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Original Article

Hemodynamic effects of Purkinje potential pacing in the left ventricular endocardium in patients with advanced heart failure

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ABSTRACT

Background: Various difficulties can occur in patients who undergo cardiac resynchronization therapy for drug-refractory heart failure with respect to placement of the left ventricular (LV) lead, because of anatomical features, pacing thresholds, twitching, or pacing lead anchoring, possibly requiring other pacing sites. The goal of this study was to determine whether Purkinje potential (PP) pacing could provide better hemodynamics in patients with left bundle branch block and heart failure than biventricular (BiV) pacing.

Methods: Eleven patients with New York Heart Association functional class II or III heart failure despite optimal medical therapy were selected for this study. All patients underwent left- and right-sided cardiac catheterization for measurement of LV functional parameters in the control state during BiV and PP pacing.

Results: Maximum d*P*/d*t* increased during BiV and PP pacing when compared with control measurements. This study compared parameters measured during BiV pacing with PP pacing and non-paced beats as the control state in each patient (717 ± 171 mmHg/s vs. 917 ± 191 mmHg/s, $p < 0.05$; and 921 ± 199 mmHg/s, $p < 0.005$); however, the difference between PP pacing and BiV pacing was not significant. There was no difference in heart rate, electrocardiographic wave complex duration, minimum d*P*/d*t*, left ventricular end-diastolic pressure, left ventricular end-systolic pressure, pulmonary capillary wedge pressure, or cardiac index when comparing BiV pacing and PP pacing to control measurements.

Conclusions: The hemodynamic outcome of PP pacing was comparable to that of BiV pacing in patients with advanced heart failure.

1. Introduction

Cardiac resynchronization therapy (CRT) is an important treatment for drug-refractory heart failure and left ventricular (LV) dyssynchrony. Pacing leads have often been placed at the coronary vein and right ventricle to reduce LV dyssynchrony and to improve hemodynamics in patients with heart failure. In some patients, clinicians encounter difficulties when placing leads; in approximately one-quarter of patients, there is an insufficient response to biventricular (BiV) pacing, primarily because of difficulty in accurately placing the LV lead due to patients' anatomical features, pacing thresholds, twitching, or pacing lead anchoring [1]. Some researchers have described other pacing sites that yield better hemodynamics and less dyssynchrony than BiV pacing. For example, Derval et al. attempted lateral LV wall pacing in patients with left bundle branch block pattern who were referred for CRT device implantation [2]. Van Gelder et al. reported that transseptal lead placement was useful in cases where there was difficulty in placing a coronary sinus (CS) lead [3]. Yoshida et al. reported that triventricular pacing, which uses two right ventricular leads and one LV lead, results in greater improvement in hemodynamics in patients with severe heart failure, when compared with Bi-V pacing [4], Sashida et al. reported improved LV function with His bundle pacing (HBP) in a patient with dilated cardiomyopathy due to atrial fibrillation without intraventricular conduction delay [5], However, whether these or other pacing sites are superior to conventional BiV pacing remains unclear. Some recent studies reported that BiV pacing with LV endocardial stimulation sites yield better hemodynamics and LV synchrony, compared with conventional BiV pacing. These procedures would have the benefit of lead placement in an extended area, regardless of coronary vein location, with better threshold and avoidance of twitching.

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On the other hand, it has been reported that the Purkinje network can survive in patients with ischemic or idiopathic cardiomyopathy [6], and in patients with heart failure and left bundle branch block (LBBB). In addition, idiopathic LV tachycardia that involves the Purkinje network as the circuit is characterized as showing a narrow QRS [7]. Therefore, it is conceivable that direct pacing of the Purkinje fiber or Purkinje network may show a narrow QRS, comparable to conventional BiV pacing in favor of shorter QRS duration, and lead to impulse conduction in the LV endocardium in patients with advanced heart failure. Furthermore, Purkinje fibers are widely distributed in the LV and are easy to detect. We believe that PP pacing is superior to other LV endocardial pacing in reproducibility and ability to detect the Purkinje fiber as the pacing site, even in injured myocardium, but there has been no report of direct pacing of the Purkinje network.

We hypothesized that direct pacing of the peripheral network in patients with LBBB and heart failure might lead to more physiological pacing than conventional pacing. This study was done to verify that Purkinje potential (PP) pacing is a promising strategy for resynchronization and for improving hemodynamics in such patients. The goal of the present study was to compare the effects of PP and BiV pacing on hemodynamics in patients with drug-refractory heart failure.

