Pulmonary Right Ventricular Resynchronization in Congenital Heart Disease Acute Improvement in Right Ventricular Mechanics and Contraction Efficiency

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Acute Improvement in Right Ventricular Mechanics and Contraction Efficiency

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Background—Electromechanical discoordination may contribute to long-term pulmonary right ventricular (RV) dysfunction in patients after surgery for congenital heart disease. We sought to evaluate changes in RV function after temporary RV cardiac resynchronization therapy.

Methods and Results—Twenty-five patients aged median 12.0 years after repair of tetralogy of Fallot and similar lesions were studied echocardiographically (n=23) and by cardiac catheterization (n=5) after primary repair (n=4) or after surgical RV revalvulation for significant pulmonary regurgitation (n=21). Temporary RV cardiac resynchronization therapy was applied in the presence of complete right bundle branch block by atrial-synchronized RV free wall pacing in complete fusion with spontaneous ventricular depolarization using temporary electrodes. The q-RV interval at the RV free wall pacing site (mean 77.2% of baseline QRS duration) confirmed pacing from a late activated RV area. RV cardiac resynchronization therapy carried significant decrease in QRS duration (P<0.001) along with elimination of the right bundle branch block QRS morphology, increase in RV filling time (P=0.002), pulmonary artery velocity time integral (P=0.006), and RV maximum +dP/dt (P<0.001), and decrease in RV index of myocardial performance (P=0.006). RV mechanical synchrony improved: septal-to-lateral RV mechanical delay decreased (P<0.001) and signs of RV dyssynchrony pattern were significantly abolished. RV systolic stretch fraction reflecting the ratio of myocardial stretching and contraction during systole diminished (P=0.001).

Conclusions—In patients with congenital heart disease and right bundle branch block, RV cardiac resynchronization therapy carried multiple positive effects on RV mechanics, synchrony, and contraction efficiency. **(*Circ Cardiovasc Imaging*. 2017;10:e006424. DOI: 10.1161/CIRCIMAGING.117.006424.)**

Key Words: cardiac resynchronization therapy ■ echocardiography ■ heart defects, congenital ■ pediatrics ■ right ventricle ■ tetralogy of Fallot

Pulmonary right ventricular (RV) dysfunction and occasional failure are associated with many congenital heart lesions, most predominantly but not limited to postoperative tetralogy of Fallot. They are attributed to several factors including myocardial fibrosis because of preoperative hypoxemia and pressure overload, surgical scar, and long-term postrepair volume overload caused by pulmonary regurgitation. RV revalvulation is thought to reverse pathological RV remodeling. However, a decreased probability of reverse remodeling has been reported in patients with high RV end-diastolic and end-systolic volumes, low RV ejection fraction, and those with wide QRS complex (≥160 ms).[1–5] Thus, pulmonary valve replacement alone may not lead to RV performance normalization. Right bundle branch block (RBBB) is the most frequent cause of electromechanical discoordination in congenital heart disease. In postoperative tetralogy of Fallot, RV dyssynchrony has been associated with decreased RV ejection fraction, mechanical inefficiency, and impaired exercise capacity[6,7] and is hypothesized to play a significant role in RV dysfunction progression. Cardiac resynchronization therapy (CRT) has to date been used to treat dyssynchrony in the failing systemic (left) ventricle. Reports of pulmonary RV cardiac resynchronization therapy (RV-CRT) are scarce. Limited data show that acute RV-CRT through either

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RV or biventricular pacing improves short-term hemodynamics in both children and adults with congenital heart disease and RBBB.[8–13] The impact of RV-CRT on RV mechanics and contraction efficiency has, however, never been studied despite the fact that pulmonary RV dysfunction and failure are common sources of morbidity and reason for reinterventions in both pediatric and adult congenital heart disease. The present report gives insights into the potential role of RV-CRT in this specific patient group. We sought to zevaluate changes in global and local RV function and synchrony after temporary RV-CRT.

Patients and Methods

Patients

Twenty-five patients (15 male, 10 female; median age 12.0 years; interquartile range, 7.1–17.4 years) with previously repaired tetralogy of Fallot (n=12), pulmonary atresia (n=6), double outlet RV (n=3), absent pulmonary valve syndrome (n=2), and arterial trunk (n=2) were studied echocardiographically (n=23) and by cardiac catheterization (n=5) after primary repair (n=4) or after surgical RV revalvulation for significant pulmonary regurgitation (n=21). All patients were in sinus rhythm and had normal atrioventricular (AV) conduction intervals along with a complete RBBB with a mean (SD) QRS duration of 142 ms (21 ms). Six of the 25 patients were intubated, 4 had intravenous inotropic support, and 2 patients were in manifest right heart failure at the time of the study. Baseline systolic RV function was graded echocardiographically as good in 19 of 25, decreased in 3 of 25, and severely decreased in the remaining 3 patients.

