Isolated right ventricular failure and abnormal hemodynamics caused by right ventricular pacing are reversed with cardiac resynchronization therapy

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Introduction

Chronic right ventricular (RV) pacing may lead to both RV and left ventricular (LV) dysfunction (LV ejection fraction [EF] <40%) and improve with biventricular pacing. The role of cardiac resynchronization therapy (CRT) in isolated RV dysfunction has not been reported. We demonstrate that pacemaker-induced isolated RV failure responds to CRT, as proven by intracardiac hemodynamics and symptom improvement within 2 months after the procedure.

Case report

A 45-year-old previously healthy and physically active attorney presented to a local hospital with symptoms of acute dizziness, dyspnea, and fatigue while mowing his lawn. Serial ECGs revealed sinus rhythm with left bundle branch block (Figure 1A) and second-degree AV block with incomplete right bundle branch block (Figure 1B). A dual-chamber pacemaker was urgently placed, with resolution of symptoms. Over a 5-year period, he developed progressive exertional dyspnea (1 flight of stairs) and fatigue New York Heart Association (NYHA) functional class IIIB heart failure. He sought help at our institution. His blood pressure was 132/82 mm Hg, heart rate 70–106 bpm (89% paced), and he was taking no cardiac medications. Physical examination was unremarkable. Transthoracic echocardiography revealed mildly impaired LV systolic function (EF = 50%) with no hemodynamically significant valve disease. Cardiac computed tomography showed an Agatston score of 0 with left dominant anatomy and normal coronaries (Figures 1C and 1D), dilated RV chamber size with decreased RV EF to 40% (Figures 1E and 1F), and an aneurysmal interatrial septum. LV dyssynchrony could not be appreciated. Transesophageal echocardiography confirmed RV global hypokinesis, mild tricuspid regurgitation, and no intracardiac shunt.

The patient underwent cardiopulmonary testing, during which he achieved maximal exercise with an appropriate chronotropic response and peak heart rate of 179 bpm. Hemoglobin was 15.6 g/dL (normal 13.2–17.7 g/dL), but peak VO_2 was decreased (73% of predicted) and O_2/pulse was low (71% of predicted). Anaerobic threshold measured by the V-slope method was low–normal (42%) in the absence of a ventilatory or gas exchange limitation to exercise. Right heart catheterization (Figure 2) showed a decreased cardiac index of 1.56 L/min/m^2 (normal 2.8–4.2 L/min/m^2), elevated mean right atrial pressure of 11 mm Hg (normal –1 to +8 mm Hg), normal pulmonary capillary wedge pressure of 12 mm Hg (normal 6–15 mm Hg), and mean pulmonary arterial pressure of 16 mm Hg (normal 10–22 mm Hg). Interestingly, the Kussmaul sign was present.

We suspected that predominant RV pacing over time led to isolated RV failure as the explanation for his symptoms and discussed implantation of a cardiac resynchronization therapy device. He agreed to undergo the procedure even though a positive outcome could not be guaranteed. Two weeks after the procedure, the patient reported a dramatic improvement in symptoms and overall functional capacity. Repeat right heart catheterization 2 months later revealed normal right-sided filling pressures, and the Kussmaul sign was absent. Six months later, histograms demonstrated an increase in the percentage of lower heart rates (Figure 3A). Comparison of representative 24-hour densitometry plots before and after the procedure showed an increase in heart rate variability with CRT therapy (Figure 3B). Despite improvement in symptoms and RV function, cardiac index remained low and prompted further evaluation for possible subclinical infiltrative pathology, including light-chain amyloidosis, cardiac sarcoidosis, collagen

KEYWORDS Right ventricular failure; Pacemaker; Cardiac resynchronization therapy

ABBREVIATIONS **CRT** = cardiac resynchronization therapy; **EF** = ejection fraction; **LV** = left ventricle; **NYHA** = New York Heart Association; **RV** = right ventricle (Heart Rhythm Case Reports 2015;1:182–185)

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KEY TEACHING POINTS

- Pacemaker-induced isolated right ventricular (RV) failure quickly responds to cardiac resynchronization therapy (CRT).
- Hemodynamic assessment and right heart catheterization are superior to standard imaging modalities such as echocardiography, cardiac computed tomography, and cardiopulmonary testing in diagnosing isolated pacemaker-induced RV failure.
- CRT has benefits beyond left ventricular improvement.

vascular disease, and muscular dystrophy, as well genetic testing using a comprehensive arrhythmia panel, which was unrevealing.

