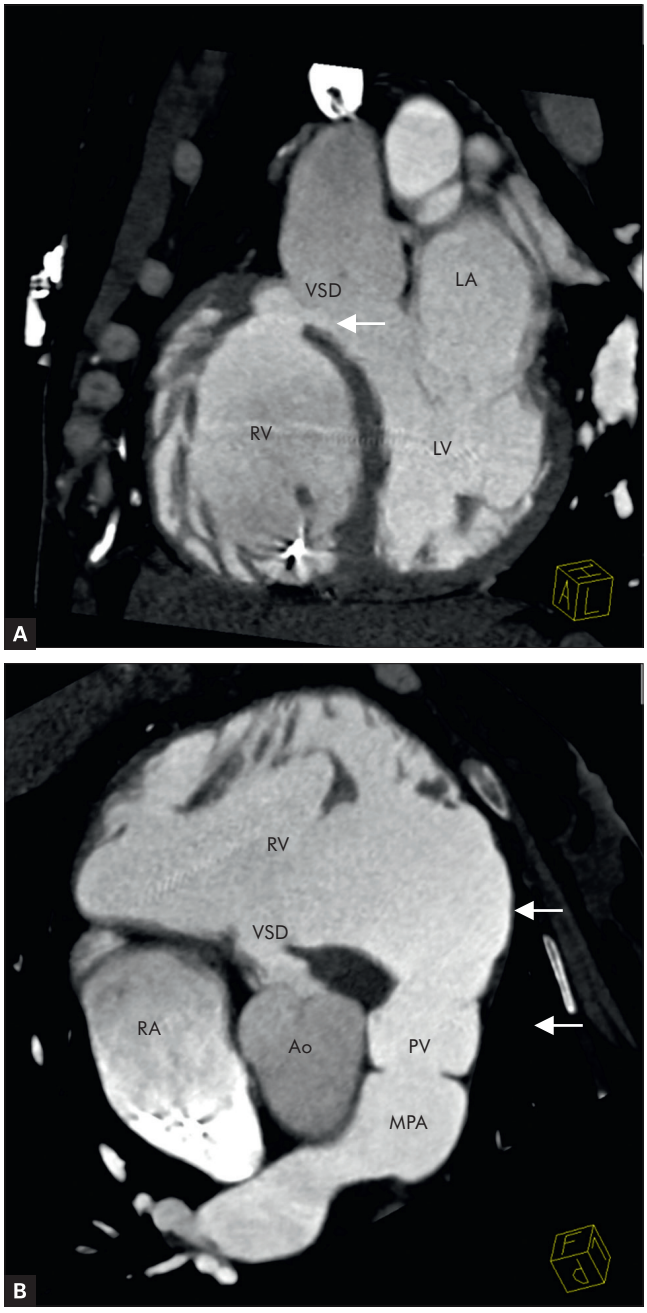

Figure 2. Cardiovascular computed tomography. **A.** Short axis view. **B.** Right ventricular outflow tract. VSD – residual perimembraneous ventricular septal defect; RV – right ventricle; LV – left vetricle; RA – left atrium; RA – left atrium; Ao – aorta; MPA – main pulmonary artery; PV – pulmonary valve

the following: RV enlargement, impaired RV systolic function, rVSD situated below the right cusp of the aortic valve (the defect size was 12 × 15 mm), and dilation of the main pulmonary artery and branch pulmonary arteries (Figure 2).

Coronary angiography revealed no critical lesions in the coronary arteries. The findings of left ventriculography and pulmonary angiography were consistent with those of echocardiography and CT. Right heart catheterization confirmed the presence of rVSD with left-to-right shunt (the ratio of pulmonary-to-systemic flow was 2:1). Other findings included mild pulmonary hypertension (mean pulmonary artery pressure, 29 mm Hg; normal value, <25 mm Hg), increased pulmonary vascular resistance (203.9 dyne × s × cm^{-5}; normal value, <130 dyne × s × cm^{-5}), and increased pulmonary capillary wedge pressure (16 mm Hg; normal value, <12 mm Hg). An increase in the pulmonary pressure and resistance had been observed since 2007 (Table 1).