RV Resynchronization

Temporary RV-CRT was applied by atrial-synchronized RV free wall pacing in bipolar configuration from 2 closely spaced electrodes placed at the border between the inflow and outflow parts in the proximity of the tricuspid annulus. This region has been reported as the site of latest activation in the postrepair tetralogy of Fallot patients with RBBB[12] (Figure 1). Sensed (echocardiographic evaluation) or paced (catheterization) AV delays were set to achieve maximum shortening of the QRS complex through fusion of the intrinsic and paced ventricular depolarization waves. In 23 patients, temporary RV-CRT was a routine part of the acute postoperative management[8] using temporary epicardial pacing wires. In addition, 5 patients underwent temporary RV-CRT by transvenous diagnostic electrophysiology catheters during cardiac catheterization indicated for other reasons to test RV-CRT effect and potentially establish the indication for permanent RV resynchronization. Short-term echocardiographic and catheter-based measurements were performed to confirm hemodynamic efficacy while switching RV-CRT off and on for 15 to 20 cardiac cycles to allow for stable measurements during each mode.

Electrocardiogram

Twelve-lead ECG was recorded during both the baseline rhythm and RV-CRT pacing. QRS duration was manually measured from earliest QRS onset to latest QRS offset in any lead. In addition, local bipolar electrograms were recorded from the RV pacing site. The q-RV interval was measured during baseline rhythm as the time between the earliest QRS onset and the local electrogram (first rapid baseline crossing) and expressed as percent of baseline QRS duration.

Echocardiography

Echocardiograms were obtained in 23 of 25 patients during baseline rhythm and RV-CRT, respectively, using the Vivid 7, Vivid E9, or Vivid E95 equipment (GE-Vingmed, Horten, Norway) and stored as raw data in the EchoPac version 113.0.3 workstation. Transducers (3.5 or 5 MHz) with a minimal frame rate of 30 s^{-1} (ideally 60–90 s^{-1}) were used. Three consecutive cardiac cycles with simultaneous ECG recording to allow for identification of QRS onset were analyzed, and the results were averaged. In 10 randomly selected patients, measurements were repeated by another operator blinded to the pacing intervention to allow for the calculation of interobserver variability. The following parameters were evaluated:

1. RV systolic function was assessed visually and graded as good, decreased, and severely decreased.
2. RV and left ventricular (LV) filling times were measured from transtricuspid and transmitral pulsed-wave Doppler recordings, respectively, and expressed as corrected value by the following formula: corrected filling time=absolute filling time+0.87×(1000−cycle length),[14] with absolute filling time and cycle length in ms, to adapt for minor changes in heart rate during the measurements.
3. Maximum rate of systolic RV pressure rise (dP/dt_{max}) was measured from the tricuspid regurgitation jet if present (12/25 patients) between the velocities of 1 and 2 m/s according to published recommendations.[15]
4. RV and LV ejection times were measured from pulsed Doppler in the RV outflow tract and expressed as corrected value using the Bazett formula.[16]
5. The velocity time integral of the RV and LV ejection jet was measured from pulsed Doppler in the RV and LV outflow tract, respectively.
6. RV index of myocardial performance was calculated as follows: (cycle length−RV filling time−RV ejection time)/RV ejection time.[15]

Speckle-Tracking Echocardiography

To evaluate the effect of RV-CRT on RV mechanical discoordination, RV speckle-tracking analysis was performed using the EchoPac workstation. Baseline and RV-CRT echocardiographic raw data of sufficient quality for speckle-tracking strain analysis were available for 20 subjects. Two-dimensional B-mode images were recorded in the apical 4-chamber view to allow complete visualization of both the septum and RV free wall. Both walls were divided into 3 segments: apical, midventricular, and basal. Thus, a total of 6 segments were evaluated. Segments automatically rejected by the software or those with unclear peaks were not used for analysis. Measurements were technically feasible in 75% of all segments (91.3% of basal and midventricular and 42.5% of apical segments, respectively) with a median of 4.5 of 6 segments evaluated per patient. The majority of the most important segments for the analysis of septal-to-lateral RV mechanical dyssynchrony (ie, basal and midventricular segments) were thus included in the analysis. Care was taken to assess identical segments at baseline and during RV-CRT pacing. Longitudinal strain curves from available segments were exported in digital format from the EchoPac workstation. Further analysis