Discussion

Based on the 2012 ACCF/AHA/HRS focused update incorporated into the 2008 guidelines for device-based therapy of cardiac rhythm abnormalities, biventricular pacing is currently recommended for selected patients with LV systolic heart failure and NYHA class III/IV symptoms, QRS $\geq$130 ms, and baseline impaired LV function (EF $<$40%).[1,2] The guidelines recognize that selected patients, especially younger individuals with normal baseline LV EF, may experience deterioration in LV contractile function due to chronic RV pacing, and the guidelines question whether these patients would also benefit from initial implantation of a biventricular device, future device upgrade, or alternative sites of ventricular pacing.[3]

More recent studies have focused on the effect of CRT on RV function and remodeling. MADIT-CRT investigators showed a significant improvement in RV function in parallel with improvement in LV function in patients with only mild heart failure symptoms (NYHA I/II), low EF, and a wide QRS complex who were randomized to CRT plus implantable cardioverter-defibrillator therapy at 1 year or to implantable cardioverter-defibrillator therapy alone.[4]

Our patient had dramatically improved symptoms and quality of life soon after biventricular pacing. The key data supporting such a decision were derived from right heart catheterization. Intracardiac pressures clearly revealed primary RV failure most likely due to pacing, supported by the Kussmaul sign in the absence of LV dysfunction or