Table 1. Hemodynamic data

Pressure [mm Hg]	2007	2011
RA	14/16/12	16/19/14
RV	51/3/11	61/8/17
pulmonary artery	49/11/23	59/12/29
pulmonary capillary wedge pressure	13/12/12	20/9/16
aorta	116/65/84	126/74/95
Saturation [%]		
superior vena cava	53.8	50.3
inferior vena cava	60.6	62.8
pulmonary artery	72.6	77.9
aorta	91	97.1
cardiac output [L/min]	5.3	5.1
ratio of pulmonary-to-systemic flow	2.16:1	2.00:1
pulmonary vascular resistance [dyne × s × cm^{-5}]	175	203.9
total peripheral resistance [dyne × s × cm^{-5}]	1940	1490

RA – right atrium; RV – right ventricle

Review of the literature

We described a case of a patient after repair of ToF with severe PR and significant left-to-right shunting through the rVSD. Patients after transannular patch repair of the RVOTO have higher degree of PR compared with patients with subvalvular resection or repair without a patch [2]. PR may be well tolerated for decades before any symptoms develop but, in some patients, it can lead to progressive RV dilatation, onset of TR, and the need for surgery. It is also known as a risk factor for ventricular arrhythmias and sudden cardiac death [3]. Long-term consequences of PR are augmented by coexisting distal pulmonary stenosis and pulmonary arterial hypertension.

CMR is the gold standard to measure the RV function and severity of PR. A regurgitation fraction of 20% to 40% assessed with cardiac MRI is regarded as severe regurgitation [4]. Cardiac MRI cannot be performed in the presence of pacemakers, implantable cardioverter-defibrillators, cochlear implants, and clips for aneurysms in the brain.

Table 2. Pulmonary regurgitation (PR) severity assessment [5]

Parameters	Mild PR	Severe PR
pulmonary valve morphology	normal	abnormal
color-flow jet width	small, <10-mm in length with narrow origin	large, with wide origin; may be brief in duration
continuous-wave Doppler signal of PR jet	faint/slow deceleration	dense/steep deceleration, early termination of diastolic flow
pulmonary vs. aortic flow by pulsed-wave Doppler ultrasound	normal or slightly increased	greatly increased

Table 3. Indications for intervention after repair of tetralogy of Fallot [7]

	class* level#
Aortic valve replacement in patients with severe aortic regurgitation with symptoms or signs of left ventricular dysfunction	I/C
Pulmonary valve replacement in symptomatic patients with severe pulmonary regurgitation and/or stenosis (RV systolic pressure >60 mm Hg, tricuspid regurgitation velocity >3.5m/s)	I/C
Pulmonary valve replacement in asymptomatic patients with severe pulmonary regurgitation and/or stenosis when at least one of the following criteria is present: – decrease in objective exercise capacity – progressive right ventricular dilation or systolic dysfunction – progressive tricuspid regurgitation (at least moderate) – right ventricular outflow tract obstruction with right ventricular systolic pressure >80 mm Hg (tricuspid regurgitation velocity >4.3 m/s) – sustained atrial/ventricular arrhythmias	IIa/C
Ventricular septal defect closure in patients with residual ventricular septal defect and significant left ventricular volume overload or if the patient is undergoing pulmonary valve surgery	IIa/C

* class of recommendation; # level of evidence

Table 4. Indications and contrindications for surgical ventricular septal defect closure (VSD) [7]

	class* level#
Indications for surgical VSD closure:	
Patients with symptoms that can be attributed to left-to-right shunting through VSD and who have no severe pulmonary vascular disease	I/C
Asymptomatic patients with evidence of left ventricular volume overload attributable to VSD	I/C
Patients with a history of infective endocarditis	IIa/C
Patients with VSD-associated prolapse of an aortic valve cusp causing progressive aortic regurgitation	IIa/C
Patients with VSD and pulmonary arterial hypertension when there is still net left-to-right shunt (Qp:Qs >1.5) present and pulmonary artery pressure or pulmonary vascular resistance are below 2/3 of systemic values (baseline or when challenged with vasodilators, preferably nitric oxide, or after targeted pulmonary arterial hypertension therapy)	IIa/C
Contraindications for surgical VSD closure:	
Eisenmenger's VSD and when exercise-induced desaturation is present	III/C
If the VSD is small, not subarterial, does not lead to left ventricular volume overload or pulmonary hypertension, and if there is no history of infective endocarditis	III/C

