Role of Surface Electrocardiograms in Patients with Cardiac Implantable Electronic Devices

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KEYWORDS

• Electrocardiogram • Cardiac pacing • Pacemaker • Implantable cardioverter-defibrillator • Cardiac resynchronization • Pacing mode • Cardiac arrhythmias • Syncope

KEY POINTS

- Surface electrocardiograms play an essential role in establishing indications for cardiac implantable electronic devices, and in the evaluation of patients already implanted.
- Surface electrocardiograms remain the critical tool to detect device malfunction, evaluate programming and function, verify the automatic arrhythmia analysis and the delivered electric therapy, and prevent inappropriate intervention.
- For a correct interpretation of the surface electrocardiograms (both baseline 12-lead and ambulatory) it is mandatory to have information on the cardiac implantable electronic device characteristics and programming.
- Ambulatory monitoring can be useful in patients with symptoms suggestive of device malfunction when routine device interrogation does not reveal the reason for the corresponding clinical symptoms.

INTRODUCTION

Surface electrocardiograms (ECGs), both baseline 12-lead ECG and ambulatory ECG monitoring (AECGM), not only play an essential role in establishing indications for pacemaker (PM) implantation, but also for the evaluation of patients with cardiac implantable electronic devices (CIED). Current CIEDs (PMs, implantable cardiac defibrillators [ICDs], and cardiac resynchronization devices [CRTs]) have prolonged memory capabilities (often defined as Holter functions) and remote monitoring capabilities, allowing the evaluation of electrical properties and detection of arrhythmias.[1–5] Nonetheless, the availability of sophisticated self-analysis and prolonged memory capabilities cannot replace the analysis of surface ECG, which remains critical to detect device malfunction, evaluate the device programming and function, verify the arrhythmia analyses, and minimize the risk of inappropriate interventions.[6–10]

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Over the years, CIEDs evolved considerably from simple life-saving PMs to highly sophisticated multichamber devices performing near-physiologic stimulation and complex arrhythmias analysis and, in the case of ICDs, delivering antitachycardia therapy. Several automatic algorithms have been developed from the "rate-responsive (R-R) function," adapting the heart rate response during physical activity through special sensors; to the "minimizing ventricular pacing" function, favoring the emergence of spontaneous beats, to the "rate-smoothing" functions, reducing the cycle length fluctuations in case of frequent supraventricular or ventricular arrhythmias and of heart rate drops, to prevent symptoms and arrhythmogenesis. The knowledge of those complex functions is crucial to evaluate the correct function of the devices and to avoid erroneous diagnosis of device malfunctions.

Finally, in the last decades, CRT devices aimed to resynchronize the left ventricular mechanical activity in heart failure patients have been developed, and according to the current guidelines, the surface ECG is the essential tool to identify patients eligible for a CRT procedure, and to verify the correct function of CRT systems.[2,8,9]

ROLE OF SURFACE ELECTROCARDIOGRAMS TO ESTABLISH INDICATIONS FOR CARDIAC IMPLANTABLE ELECTRONIC DEVICE IMPLANTATION

Surface ECG plays a crucial role in the identification of patients requiring CIED—PM, ICD, and CRT.[1,2,8] Specifically, AECGM monitoring may provide valuable information regarding the type of device to be implanted in terms of single versus dual chamber. As examples, DDD pacing with preferential algorithms to minimize ventricular pacing (MVP) may be preferred in patients with sick sinus syndrome with preserved A-V conduction. The detection of frequent, even asymptomatic, episodes of atrial arrhythmias and/or bradyarrhythmias in patients referred for an ICD implantation may suggest that a dual chamber device should be preferred, because these patients may require permanent pacing if antiarrhythmic drugs are to be administered during follow-up, or for tracking the tachyarrhythmia burden, for better discrimination of supraventricular versus ventricular tachyarrhythmias. AECGM may also be useful in CRT candidates, particularly in patients with permanent persistent atrial fibrillation, in whom the analysis of the ventricular rate response can contribute to optimize the response to biventricular pacing. In patients with poorly controlled ventricular response, A-V node ablation may be recommended at the time of or after CRT implantation, the so-called ablate-and-pace strategy.[1,2,8]

ELECTROCARDIOGRAPHIC METHODOLOGIES USED IN THE EVALUATION OF PATIENTS WITH CARDIAC STIMULATION

The main ECG modalities to evaluate the correct CIED function are the following.

a. Baseline 12-lead ECG, alone or in conjunction with the use of device programmer, remains the starting point of every electrophysiologic investigation in patients with CIEDs, because it can provide critical and immediate information on the basic functions of pacing and sensing and on the type of pacing mode.[1–4]
b. AECGM, or Holter monitoring, lasting from 24 hours to several days, and recently up to 3 to 4 weeks, can be useful to correlate symptoms suggestive of arrhythmias or device malfunctioning, or to optimize the device programming.[6,7,9] AECGM is no longer used as a routine test after CIED implantation, owing to the availability of sophisticated autoanalysis algorithms. Myopotential inhibition, crosstalk, and PM-mediated tachycardia (PMT), that is, the PM disfunctions more frequently detected by AECGM, are now less frequently encountered, and may be detected and notified by remote monitoring.[5,10] AECGM can also contribute to the evaluation of the correct performance of advanced systems, such as sequential A-V pacing systems with special rate-adaptive pacing algorithms, or ventricular resynchronization systems with biventricular stimulation.[6–10]
c. ECG monitoring during exercise stress testing is rarely used nowadays in the current evaluation of patients with cardiac stimulation, and it is mainly used to verify the correct programming of rate adaptive algorithms.
d. Remote CIED control is now the technique of choice to monitor the patients with CIEDs, allowing the timely detection of changes in the pacing and sensing functions, the identification of electrocatheter malfunctions, the evaluation of the correct diagnosis and therapies of supraventricular and ventricular arrhythmias, and the performance of CRT functions.[5,8,10]

BASIC PRINCIPLES OF INTERPRETATION OF SURFACE ELECTROCARDIOGRAMS IN PATIENTS WITH A CARDIAC IMPLANTABLE ELECTRONIC DEVICE

Most current CIEDs include the ability to sense and/or stimulate both the atrial and ventricular chambers. When the device does not detect a heartbeat within a predefined interval, it