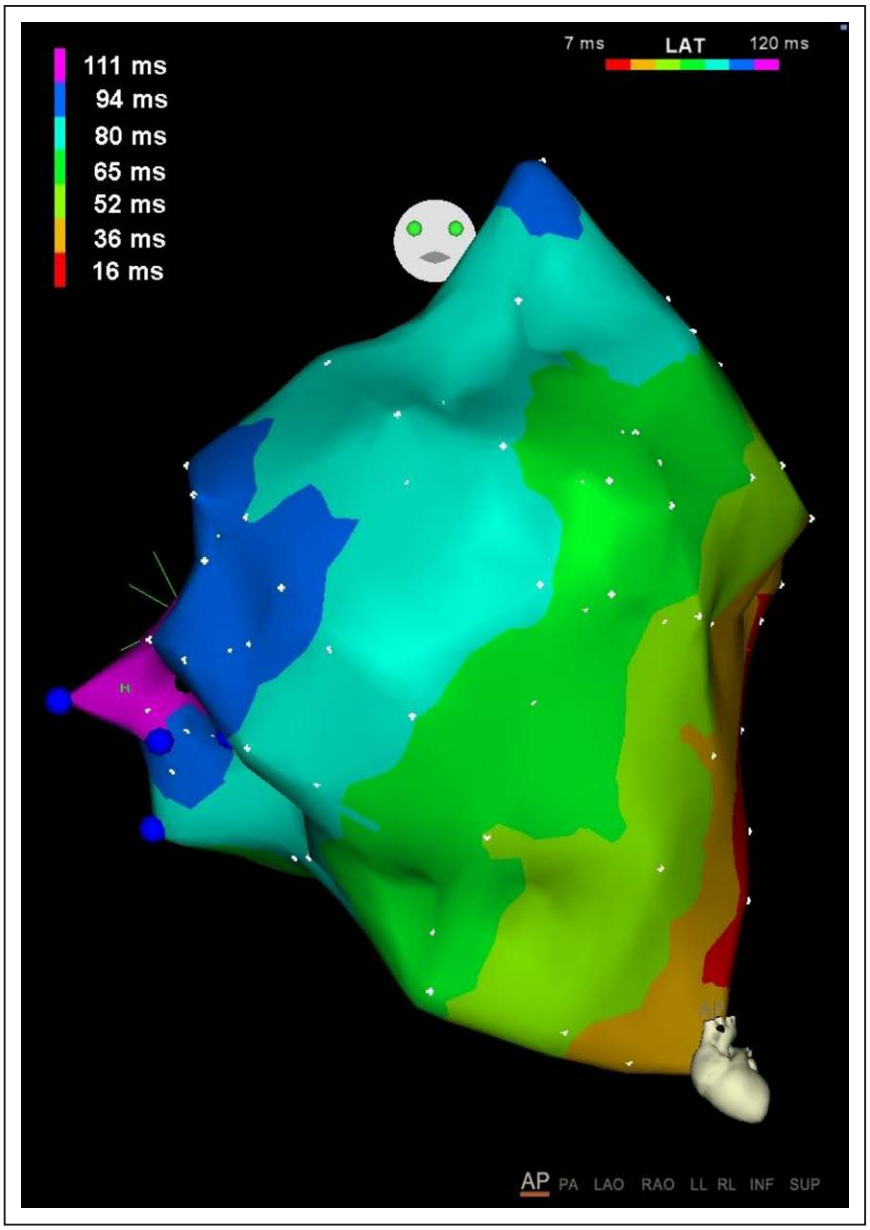

Figure 1. Right ventricular (RV) activation map by CARTO from a repaired tetralogy of Fallot patient undergoing catheterization. The color coding shows latest activation at the border between RV inflow and outflow close to the tricuspid valve annulus. AP indicates antero-posterior projection; LAT, local activation time.

was performed by a custom-made algorithm developed using Matlab (version R2014b; The MathWorks, Natick, MA). The following parameters were automatically calculated:

1. Septal-to-lateral RV mechanical delay defined as the time difference between earliest and latest peak septal and RV free wall negative systolic strain. Positive values indicate an earlier septal contraction and negative values an earlier RV free wall contraction.
2. RV systolic stretch fraction was calculated as a modification of internal stretch fraction[17] and wasted work ratio[18] to calculate RV contractile efficiency. The beginning (T1) and termination (T2) of systole was defined as the earliest onset and latest offset of negative strain rate in any of the 6 RV segments, respectively. For each strain rate signal (SR(t)), the positive SR (pSR(t)) and negative SR (nSR(t)) signals were summed according to Equation 1. The amount of local stretch was determined by integration of the positive strain rate signal within the systolic time interval [T1–T2]. The amount of local contraction was calculated in analogy as the integration of negative signal. Total amount of stretch/contraction was determined as the sum of segmental data (Equation 2). Equations 1 and 2 were implemented numerically using respective strain rate signals, with i and n indicating segment number and total number of segments used, respectively. Systolic stretch fraction represents a ratio of total stretch over total contraction during systole with a higher number indicating decreased global contractile efficiency (Figure 2).

$$\begin{aligned} &pSR(t) = SR(t);\ \ SR(t) \in (0;\infty) \quad \text{and} \\ &nSR(t) = SR(t);\ \ SR(t) \in (-\infty;0) \end{aligned} \tag{1}$$

$$SSF = -\frac{\sum_{i=1}^{n}\left[\int_{T1}^{T2} pSR_i(t)\,dt\right]}{\sum_{i=1}^{n}\left[\int_{T1}^{T2} nSR_i(t)\,dt\right]} \tag{2}$$

3. The presence of the components of classical strain pattern reflecting early contraction in one wall and prestretching of the opposing wall followed by late contraction was evaluated in the RV in analogy to published data for the LV[19] (Figure 3). Each of the 3 components of this pattern was graded as either present or absent before and after RV-CRT.

