Right Ventricular Lead Ring Capture in Sequential Biventricular Pacing with Pseudo-bipolar Left Ventricular Lead Configuration: an Unwanted Effect

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We report here on three patients who underwent biventricular pacing (BVP) for severe heart failure and the problems encountered with pseudo-bipolar left ventricular (LV) lead configuration. With this configuration, right ventricular anode capture with simultaneous biventricular stimulation was noted at higher output during the isolated LV pacing mode in these patients, which forced us to program the LV pacing to unipolar configuration in one patient. The implication of this phenomenon in sequential BVP therapy is discussed. *(Chang Gung Med J 2007;30:178-83)*

Key words: heart failure, sequential biventricular pacing, left ventricle, pseudo-bipolar configuration

Biventricular pacing (BVP) is effective in patients with severe congestive heart failure (CHF) and ventricular dyssynchrony. It improves the hemodynamic status acutely,[1] as well as heart failure symptoms, exercise capacity, quality of life and morbidity.[2,3] To achieve a favorable outcome with BVP, left ventricular (LV) pacing is mandatory in the majority of patients. The current preferred approach for LV pacing is through the coronary sinus (CS) tributaries by transvenous access. In recent years, several lead systems have been developed by different manufacturers for effective LV pacing through the CS. However, there are certain drawbacks with some of these leads. We report here, three patients who underwent sequential BVP for drug refractory CHF symptoms and the problem encountered with LV pacing in pseudo-bipolar LV lead configuration, i.e. LV lead tip electrode as the cathode and right ventricle (RV) lead proximal ring electrode as the anode (Fig. 1), and its implications in the delivery of sequential BVP, which is the currently preferred mode of BVP therapy.

CASE REPORTS

Case 1

A 63-years-old male patient with a diagnosis of ischemic cardiomyopathy and severe LV dysfunction had a history of dyspnea on exertion of New York Heart Association (NYHA) function class IV. The patient also had an associated problem of chronic renal failure for which he underwent regular hemodialysis. His electrocardiogram (ECG) showed sinus rhythm, left bundle branch block (LBBB) pattern QRS of 0.16 sec duration and PR interval of 0.20 sec. His echocardiogram showed a left ventricu-

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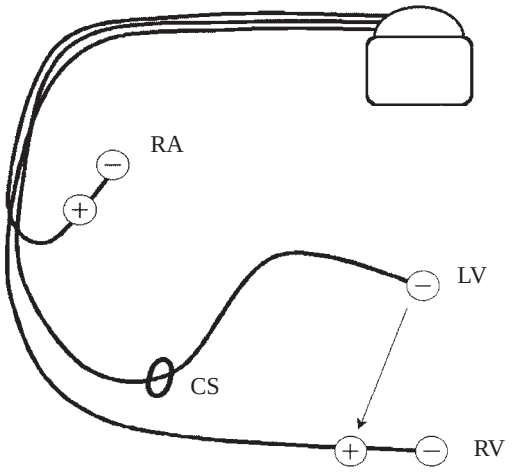

Fig. 1 Pseudo-bipolar LV lead configuration: cathode (-) in the LV lead tip (arrow) positioned in the cardiac vein against anode (+) in the endocardial RV lead.
LV: left ventricle; RV: right ventricle; RA: right atrium; CS: coronary sinus.

lar ejection fraction (LVEF) of 20%. In view of uncontrolled CHF symptoms with optimal medical treatment, the patient was subjected to BVP.

