How to define setup channels for an electrophysiological recording system in left bundle branch pacing

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DOI: 10.33963/KP.a2023.0033

Received:
June 13, 2022

Accepted:
January 22, 2023

Early publication date:
January 29, 2023

INTRODUCTION

In the present study, we used an electrophysiological recording system to record an intracardiac electrogram (EGM) and an electrocardiogram (ECG) in left bundle branch pacing (LBBP). In the process, we used clipping, high pass, and low pass settings. ECG morphology changes were evaluated using different signal trace setup conditions. Recently, our group reported on a novel LBBP lead implantation technique assisted by John Jiang's connecting cable [1] to record an isoelectric interval in the pacing lead as an endpoint for lead implantation with continuous monitoring of paced EGM [2]. An isoelectric interval was used as a criterion to confirm selective left bundle branch (LBB) capture [3]. This study discusses how to define setup channels for an intracardiac electrogram for observing isoelectric interval to determine the depth of the lead to avoid perforation.

METHODS

All patients underwent a novel LBBP procedure guided by recording an isoelectric interval as an endpoint for lead implantation using the continuous pacing and recording technique, which had been described in detail elsewhere [2], at Hwa Mei Hospital, University of Chinese Academy of Sciences from May 2021 to January 2022. All procedures involving human participants were performed in accordance with the ethical standards of the institutional research committee and the Helsinki Declaration (as revised in 2013). Written informed consent for publication of this study and any accompanying images was obtained from the patients.

We consider LBB capture as present when the isoelectric interval was observed and the shortest and constant V6 R-wave peak time (V6 RWPT) was measured [2]. If these criteria were not met, we diagnosed left ventricular septal pacing (LVSP).

The isoelectric interval was defined as the segment from the pacing stimulus to discrete ventricular deflection on EGM. An isoelectric interval was categorized into two EGM morphologies as follows: (1) superior oblique or downsloping with no notch after the pacing spike (generally in the initial time after implantation because of currency of injury); (2) a horizontal segment after the pacing spike (generally a period after implantation because of recovery from injury).

All EGM morphologies were analyzed independently by two physicians, and in the absence of consistency between the two observers, a third physician adjudicated the results. ECGs and EGMs of adjacent beats were monitored and recorded during transseptal placement of the pacing lead in real time. The differences in morphologies were retrospectively compared and analyzed under different high pass filters (30 Hz, 60 Hz, 100 Hz, 200 Hz) and low pass filters (300 Hz, 500 Hz) to identify the most favorable setup criteria for LBB capture with an electrophysiological recording system (EP-WorkmateV4.3.2, St. Jude Medical, St. Paul, MN, US). For each patient, the sweep speed was 150 mm/s. The clipping was set at 3 cm, and the amplitude was set at 0.5 mV/cm (Figure 1).

Statistical analysis

Continuous variables were reported as mean (standard deviation [SD]). Categorical variables were expressed as percentages. The chi-square test was used to compare proportions between two or more groups. To evaluate the diagnostic accuracy of detecting discrete EGM, we calculated sensitivity, specificity, pos-