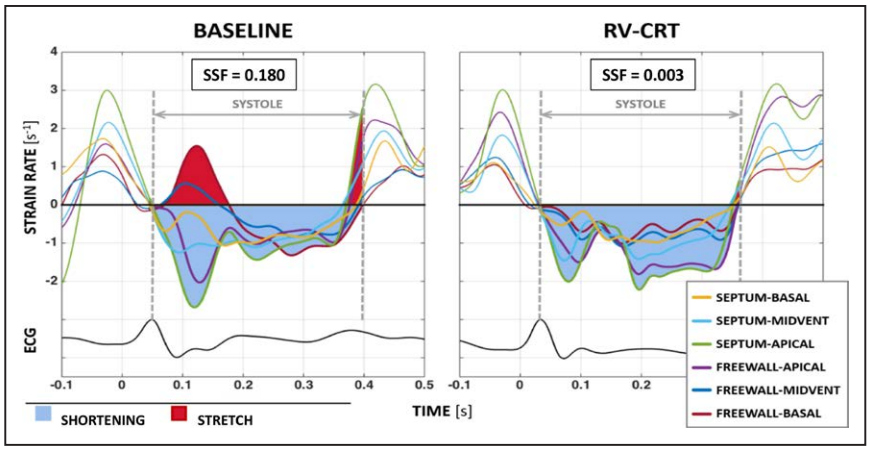

Figure 2. Systolic stretch fraction analysis. Comparison of baseline condition and right ventricular cardiac resynchronization therapy (RV-CRT). The area under the strain rate curves is marked blue in shortening segments and red in stretching segments. Calculation of the area under curve is performed for each segment separately (Methods). Almost total elimination of systolic stretch is present after RV-CRT. SSF indicates systolic stretch fraction.

Cardiac Catheterization

Five of the 25 patients were subjected to invasive hemodynamic evaluation including temporary RV-CRT during cardiac catheterization indicated for other reasons. RV and arterial pressures (all 5 patients) and LV pressures (2 patients) were measured simultaneously to evaluate systolic timing and maximum +dP/dt. To allow for maximal cycle length stabilization while testing the CRT effect, measurements were performed using AAI and AV sequential RV-CRT pacing, respectively. Two different pacing rates 10% and 30% to 50% above the intrinsic heart rate were used. Pressure waveform acquisitions were performed by a conventional catheterization method using extravascular pressure sensors. Mac-Lab IT system (GE Healthcare, Chicago, IL) was used for signal digitalization. Time continuous data records were postprocessed by ECG synchronized averaging algorithm (Matlab R2014_b software; The MathWorks, Natick, MA). Each presentable average waveform was composed of pressure signal examples from at least 10 consecutive heart cycles. A 3-dimensional CARTO (Biosense Webster Inc, South Diamond Bar, CA) RV activation map was obtained in baseline rhythm in 1 of the 5 patients as a part of an associated electrophysiology procedure.

Statistics

SigmaPlot for Windows Version 12·0 (Systat Software Inc, San Jose, CA) was used for statistical analysis. Continuous variables were expressed as mean (SD) or median (interquartile range) as appropriate according to the data distribution pattern. Paired *t* test or paired sample Wilcoxon signed-rank test was used for intrapatients comparisons of continuous variables. The number of individuals that fall into different categories before and after a single treatment was analyzed by the McNemar test. Coefficient of variation[20] was used to evaluate interobserver variability of echocardiographic measurements. Differences were declared statistically significant if $P \leq 0.05$.