* class of recommendation; # level of evidence

The measurement of PR severity by echocardiography is less validated than that of mitral and aortal regurgitation degree. The European Association of Echocardiography recommends several parameters for grading the severity of PR: pulmonary valve morphology, color-flow jet width, continuous-wave signal of the PR jet, and pulmonary-to-aortic flow by pulsed-wave Doppler. The cut-off values for the vena contracta width, effective regurgitant orifice area, and regurgitant volume have not been established for routine use in the clinical setting [5]. Silversides et al. [4] reported a pressure half time of less than 100 ms to be highly sensitive and specific for identifying severe PR in patients after repair of tetralogy of Fallot or after pulmonary valvulotomy [4]. Puchalski et al. [6] reported that jet/annulus width exceeding 50% identified patients with severe PR (Table 2).

Timing for pulmonary valve replacement is the most challenging aspect of treatment. Possible beneficial effects should be weighed against the risk of reoperation due to graft dysfunction. Perioperative mortality in patients without heart failure is low (<1%) [7]. Pulmonary valve replacement (PVR) results in improvement in exercise capacity, reduction of the RV size, and decrease in QRS duration [8]. A positive effect of PVR on the RV function is unlikely as soon as the end-diastolic volume exceeds 160 mL/m^2. Delaying PVRt until the patient becomes symptomatic may increase the risk of high preoperative RV volume [9]. Achieving normalization in the RV volume may improve long-term outcome but there are very limited data on long-term mortality. The development of complications that require a surgery, for example, significant rVSD, severe TR, or pulmonary stenosis may affect the timing of PVR. Another factors include the development of sustained atrial or ventricular arrhythmias, QRS duration, and the presence of myocardial fibrosis on CMR [6,7].

There are a number of different pulmonary valve prostheses, such as allografts, xenografts, and mechanical prostheses. Allografts are most common but approximately 50% of the patients will require reoperation due to graft dysfunction 10 years after the surgery [10]. Compared with bioprosthesis, mechanical valve prosthesis shows a lower initial gradient and no substantial increase in the gradient

or regurgitation with time. The advantages are reduced by the risk of valve thrombosis and pannus-related dysfunction, leading to similar reoperation rates [11]. Percutaneous pulmonary valve implantation (PPVI) (Melody, Medtronic, Inc.) may be an option for selected patients with pulmonary homograft dysfunction. Patients after repair of ToF involving valvotomy or valvectomy may not provide secure anchorage to the stented valve. Early after PPVI, a significant decrease in the RV end-diastolic volume is observed [12]. The rate of complications in short-term follow-up is low but the longevity of the valve is unknown [13].

According to the current guidelines, PVR is the standard treatment in symptomatic patients with severe PR. It should be considered in asymptomatic patients with progressive RV dilation or systolic dysfunction, progressive TR, and sustained atrial or ventricular arrhythmias (Table 3) [7].

TR occurs mainly from RV and tricuspid annular dilatation. It results in progressive RV enlargement. Tricuspid valve repair (TVR) is indicated in patients with moderate and severe dilation of the annulus (diameters, >40 mm or >21 mm/m^2) undergoing cardiac surgery. TVR using an annuloplasty ring is the preferred surgical approach for TR [14].

rVSD requiring reintervention after primary surgical repair of ToF is rare [15]. Significant left-to-right shunting through VSD leads to LV volume overload, pulmonary hypertension, resulting in shunt reversal and Eisenmenger's syndrome. Patients with symptoms that can be attributed to left-to-right shunting through VSD who have no severe pulmonary vascular disease as well as patients with VSD and pulmonary arterial hypertension with left-to-right shunt (Qp:Qs >1.5) and pulmonary artery pressure or pulmonary vascular resistance below 2/3 of systemic baseline values or when challenged with vasodilators are candidates for surgery. Moreover, residual VSD closure is recommended if the patient is undergoing pulmonary valve surgery (Table 3,4).

Patient management and follow-up

Echocardiography and right heart catheterization confirmed that symptoms can be attributed to left-to-right shunting through rVSD, PR ad TR. There are several strong indications for complex surgery according to the European Society of Cardiology guidelines for the management of grown-up congenital heart disease and guidelines on the management of valvular heart disease (Table 3). Our patient was scheduled for complex surgical closure of rVSD, PVR, and TVR.

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