

## REVIEWS

# The principles of analysing the archived electrograms recorded from implanted cardiac defibrillators

Mona Musteata<sup>1,2</sup>, Radu Ciudin<sup>1,2</sup>, Gabriela Silvia Gheorghe<sup>2,3</sup>, Carmen Ginhina<sup>1,2</sup>, Tiberiu Nanea<sup>2,3</sup>

**Abstract:** The electrograms are recordings produced by changes in the electric potential of the heart, taken directly from the surface by unipolar or bipolar leads. When interrogating the implantable cardiac devices, the archived electrograms can bring valuable information about the evolution of the patient and the device itself.

The nowadays implanted cardiac defibrillators (ICDs) have complex algorithms to sense, identify and analyze the arrhythmias in order to treat them by delivering electric shocks.

Antitachycardia pacing (ATP) refers to the use of pacing stimulation techniques for termination of tachyarrhythmias. Such techniques can be automatically applied using implantable ICDs and offer the potential for painless termination of ventricular tachycardia (VT). There are also potential proarrhythmic effects of the ATP.

There can be multiple sorts of ICD malfunction: undersensing, oversensing or other malfunctions due to electromagnetic interferences, noise artefacts secondary to fractured lead, profound respiratory movements.

The ICDs malfunction due to incorrect programming of the devices or to environmental hazards may lead to several situations that request specific solutions.

**Keywords:** archived electrograms recorded from ICDs, antitachycardia pacing, ICD malfunction, ventricular tachycardia, ventricular fibrillation

**Rezumat:** Electrogramele intracavitare sunt înregistrări ale potențialelor electrice de la nivelul cordului, înregistrări efectuate cu sonde unipolare sau bipolare.

La interogarea dispozitivelor cardiace implantabile, electrogramele arhivate în aceste dispozitive aduc informație valoroasă despre evoluția pacientului și despre dispozitiv în sine.

Defibrilatoarele implantabile (ICD) folosite acum funcționează pe baza unor algoritmi complecși, pentru identificarea și analizarea evenimentelor aritmice în vederea administrării de șoc electric intern la nevoie.

Pacingul anti-tahicardic se referă la utilizarea unor tehnici de tip overdrive, în vederea stopării unui eveniment tahiaritmic; această tehnică poate fi aplicată automat de către defibrilatorul intern în vederea unei defibrilări eficiente și nedureroase.

Pacingul anti-tahicardic poate avea, la rândul său, efecte pro-aritmogene.

Există mai multe tipuri de disfuncții de ICD: undersensing, oversensing sau alte probleme cauzate de interferențe electromagnetice, artefacte secundare unei fracturi de sondă, mișcări respiratorii profunde.

Disfuncția de ICD secundară unei programări inadecvate sau unor interferențe exterioare, conduce la soluții specifice pentru probleme specifice.

**Cuvinte cheie:** electrograme arhivate în memoria defibrilatoarelor implantabile, pacing anti-tahicardia, disfuncție de ICD, tahicardie ventriculară, fibrilație ventriculară

## INTRODUCTION

The electrograms are recordings produced by changes in the electric potential of the heart, taken directly from the surface by unipolar or bipolar leads. Intracardiac electrograms are recorded from the right atrium

(RA), coronary sinus (CS), His bundle and right ventricular apex (RVA)<sup>1</sup>.

When interrogating the implantable cardiac devices, the archived electrograms can bring valuable information about the evolution of the patient and the device itself<sup>2</sup>.

<sup>1</sup> Emergency Institute for Cardiovascular Diseases "Prof. Dr. C. C. Iliescu" Bucharest, Romania

<sup>2</sup> University of Medicine and Pharmacy "Carol Davila", Bucharest, Romania

<sup>3</sup> Internal Medicine and Cardiology Department - "Theodor Burghel" Clinical Hospital, Bucharest, Romania

### ✉ Contact address:

Mona Musteată, MD

University of Medicine and Pharmacy "Carol Davila"

Emergency Institute for Cardiovascular Diseases "Prof. Dr. C. C. Iliescu".