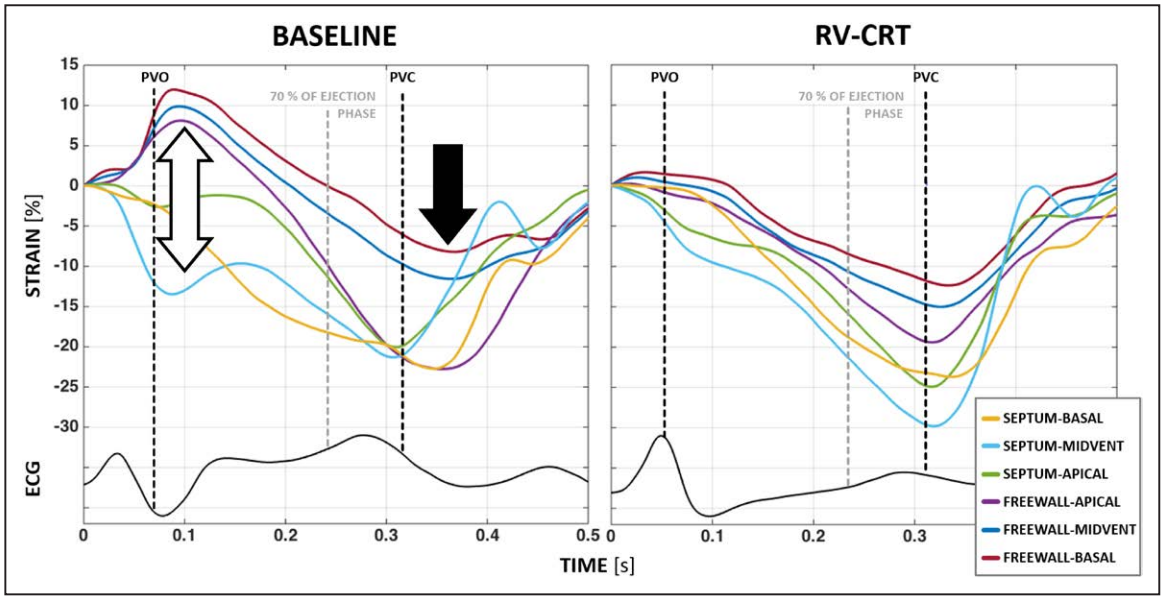

Figure 3. Analysis of classical RV strain pattern. Baseline rhythm: the pattern is characterized by the following signs: (1) Early shortening of at least 1 basal or midventricular segment in the septal wall (yellow and light blue curves) and early stretching in at least 1 basal or midventricular segment in the opposing wall (red and dark blue curves, white arrow). (2) Early peak shortening does not exceed 70% of the ejection phase (not fulfilled in this example). (3) The early stretching wall shows peak shortening after pulmonary valve closure (red and dark blue curves, black arrow). Right ventricular cardiac resynchronization therapy (RV-CRT): elimination of both signs 1 and 3. PVC indicates pulmonary valve closure; PVO, pulmonary valve opening.

Independent Data Access and Analysis

The corresponding author has full access to all the data in the study and takes responsibility for data integrity and analysis.

Ethics

The study was approved by the Institutional Review Board of the University Hospital Motol. The patients and parents (whatever applicable according to patients' age) were familiarized with the study principles and signed the informed consent form.

Results

Electrocardiogram

RV-CRT significantly decreased QRS duration from 142 ms (21 ms) to 98 ms (16 ms; $P<0.001$) along with disappearance of the RBBB QRS morphology in all patients (Figure 4), reflecting successful elimination of late RV activation.

Echocardiographic Data

Results are summarized in Table 1. Both systolic RV function and RV filling improved by RV-CRT, as reflected by increases in RV maximum +dP/dt, pulmonary artery velocity time integral, and RV filling time and decrease in the RV index of myocardial performance. Changes in other measured variables including the LV filling and ejection parameters were not significant. All evaluated RV dyssynchrony parameters improved and 2 of the 3 signs of classical strain pattern[19] were significantly diminished (Figures 2 and 3; Table 1; Movie file in the Data Supplement). The interobserver variability was assessed by coefficient of variation as follows: corrected RV filling time=9.7%, RV outflow tract velocity time integral=1.4%, and RV maximum +dP/dt=13.4%. The interobserver variability for other echocardiographic parameters used in the study was reported by our laboratory earlier.[21]

Invasive Hemodynamic Study

Catheterization revealed further insight into the pacing-induced interventricular resynchronization and confirmed the positive effect of RV-CRT on RV pump function indicated by the noninvasive measurements. RV-CRT expedited RV pressure rise and thereby synchronized it with LV pressure rise (Figure 5). Maximum systolic RV dP/dt improved in all but one case. The effect was present at both pacing rates tested. Data are summarized in Table 2.

On the basis of acute RV-CRT testing, 3 patients experiencing manifest right heart failure and showing a greatly positive response have been subjected to permanent RV-CRT. One of these patients has been described in a case report previously.[22]

Discussion

Pulmonary RV electromechanical dyssynchrony occurs in a significant portion of repaired congenital heart disease. It is caused by surgically induced RBBB, either proximal mostly as the consequence of ventricular septal defect closure, or distal as associated with right ventriculotomy. To date little attention has been paid to consequences of RV electromechanical dyssynchrony in these patients. Therapeutic measures were mainly focused on the relief of pulmonary regurgitation as the major source of RV dysfunction. In repaired tetralogy of Fallot, the relatively largest population of patients with RV volume overload and RBBB, indications for RV revalvulation