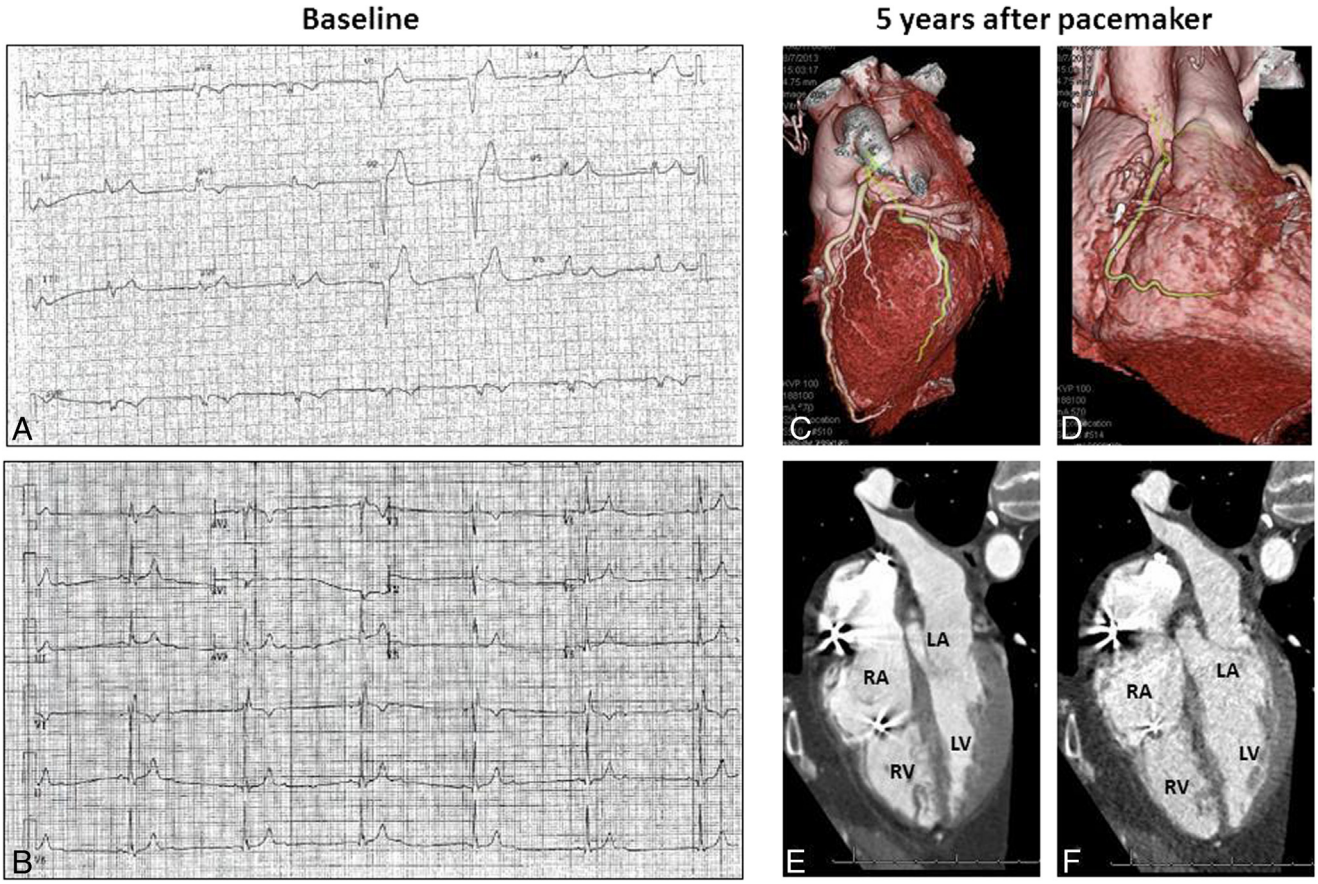
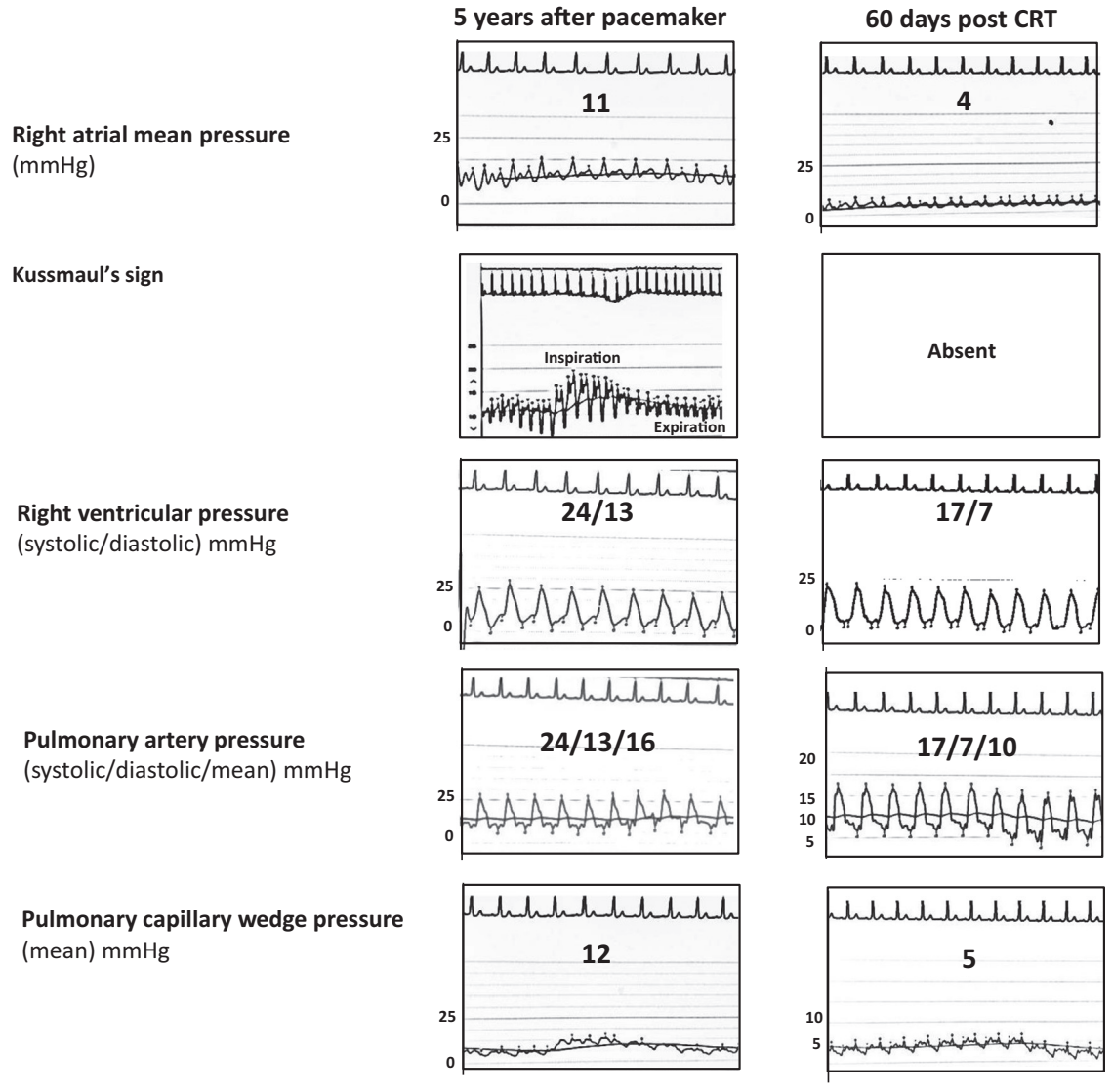


Figure 1 **Left:** baseline. ECGs of a symptomatic patient show left bundle branch block **(A)** and incomplete right bundle branch block **(B). Right:** Five years after dual-chamber pacemaker implantation. Volume-rendered dual-source computed tomographic images show plaque-free left dominant system **(C)** and nondominant right coronary artery **(D).** Four-chamber views obtained during systole **(E)** and diastole **(F)** show right-sided chamber enlargement and poor fractional shortening. Right ventricular pacemaker lead creates metal artifacts. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.



