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Diagnostic accuracy of pace spikes in the electrocardiogram to diagnose paced rhythm

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Abstract

Objective: To determine how often cardiac resynchronization therapy (CRT) pacing systems generate visible pace spikes in the electrocardiogram (ECG).

Methods: In 46 patients treated with CRT pacing systems, we recorded ECGs during intrinsic rhythm, atrial pacing and ventricular pacing. ECGs were analysed for atrial and ventricular pace spikes by two experienced ECG readers blinded to the pacing therapy and to the study purpose.

Results: Atrial pacing generated visible pace spikes in less than 70% of the ECGs, whereas ventricular pacing generated visible pace spikes in about 90% of ECGs. The sensitivity of manual ECG interpretation for pace spikes was low for atrial pacing (Reader 1: 0.62 [95% confidence interval (CI) 0.50–0.74]; Reader 2: 0.65 [95% CI 0.53–0.77]) and moderate for ventricular pacing (Reader 1: 0.88 [95% CI 0.81–0.93]; Reader 2: 0.93 [95% CI 0.87–0.97]).

Conclusions: In patients with CRT pacing systems, the absence of visible pace spikes in the ECG does not rule out paced rhythm.

Keywords: Electrocardiogram; Pacemaker; Pace spike; Bipolar pacing; Diagnostic accuracy; Cardiac resynchronization therapy

Introduction

In patients presenting with acute broad complex arrhythmias, pace spikes in the electrocardiogram (ECG) are used for differentiating paced rhythm from other broad cardiac rhythms, including ventricular arrhythmias. It has become increasingly difficult, and not always possible, to detect pace spikes in the ECG due to the very small pacemaker pulse amplitudes generated by the modern bipolar pacemakers [1].

The use of modern bipolar pacemakers is rapidly increasing after cardiac resynchronization therapy (CRT) has become a recognized treatment for patients with heart failure and left bundle branch block [2–7]. Manual ECG interpretation is still the preferred diagnostic tool to determine the heart rhythm in these patients, also in emergency settings.

The problem to detect pace spikes in the ECG is well recognized among clinicians. Despite this, it is currently unknown how often modern bipolar pacemakers generate visible pace spikes in the ECG and what the diagnostic accuracy of manual ECG interpretation to diagnose paced rhythm is nowadays. This is problematic and challenges diagnosis and treatment in the acute setting in patients with broad complex arrhythmias.

We aimed to study how often modern bipolar pacemakers generate visible pace spikes in standard 12-lead ECGs obtained from patients with modern CRT pacing systems. Further, we aimed to evaluate the diagnostic accuracy of pace spikes in the ECG to diagnose paced rhythm.

Methods

Patients

In this prospective, clinical study, we included patients with CRT pacing systems (CRT-Pacemaker [CRT-P] or

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CRT-Defibrillator [CRT-D] systems), with pace leads in both atrium and ventricles, since these systems offer a large variety of optional pacing modalities. We identified all patients with CRT systems (St. Jude Medical) and in-hospital follow-up in June 2011 at the pacemaker and ICD outpatient clinic at the Department of Cardiology, Copenhagen University Hospital, Rigshospitalet, Denmark. Eligible patients were invited to participate in the study when attending their yearly routine pacemaker control. Patients were excluded if they were hemodynamically unstable to an extent that they could not undergo a complete pacemaker control, as evaluated by the clinical physician, or if they did not wish to participate in the study.

All patients were asked to fill out a questionnaire containing information on age, gender, smoking habits, and information regarding hypertension, hypercholesterolemia, previous myocardial infarction, diabetes, current medication and etiology of heart failure. Medication was grouped according to indication as presented in Table 1.

Pacemaker programming

During the routine pacemaker control we programmed the pacemaker to the following six different pacing modes: no pacing (own intrinsic rhythm), atrial pacing only, right ventricular pacing (RV) only, left ventricular pacing (LV) only, biventricular pacing (BIV) and atrial pacing followed by BIV pacing. For the paced rhythms, the pacing rate was set slightly above the intrinsic heart rate to overrule the intrinsic rhythm. We registered pacemaker output settings of pulse amplitude (voltage [V]) and pulse width (milliseconds [ms]) for the atrial, right ventricular and left ventricular pacemaker lead, respectively. Knowledge about the programmed pacing mode was used to determine the true underlying cardiac rhythm with respect to whether this was an intrinsic or paced rhythm.