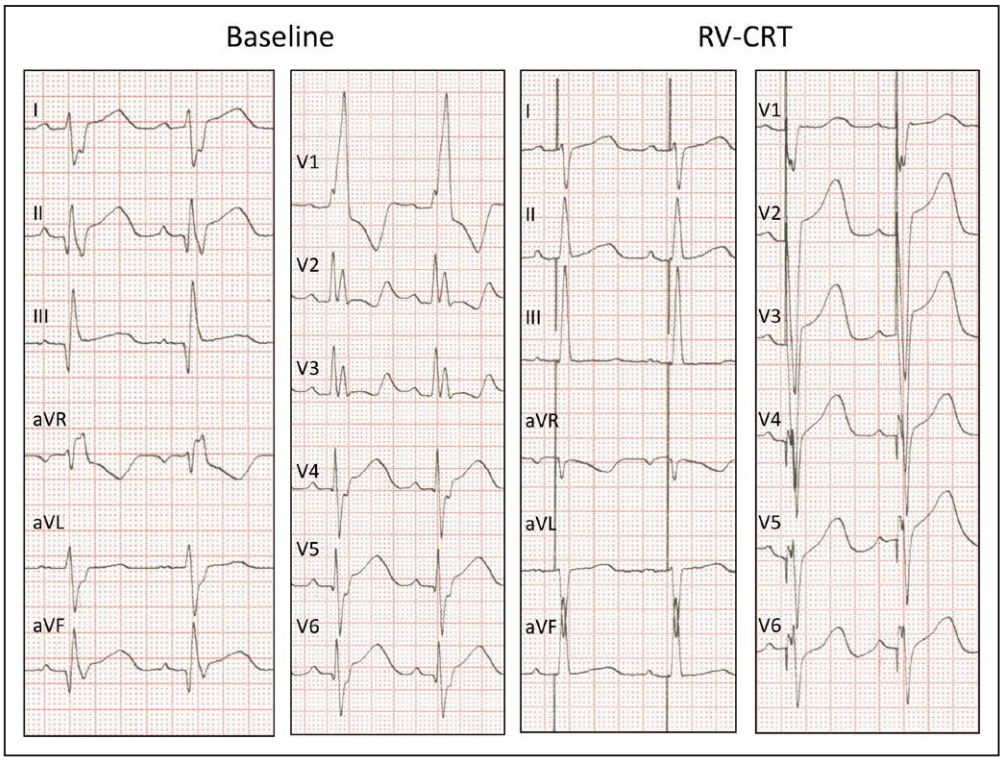

Figure 4. Twelve-lead ECG. Baseline: sinus rhythm, complete right bundle branch block. Late positive R waves in lead aVR and V_1 reflect delayed right ventricular (RV) activation. RV cardiac resynchronization therapy (RV-CRT): major decrease in QRS complex duration with disappearance of the late RV activation component. Sensed atrioventricular delay was adjusted to achieve complete fusion with spontaneous ventricular depolarization and shortest QRS duration.

Table 1. Echocardiographic Data During Baseline and RV-CRT (n=23)

Parameter	Baseline Rhythm	RV-CRT	Δ Change	*P* Value
RV filling time, ms	median624 (612 to 652)	median649 (624 to 663)	median17 (0 to 33)	0.002
RV ejection time, ms	mean325 (42)	mean331 (43)	mean6 (21)	0.202
RV max. +dP/dt, mm Hg/s	mean315 (146)	mean536 (249)	mean221 (140)	<0.001
RV outflow tract VTI, m	mean19.5 (8.1)	mean20.7 (9.0)	mean1.1 (1.7)	0.006
RV index of myocardial performance	mean0.30 (0.21)	mean0.20 (0.16)	mean–0.10 (0.15)	0.006
LV filling time, ms	mean626 (46)	mean624 (47)	mean–3 (11)	0.260
LV ejection time, ms	mean294 (23)	mean296 (25)	mean3 (6)	0.285
LV outflow tract VTI, m	mean16.6 (5.8)	mean17.2 (6.0)	mean0.6 (0.7)	0.078
RV septal-to-lateral delay, ms	median65 (45 to 79)	median16 (–16 to 37)	median–56 (–81 to –19)	<0.001
RV systolic stretch fraction	mean0.17 (0.09)	mean0.07 (0.04)	mean–0.11 (0.09)	<0.001
Presence of CSP [%]				
Sign 1	85.0	20.0	–65.0	<0.001
Sign 2	0.0	0.0	0.0	1.000
Sign 3	85.0	5.0	–80.0	<0.001

Data are displayed as mean (SD) or median (interquartile range [IQR]) according to the pattern of distribution. CSP indicates classical RV strain pattern; CRT, cardiac resynchronization therapy; LV, left ventricle; RV, right ventricle; and VTI, velocity time integral.

have been established based mainly on RV volumes and systolic function. It became evident that some patients have not benefited from pulmonary valve replacement as expected. This has drawn attention to potential presence of RV dyssynchronopathy as an additional player in the long-term disease process. In biventricular circulation, the ventricles are in series and cardiac output is determined by the weaker one. Thus, in analogy to LV failure associated with left bundle branch block, such patients could benefit from RV resynchronization.