2. Material and methods

2.1. Study patients

The study population comprised 11 patients (eight men and three women; mean age, 62 ± 14 years) with New York Heart Association functional (NYHA) class II or III heart failure despite optimal medical therapy. The echocardiographic LV ejection fraction, as determined on two-dimensional examination, was $<35\%$, and the QRS duration was >120 ms. These patients were deemed likely to require resynchronization therapy in the near future according to guideline recommendations. Patients with atrioventricular (AV) block were excluded. This study included one patient with atrial fibrillation (AF). All patients were on stable medical therapy for chronic heart failure, including diuretics ($n=10$), spironolactone ($n=7$), β-blockers ($n=11$), angiotensin-converting enzyme (ACE) inhibitors ($n=10$), and amiodarone ($n=1$). The medication regimen was not changed in any patient for at least 3 months prior to the study. Cardiac catheterization was performed to assess the acute hemodynamic effects of BiV pacing as a feasibility study for CRT implantation. This study was approved by the local research ethics committee of Hyogo College of Medicine Hospital, and patients provided written, informed consent to participate.

2.2. Cardiac catheterization

Left- and right-side cardiac catheterization was performed in all patients to assess LV function. A temporary electrode catheter was introduced into the high right atrium (HRA), and ventricular pacing catheters were placed at the right ventricular apex (RVA), coronary sinus, and LV epicardial wall. Another electrode catheter was positioned in the LV endocardium to detect the PP via the aorta. A PP was defined as a sharp, brief, high frequency potential swing in the periphery (Fig. 1). The PP pacing site was defined as the site at which the PP was detected (Fig. 2), most typically at the left posterior fascicle of the left ventricle. The LV lead was positioned mainly in the lateral branch of the coronary vein.

A 5-Fr high-fidelity micromanometer-tipped pigtail angiographic catheter (Millar Instruments Inc., Houston, TX, USA) was placed in the LV cavity via the femoral artery approach in order to determine LV pressure, as previously reported [8,9]. The micromanometer pressure was adjusted to the pressure of the fluid-filled lumen. LV pressure signals were digitized and analyzed on a computer system. Pulmonary capillary wedge pressure (PCWP) and cardiac index (CI) were measured with a Swan-Ganz catheter placed in the proximal pulmonary artery via the femoral vein. Fig. 2 illustrates the placement of the catheters.

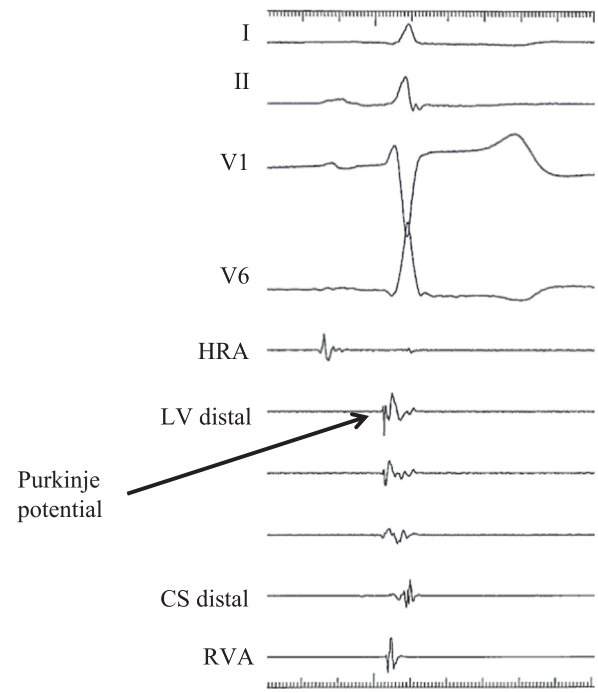

Fig. 1. Purkinje potential (PP pacing) was defined as a sharp, brief, high frequency potential swing in the periphery.

2.3. Study protocol

Six LV functional parameters were measured in the control state and during BiV and PP pacing in each patient: maximum (max) dP/dt (+dP/dt), minimum (min) dP/dt (−dP/dt), LV peak systolic pressure (LVP), LV end-diastolic pressure (LVEDP), PCWP, and CI. All parameters were measured three times in each pacing state. Typical surface electrocardiograms in the control state and during BiV and PP pacing are shown in Fig. 3. After control state measurement, BiV and PP pacing state measurements were done. The order of BiV and PP pacing was switched with each case to avoid confounding factors.

If the sinus rhythm rate was under 75 bpm, the control state was measured under atrial pacing (Ap: sinus rate + 10 to 20 bpm), and the BiV and PP pacing states were measured under the same pacing rate (ApVp: AV sequential pacing).

If the sinus rhythm rate was above 75 bpm, the control state was measured under sinus rhythm, and the BiV and PP pacing states were measured under atrial sensing ventricular pacing (AsVp).

Patients with AF underwent ventricular pacing. Measurements were collected in the non-paced state and at each pacing condition for 5 min, after 3 min of hemodynamic stabilization. AV delay was generally 150 ms in patients with a normal PQ duration, and ventricular pacing was performed with a shorter AV delay (<150 ms) in patients with a short PR duration. There was no adjustment for interventricular (VV) delay because of a limitation of time in this study.