The patient was given active fixation leads (TENDRIL SDX 1688, St Jude Medical, Sylmar, CA, U.S.A.) at the right atrial (RA) appendage and high RV septum, for pacing and sensing the respective chambers. The LV lead (Attain 4193, Medtronic Inc., Minneapolis, MN, U.S.A.) was positioned in the posterolateral cardiac vein through the CS. Acute lead testing showed the capture threshold of both RA and RV leads was < 0.5 V at 0.50 ms pulse width (PW). The capture threshold of the LV lead unipolar pacing was 1.0 V at 0.50 ms. With pseudo-bipolar configuration, the LV lead capture threshold was 0.6 V at 0.50 ms and the RV ring capture threshold was noted at 4.0 V (PW 0.50 ms). The surface ECG during LV pacing alone at the output of 4.0 V (PW 0.50 ms) and above showed changes of QRS morphology with capture of RV ring and simultaneous BVP (Fig. 2A). The leads were connected to the pulse generator (PG) (InSync III 8042, Medtronic Inc.) and sequential BVP was initiated with LV pacing at an amplitude of 1.5 V (PW 0.50 ms) in pseudo-bipolar configuration and interventricular pacing delay of 24 ms with LV pacing first followed by RV pacing. The patient had a significant improvement of his symptoms at the 1 month follow-up.

Case 2

A 73-year-old female patient presented with progressive dyspnea (NYHA Class III) of 3 years duration. She underwent coronary artery bypass surgery along with mitral valve replacement 4 years ago. Her ECG showed sinus rhythm, a PR interval of 0.16 sec and LBBB with QRS duration of 0.14 sec. Her echocardiogram showed dilated LV with global hypokinesia, an LVEF of 16% and fair mitral prosthetic valve function. BVP was considered because of drug refractory CHF.

Active fixation bipolar leads (CapSureFix Novus 5076, Medtronic Inc.) for RA and RV were deployed at the RA appendage and high RV septum. The LV lead (Attain 4193, Medtronic Inc.) was positioned in the posterior cardiac vein. The RA and RV lead parameters were within acceptable ranges. The LV lead showed a capture threshold of 2.5 V at PW 0.50 ms in unipolar mode. With pseudo-bipolar configuration, the LV lead capture threshold was 2.5 V (PW 1.0 ms) and the RV lead ring capture threshold was 5.0 V (PW 1.0 ms) in LV pacing mode. The change of QRS morphology on the ECG between simultaneous BVP caused by RV ring capture and pure LV pacing is shown (Fig. 2B). In view of this finding, the LV lead parameters were programmed in the PG (InSync III 8042, Medtronic Inc.) to unipolar configuration with an output of 5.0 V (PW 1.0 ms) and an interventricular delay of 16 ms in sequential BVP mode. The patient continued to maintain symptomatic improvement at the 6 months follow-up.

Case 3

A 67-year-old female patient suffering from dilated cardiomyopathy with progressive CHF symptoms (NYHA Class IV) despite adequate medical treatment was considered for BVP. Her ECG showed sinus rhythm, LBBB with QRS duration of 0.14 sec and a PR interval of 0.20 sec. The echocardiogram showed dilated cardiac chambers with an LVEF of 25%. To initiate BVP, passive fixation leads (CapSure Z Novus, 5554 and 5054, Medtronic Inc.) were deployed at the RA appendage and RV apex, and the LV lead (Attain 4189, Medtronic Inc.) was positioned in the lateral cardiac vein. The RA and RV leads showed satisfactory lead parameters. The