To date only few reports have been published to study the effects of pulmonary RV resynchronization in the congenital heart disease population. Our group was the first to show its use to improve hemodynamics in the acute postoperative setting.[8,13] Other authors have reported acute benefit from RV

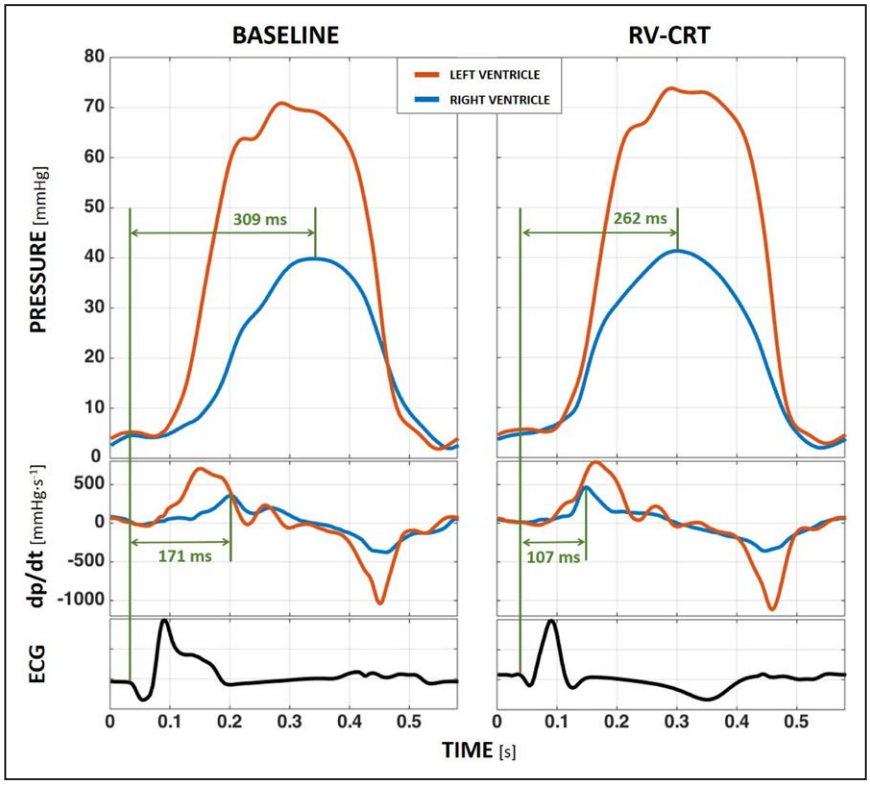

Figure 5. Right ventricular (RV; blue color) and left ventricular (LV; red color) pressure curves at baseline and after RV resynchronization therapy (RV-CRT). RV-CRT shifted the RV pressure curve peak and maximum pressure rise (dP/dt) to the left and synchronized it with LV systole.

Table 2. Catheterization Data During AAI Pacing (baseline) and RV-CRT (n=5) Measured at 2 Different Paced Heart Rates

	AAI	RV-CRT	*P* Value	AAI	RV-CRT	*P* Value
Paced heart rate, bpm	73 (7)		…	109 (12)		…
RV max +dP/dt, mm Hg/s	345 (122)	429 (158)	0.054	354 (97)	460 (114)	0.010
LV max +dP/dt,* mm Hg/s	709 (57)	697 (21)	…	878 (238)	918 (176)	…
QRS onset to RV max +dP/dt, ms	164 (17)	129 (11)	0.004	175 (17)	126 (8)	0.005
QRS onset to LV max +dP/dt,* ms	116 (31)	131 (9)	…	115 (15)	140 (4)	…
RV-LV max +dP/dt delay,* ms	39 (8)	–11 (0)	…	53 (1)	–17 (1)	…

Data are displayed as mean (SD). CRT indicates cardiac resynchronization therapy; LV, left ventricle; and RV, right ventricle.
*Measurements available in 2 patients only.

resynchronization in small groups of tetralogy of Fallot patients by measuring invasively or noninvasively short-term changes in cardiac index and maximum RV +dP/dt.[9–12] These studies did not, however, assess the effects on RV synchrony and mechanics. They have differed in RV pacing sites and pacing methodology using single-site, dual-site RV or even biventricular pacing with different degrees of RV preexcitation. Thus, pacing may have not resynchronized fully the RV free wall to the septum or may have preexcited the RV too much causing RV-pacing–induced LV dyssynchrony. In the present study, we have used atrial-synchronized pacing from a late activated RV site. Care was taken to achieve complete fusion of the pacing-induced depolarization wave with the spontaneous activation resulting in shortest possible QRS duration along with elimination of the late RV activation component of the QRS complex. At the same time, we avoided to pace the RV too early to prevent RV pacing-associated LV desynchronization. Our pacing technique was chosen in analogy to a report by Gold et al.[23] They compared single-site LV pacing to biventricular pacing in an acute hemodynamic study in adult patients with dilated cardiomyopathy and left bundle branch block. After optimizing the AV delay, both pacing modes were similar in terms of LV contractility increase. Mean optimal AV delay during AV sequential pacing was very close to the mean baseline PR interval. The authors concluded that LV-only pacing at the free wall in optimal fusion with intrinsic septal activation will carry similar hemodynamic improvement as biventricular pacing.