Table 1
Clinical characteristics of the study population.

	Patients (n = 46)
Male gender, no. (%)	34 (74)
Age, y (range)	65 (46–85)
Etiology of heart failure, no. (%)	
Ischemic heart disease	22 (48)
Dilated cardiomyopathy	24 (52)
Cardiac risk factors, no. (%)	
Previous myocardial infarction	21 (46)
Hypertension	21 (46)
Hypercholesterolemia	20 (44)
Diabetes	13 (28)
Smoker or previous smoker	32 (70)
ECG characteristics	
PR interval (ms)	200 (100–300)
QRS interval (ms)	150 (90–210)
QTc interval[a] (ms)	480 (400–560)
Left bundle branch block, no. (%)	31 (67)
Right bundle branch block, no. (%)	7 (15)
Intermittent bundle branch block[b] (%)	4 (9)
Medication, no. (%)	
Antiarrhythmic (class I-IV)	40 (87)
Antihypertensive	39 (85)
Antithrombotic	34 (74)
Antidiabetic	9 (20)
Diuretics	37 (80)
Cholesterol lowering medication	24 (52)
Psychiatric drugs	1 (2)
Others	31 (67)

Data are presented as numbers (%) or mean (95% confidence interval) unless otherwise indicated. Values for ECG characteristics are given during intrinsic rhythm and based on intervals determined by manual measurements.

No., numbers; ms, milliseconds.

[a] Corrected QT interval (QTc), Bazett's formula = (QT interval)/(√RR interval).

[b] No bundle branch block at the time of ECG recording.

ECG recording and analysis

We aimed to record one 12-lead ECG for each pace mode in all study subjects, i.e., 6 ECG recordings for each patient. ECGs were digitally recorded using CardioSoft™ Diagnostic System Resting ECG, version 6.61, CAM-14 (GE Healthcare, UK). The ECG recorder was set to 25 mm/s and calibrated at 1 mV/cm. The high frequency (low pass) filter was set to 150 Hz, which is the recommended setting by The American Heart Association [1]. The sampling rate used was 500 Hz. The pace enhancement function was inactivated in order to imitate a daily clinical setting in an emergency department or other non-specialized departments where activation of the pace enhancement function is often not considered.

The ECGs were randomly assigned a case number and presented in a randomly distributed order. We removed any patient identifiers and the automatic computer algorithm readings from the ECGs. All ECGs were independently analysed by two persons highly experienced in ECG interpretation (Reader 1 [M.T.] and Reader 2 [T.B-S.]). The ECG readers were fully blinded to the purpose of the study and the pacing mode. The readers were asked to focus on general systematic ECG analysis and analysed the ECGs manually for heart rhythm, interval durations (PR, QRS, RR, QT and QTc), QRS morphology, concordance and presence of pace spikes (yes/no). In the presence of pace spikes, the readers were instructed to register all ECG leads with pace spikes and note the lead with the maximum amplitude of the pace spike. Paced rhythm was diagnosed in the presence of pace spikes. We also registered the ECG rhythm proposed by the computerized ECG reading algorithm output.

Statistical analysis

Numerical data are presented as mean and standard deviation (SD) or median and interquartile range (IQR) where appropriate. Categorical data are presented as numbers and percentages. To evaluate the diagnostic accuracy of manual ECG interpretation for detecting pace spikes, we calculated sensitivity, specificity, predictive positive and negative values, likelihood-ratios (LR) and area under the receiver operating characteristic (ROC) curve. The pacing mode that the pacemaker was programmed to during the ECG recording was used as the golden standard of the heart rhythm. The inter-rater agreement for detection of pace spikes between the two readers was evaluated with Cohen's kappa coefficient (κ). To test the correlation between pacemaker output settings