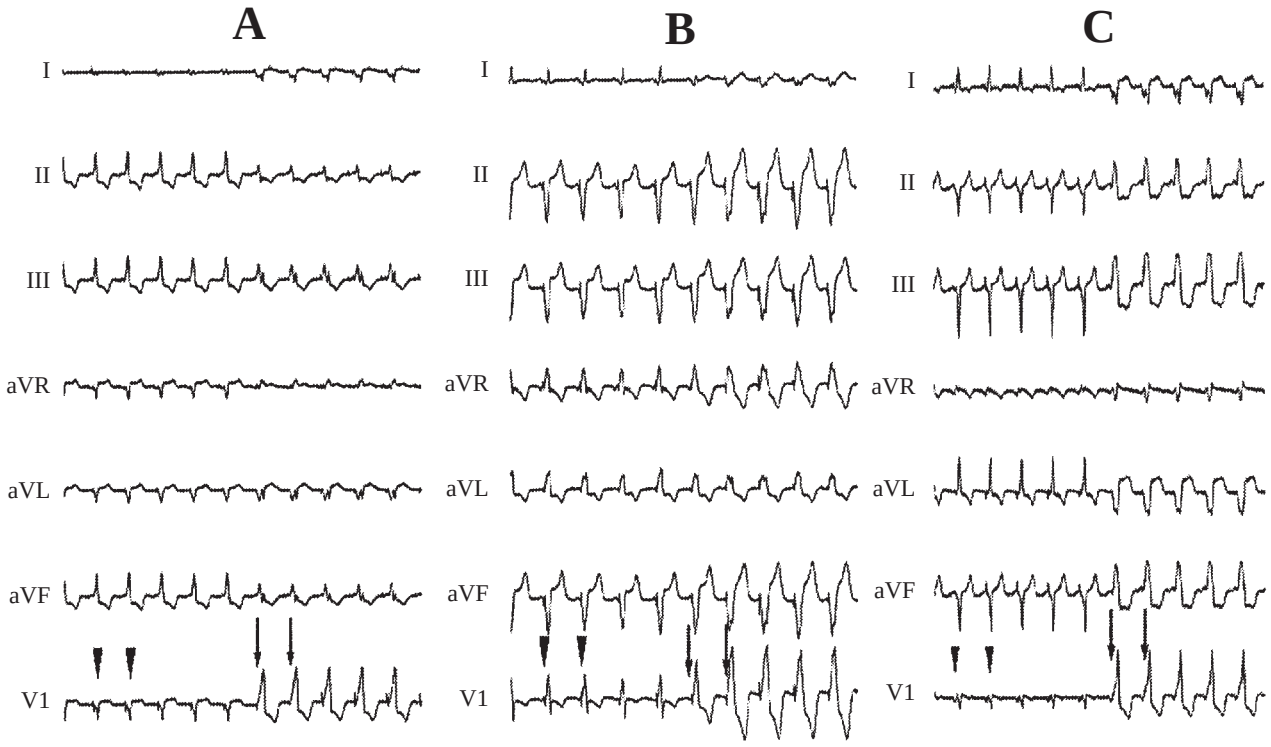

Fig. 2 Surface ECGs (A, B, C) of the patients under discussion during LV lead threshold testing in pseudo-bipolar configuration showing simultaneous biventricular capture (arrow heads) at higher amplitude and isolated LV capture at lower amplitude (arrows). ECGs: electrocardiograms; LV: left ventricle.

LV lead threshold in unipolar configuration was < 0.5 V (PW 0.50 ms). In pseudo-bipolar configuration, the LV lead showed a capture threshold of 0.5 V (PW 0.50 ms), and the RV ring capture with simultaneous pacing of RV and LV was noted at 3.0 V (PW 0.50 ms). The change of QRS morphology between simultaneous BVP due to RV ring capture and pure LV pacing is shown (Fig. 2C). The LV lead parameters programmed in the PG (InSync III 8042, Medtronic Inc.) were 1.5 V (PW 0.50 ms) in pseudo-bipolar configuration and sequential BVP mode. The patient had marked improvement of symptoms with BVP.

DISCUSSION

Currently available CS leads are of unipolar or bipolar configuration. In comparison with bipolar leads, unipolar ones are of smaller diameter, which facilitates the over-the-wire technique, and makes it easier to reach the tortuous and distal target sites in the cardiac veins. Although anodal capture may occur with high output in traditional bipolar endocardial RV pacing, this phenomenon is not discernible on the ECG.[4] Usually, a unipolar lead for LV pacing via a coronary vein is used in BVP. In pseudo-bipolar configuration, the tip electrode of the LV lead is the cathode and the proximal ring electrode of the bipolar RV lead is the anode for LV pacing. This creates a common anode for RV and LV pacing leads. This configuration allows for extended bipolar pacing of the LV lead and limits sensing to the heart, thereby avoiding myopotential oversensing or muscle stimulation that can happen with unipolar pacing. A high current density from two sources at the common anode during BVP may cause anodal capture manifesting with a different QRS morphology from that of pure BVP.[5] Anodal capture involving the ring electrode of the bipolar RV lead can also occur during monochamber LV pacing at a relatively high out-