In the present report, we could for the first time clearly document multiple beneficial effects of RV-CRT on disturbed RV mechanics.[7] RV-CRT decreased the contraction delay between RV septum and free wall and improved RV mechanical coordination. The components of the classical strain pattern[17,19] were significantly eliminated. In addition, RV contraction efficiency was improved as reflected by the decrease in systolic stretch fraction.[18] Both the classical strain pattern and systolic stretch fraction have been shown to characterize a mechanical discoordination amenable to resynchronization and to predict efficacy of CRT in adults with idiopathic or ischemic dilated cardiomyopathy. In this way, our study extends the knowledge on the use of CRT in patients with RBBB presented in a review of Auricchio et al.[24]

Whether permanent RV-CRT may be of benefit in this patient group remains to be studied. According to a well-documented case report,[22] this may be the case in patients with continuing dysfunction of the pulmonary RV despite elimination of hemodynamic residual findings like pulmonary regurgitation. Exact indications for permanent RV-CRT are, however, not yet settled. The presented data may help to design an ethically acceptable prospective, randomized trial using RV-CRT with magnetic resonance imaging compatible pacing systems in patients late after repair of tetralogy of Fallot undergoing pulmonary valve replacement to observe chronic RV functional parameters, exercise capacity, and clinical outcome.

This study has several limitations. Echocardiography was limited to the apical 4-chamber view. Thus, all dyssynchrony indices reflected only the septum and RV free wall and did not include the RV outflow tract. However, RV-CRT carried a significant improvement in global RV contractility as demonstrated by the uniform increase in maximum systolic RV dP/dt indicating effective resynchronization. The baseline and pacing periods lasted 15 to 20 cycles only. This period may be too short to allow for complete stabilization of hemodynamics. Our study, however, mainly focused on mechanistic RV-CRT effects. These effects are immediately visible after switching RV-CRT on and include an immediate increase in RV contractility as reflected by dP/dt_{max}. Short measurement periods were reported by others[25] when assessing the impact of CRT optimization. They identify the direct resynchronization effects, which may become lost because of autonomic regulation when waiting for a longer time. Data on catheterization were available in 5 patients only but were in accordance with the echocardiographic findings and illustrate well the time/pressure changes in the RV and LV before and after RV-CRT, respectively. The study group was not homogenous and included patients after primary repair of tetralogy of Fallot, surgical revalvulation for significant pulmonary regurgitation, pulmonary atresia, double outlet RV, and absent pulmonary valve. All of these patients had, however, a dyssynchronous RV and fall into the cohort of congenital heart disease patients at risk of RV failure and are thus relevant to the study. Some of the patients were analyzed during mechanical ventilation or inotropic support which may have changed RV hemodynamics significantly and thereby reduces uniformity of the study group. The LV function parameters did not change in response to the pacing maneuvers. This may be explained by the fact that most of the patients were not in overt heart failure during the time of the study, and, thus, acute change in global hemodynamics and cardiac output may have been negligible. In a case report on permanent RV resynchronization,[22] we observed significant improvement of both RV and LV function after 6 months of RV-CRT. Also, in a recently published study on RV-CRT used for treatment of acute right

heart failure in patients after primary repair of tetralogy of Fallot,[13] significant increases in blood pressure and cardiac output were reported suggesting a pacing-induced improvement of global cardiac function. Using single-site RV pacing in complete fusion with spontaneous activation for permanent RV-CRT may not be feasible in patients with variable or heart rate–dependent duration of spontaneous PR interval. In such patients, biventricular pacing may be needed to resynchronize the RV. This technique was not studied in the current report but has been reported elsewhere.[11] Relatively small changes in PR interval during the day may, however, lead to only partial desynchronization. To prove the results of this study also a formal prospective validation will be required in a different cohort of patients.

Conclusions

In patients with congenital heart disease and RBBB, RV-CRT carried multiple positive effects on RV mechanics, synchrony, and contraction efficiency.

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Disclosures

None.

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CLINICAL PERSPECTIVE

In patients with congenital heart disease, right ventricular (RV) dyssynchrony caused by right bundle block has been associated with decreased RV ejection fraction, mechanical inefficiency, and impaired exercise capacity and is hypothesized to play a significant role in the progression of RV dysfunction. This study could show positive immediate effects of RV cardiac resynchronization therapy on RV mechanics, synchrony, and contraction efficiency. The presented results suggest that RV cardiac resynchronization therapy may be beneficial for patients with tetralogy of Fallot and similar lesions who do not show reverse RV remodeling after pulmonary revalvulation. These data may help to design an ethically acceptable prospective, randomized trial using RV cardiac resynchronization therapy with magnetic resonance imaging compatible pacing systems in patients late after repair of tetralogy of Fallot undergoing pulmonary valve replacement to observe chronic RV functional parameters, exercise capacity, and clinical outcome.