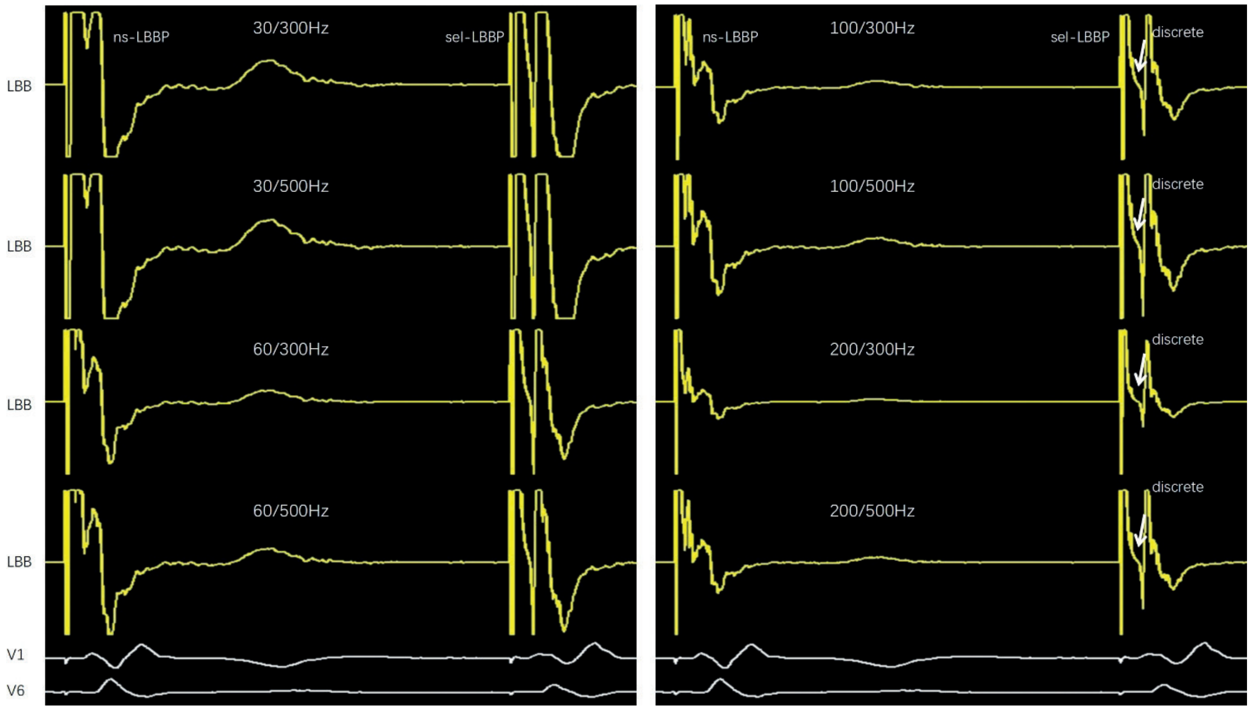

Figure 1. Paced electrocardiogram morphology changed from an "rSR'" to "M" pattern in the V1 lead, and the V6 RWPT was constant 80 ms between two adjacent beats. The isoelectric interval was apparent when the high pass filters were 100 Hz and 200 Hz and the low pass filters were 300 Hz and 500 Hz

itive predictive value (PPV), and negative predictive value (NPV) of different filter settings. Cohen's Kappa coefficient was measured by inter-rater agreement for categorical items. A *P*-value of <0.05 was considered significant. Statistical analysis was performed using IBM SPSS Statistics for Macintosh (version 26.0, IBM Corp, Armonk, NY, US).

RESULTS AND DISCUSSION

Seventy-seven patients at the average age of 71.1 (9.1) years were consecutively enrolled in the study from May 2021 to January 2022, and 39 (50.6%) were females. Evidence captured by the LBB systems was successfully obtained in 70 patients (90.9%). In seven patients, LVSP was diagnosed due to the inability to capture LBB. Pacing indications included sick sinus syndrome in 35 patients, atrioventricular block in 40 patients, and cardiac resynchronization therapy (CRT) in 2 patients. Of the 77 subjects, 20 had heart failure, 45 had atrial fibrillation, 3 had dilated cardiomyopathy, and 1 had hypertrophic cardiomyopathy.

In the 77 patients, the occurrence rates of discrete EGM were 15 (19.5%), 15 (19.5%), 33 (42.8%), 33 (42.8%), 57 (74%), 57 (74%), 64 (83.1%), and 64 (83.1%) for the corresponding filter settings of 30–300 Hz, 30–500 Hz, 60–300 Hz, 60–500 Hz, 100–300 Hz, 100–500 Hz, 200–300 Hz, and 200–500 Hz. The analysis of discrete EGM detection showed significant differences between different filter settings ($X^2 = 79.652$; $P < 0.05$). Using the LBB capture as the gold standard, the results of EGMs showed that sensitivity was 23.4% and specificity was 100% for the filter settings of 30–300 Hz, 30–500 Hz. The PPV was 100%, and the NPV was 20.96%, respectively. For the filters of 60–300 Hz and 60–500 Hz, the selective LBB capture had sensitivity of 51.56% and specificity of 100%, with a PPV of 100% and an NPV of 29.55%. The filters of 100–300 Hz and 100–500 Hz had sensitivity of 89.06% and specificity of 100%, with a PPV of 100% and an NPV of 65%. The filters of 200–300 Hz and 200–500 Hz had sensitivity of 100% and specificity of 100%, with a PPV of 100% and an NPV of 100%. Cohen's Kappa coefficient was 1 ($P < 0.05$) for filters of 200–300 Hz and 200–500 Hz, while it was 0.733 ($P < 0.05$) for filters of 100–300 Hz and 100–500 Hz.

The typical EGM filter settings are 30 Hz for a high pass channel and 500 Hz for a low pass channel for a bipolar intracardiac signal [4]. The high pass filter (HPF) removes lower frequencies by allowing frequencies higher than the filter setting to pass. The higher the frequency, the less baseline drift and the more biphasic the waveforms become. The low pass filter (LPF) removes frequencies by passing frequencies lower than the filter setting. The lower the frequency, the fewer the high-frequency signals and the lower the baseline noise. Due to the clipping level limit, it does not allow the user to view the EGM signal at high amplitude — usually, the pacing spike and the current of injury of the potential were high amplitude. Therefore, in the same conditions of the clipping level limit, it can improve the legibility of isoelectric discrete intervals on EGMs with a higher HPF. In general, different LPFs affect mainly the baseline noise. LPFs have less impact on the discrete interval because the isoelectric interval was defined as the segment from the pacing stimulus to discrete ventricular deflection without a notch.

The best parameters for an electrophysiological recording system are a low pass filter set at 300–500 Hz and a high pass filter set at 200 Hz. These settings help to observe the isoelectric interval to confirm LBB capture during lead deployment.

Article information

Conflict of interest: The corresponding author owns the patent for John Jiang's connecting cable, and other authors declare no conflict of interest.

Funding: This work was supported by the Zhejiang Provincial Public Service and Application Research Foundation, China (grant no. LGF22H020009 to LFJ), the Ningbo Health Branding Subject Fund (grant no PPXK2018-01 to HHY), and the Research Foundation of Hwa Mei Hospital, University of Chinese Academy of Sciences, China (grant no 2020HMKY60 to XJC).

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