Systemic vascular resistance (dyn·s/cm^5)	1953.05	2046.35
Pulmonary vascular resistance index (dyn·s/cm^5/m^2)	1.13	1.34
Cardiac output (Thermodilution; L/min/m^2)	3.0	3.01
Cardiac index (Thermodilution; L/min/m^2)	1.56	1.57
Cardiac output (Fick; L/min)	3.55	3.74
Cardiac index (Fick; L/min)	1.85	1.95
Pulmonary artery saturation sat %	61	64
Heart rate (bpm)	69	86
Ejection fraction % (2D Echo)	50%	50%

Figure 2 Effect of biventricular pacing on right-sided hemodynamics in a symptomatic patient with preserved left ventricular ejection fraction. Five years after dual-chamber pacemaker implantation, right atrial pressure was elevated and rose further with inspiration, consistent with Kussmaul sign and underlying primary right ventricular failure. Two months after cardiac resynchronization therapy (CRT) upgrade, right-sided filling pressures normalized, Kussmaul sign was absent, but baseline low cardiac index did not respond to resynchronization therapy.

pulmonary hypertension. Repeat cardiac catheterization 2 months after resynchronization therapy showed normal right atrial and RV filling pressures and no Kussmaul sign.

The role of CRT in isolated RV dysfunction has not been reported. Our case suggests that CRT has benefits beyond LV improvement and may help other patients with preserved LV EF who develop symptomatic primary RV failure due to pacing. However, more studies are required before we can recommend a change in future guidelines.

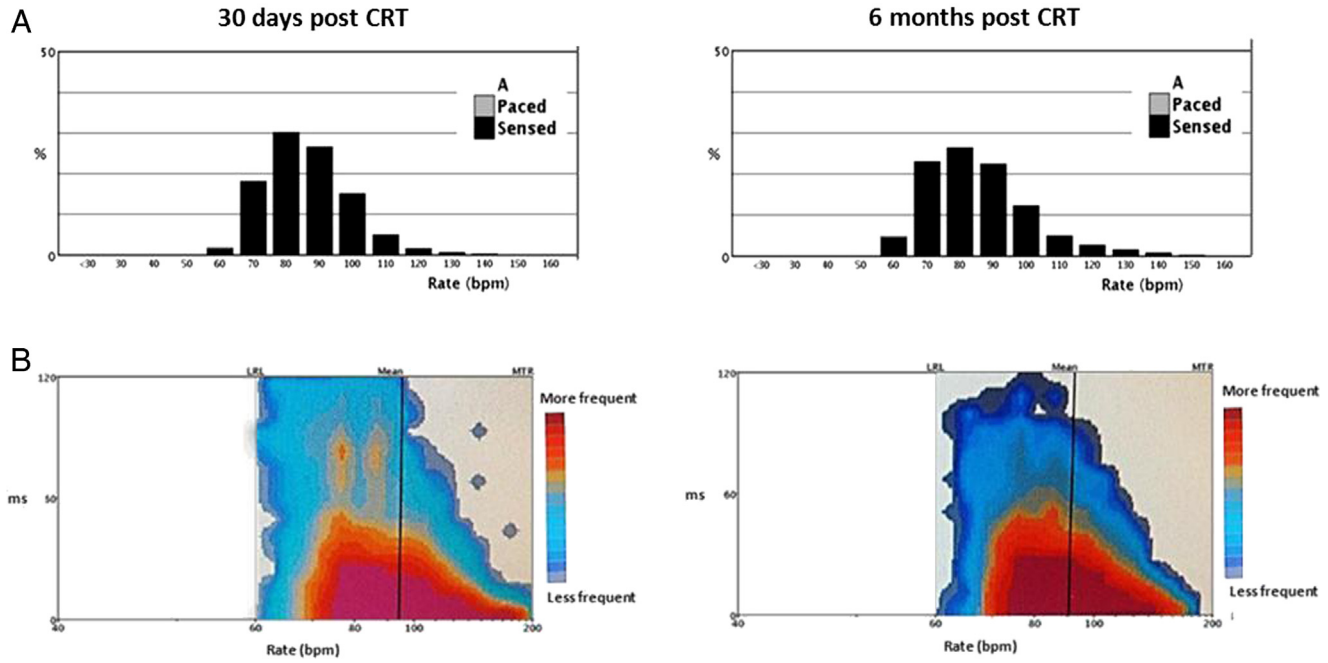


Figure 3 Effect of biventricular pacing on heart rate variability and sympathetic tone. **A:** Within the first month of cardiac resynchronization therapy (CRT), the majority of resting heart rates stayed within the range of 80–90 bpm. Six months later, periods of lower heart rates (60–70 bpm) significantly increased. **B:** Representative 24-hour densitometry plots show very subtle increases in heart rate variability and increases in lower-frequency rates after CRT.

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