put, as noted in all 3 of our patients. The QRS morphology with RV ring capture during pure LV pacing may be similar to that of BVP but the RV and LV are activated simultaneously rather than sequentially. In sequential BVP, there is a programmed inter-ventricular delay. Sogaard et al.,[6] in their study of BVP in patients with severe CHF and LBBB, noted that both LV systolic and diastolic functions improved more significantly with sequential BVP compared to simultaneous BVP.

Vogt et al.,[7] in their acute hemodynamic study and long term follow-up of 165 patients receiving BVP, reported that 33% of their patients showed significant improvement in hemodynamics as well as prognostic parameters at 1 year with only atrio-left ventricular stimulation rather than atrio-biventricular stimulation. Adding a RV apical stimulation completely reversed the beneficial effect of BVP in some patients. The different response to BVP versus LV pacing in some patients could demonstrate that the pacing site selection alone may be responsible for a patient being a responder or non-responder. In pseudo-bipolar pace setting, pure LV stimulation may not always be possible because a higher amplitude safety margin with this mode may create BVP rather than LV pacing alone. In the acute phase following LV lead implantation, a higher amplitude safety margin (3 times the basal threshold value) may be preferred for stable LV pacing. This may cause RV ring capture in pseudo-bipolar LV lead configuration at higher amplitudes, resulting in simultaneous BVP even in sequential BVP mode. This was clearly demonstrated in our case 2: in acute phase, and even after 6 months of sequential BVP therapy, the LV pacing was forced to be kept in unipolar mode to keep an adequate pacing amplitude safety margin and avoid simultaneous BVP.

When checking the LV lead capture threshold in pseudo-bipolar configuration, gradually decreasing the output from a high level and monitoring ECG morphology changes in more than one lead are essential to identify RV ring capture and simultaneous BVP. Programming the output of the LV lead meticulously, changing the LV lead to unipolar pacing configuration or utilizing a true bipolar lead for LV pacing could resolve the problem.

With the growing evidence that a significant survival benefit exists in CHF patients receiving a combined device of cardiac defibrillator and BVP,[8] more CHF patients will be offered this combined device in the future. If this is the case, LV unipolar pacing may become obsolete and pseudo-bipolar LV lead pacing with RV ring capture at higher output may cause potential problems in delivering effective BVP therapy. True bipolar LV leads are advantageous in these patients if selective LV pacing is required for hemodynamic reasons or the interventricular delay needs to be adjusted.

In conclusion, we presented here the pitfalls associated with LV pacing in pseudo- bipolar configuration in patients with sequential BVP and the possible limitations in delivering effective pacing therapy with this configuration in this group of patients.

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利用左心室導線僞雙極組態進行循序式雙心室刺激而造成右心室導線陽極環起搏：一種需注意之現象

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在本文中，我們報導了三位因爲嚴重心衰竭而接受雙心室節律器治療的病人。他們都利用左心室導線僞雙極組態來進行治療，卻發生了問題。在這種組態之下，當左心室導線的輸出較高時，右心室導線的陽極環也會起搏，形成同步雙心室刺激，而非我們想要的循序式雙心室刺激。這種情形迫使我們必須把其中一位病人的左心室導線改爲單極組態。這種現象的臨床意義將在文中詳細討論。(長庚醫誌 2007;30:178-83)

關鍵詞：心衰竭，循序式雙心室刺激，左心室，僞雙極組態

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