Sos. Fundeni 258, sector 2, 022328, Bucharest, Romania

E-mail: monaa\_dumitru@yahoo.com

## IMPLANTED CARDIAC DEFIBRILATORS

Nowadays, the implanted cardiac defibrillators (ICDs) are used to prevent sudden cardiac death (SCD) by delivering internal controlled electric shock in case of malignant ventricular arrhythmias such as sustained ventricular tachycardia or ventricular fibrillation. These devices have complex algorithms to sense, identify and analyze<sup>3,4</sup> the arrhythmia in order to treat it by delivering electric shocks.

For the device to identify the arrhythmia it must correctly sense the spontaneous (sinus) heart rhythm. Modern ICDs have algorithms that compare the QRS complex of the sinus rhythm with the QRS complex of the tachycardia in order to discriminate between supraventricular tachycardia and ventricular tachycardia. The QRS complex of supraventricular tachycardia is similar to the one of sinus rhythm, while the QRS complex of ventricular tachycardia is quite different from the sinus rhythm.

After each electric shock delivering, the device must sense if the tachycardia stopped.

## ANTITACHYCARDIA PACING

Antitachycardia pacing (ATP) refers to the use of pacing stimulation techniques for termination of tachyarrhythmias. Such techniques can be automatically applied using implantable ICDs and offer the potential for painless termination of ventricular tachycardia (VT)<sup>5</sup>.

A single critically timed extrastimulus may terminate reentrant VT but the efficacy is low. Multiple stimuli delivered in the form of pacing drive trains increase the probability of interacting with the VT circuit and terminating it. The building blocks of ATP stimulation patterns are burst and ramp pacing. A "burst" stimulation pattern consists of a train of pacing pulses with an equal interstimulus interval. A "ramp" stimulation pattern consists of a train of pacing pulses with an automatically decrementing interstimulus interval. Either stimulation pattern may be applied with "rate adaptation" which means that the interval from the last sensed ventricular event during VT to the first pacing stimulus is a programmable percentage of the detected VT cycle length<sup>6</sup>.

If there are patients with ICDs that can deliver ATP and they are confronted with multiple shock delivering or even syncope, this might be a sign that there is a sensing problem of the device.

## MALFUNCTION AND PROARRHYTHMIC EFFECT OF ATP

There can be multiple sorts of malfunction: undersensing which can lead to asynchronous pacing, to misclassification of SVT as VT or even to failing to detect ventricular fibrillation; oversensing<sup>8</sup> of the T waves which can lead to detecting false ventricular tachycardias and delivering unnecessary electric shock or other malfunctions due to electromagnetic interferences, noise artefacts secondary to a fractured lead, profound respiratory movements.

There are also potential proarrhythmic effects of the ATP<sup>9</sup>. When the ATP takes place in the ventricle, it may accelerate the VT and lead to potentially lethal ventricular fibrillation if the patient does not have a back-up ICD. When the ATP takes place in the atrium it may induce atrial fibrillation, which can lead to ventricular fibrillation in patient with WPW syndrome with a fast, anterograde accessory pathway. This is why it is important for the electrophysiologist to perform an electrophysiological study before implanting a device capable of delivering ATP<sup>10</sup>.

## ICD MALFUNCTION

The ICDs malfunction due to incorrect programming of the devices or to environmental hazards can be extracted from the archived recorded electrograms and may lead to several situations that request specific solutions.

Pacing problems may be caused by IRM investigation leading to ICD malfunction, in which case the ICD needs to be programmed again<sup>11</sup>; T wave oversensing may need reprogramming the sensing and a fractured lead has to be repositioned.

Non-detecting the malignant ventricular arrhythmias is almost always a problem of incorrect programming. If the archived electrogram shows a ventricular tachycardia with a lower frequency than the programmed frequency, the solution is to increase the detection range; a R wave undersensing will result in increasing the sensing and an oversensing of the device will lead to decreasing its sensitivity or to change the position of the intracavitary lead. A low battery will be changed.

Another serious problem is the impossibility to convert the ventricular tachycardia/ventricular fibrillation, due to an inefficient programming of the pacing; in these cases, specific problems have specific solution.

A low battery may be the cause of inefficient shocks in which case the battery must be changed.

If the right ventricle lead is at the right ventricle apex it may easier deliver electrical shocks.

Right ventricle perforation<sup>12</sup> by the defibrillator's leads may also lead to inefficient defibrillation.

Ischemic heart disease as a trigger for the ventricular tachycardia or ventricular fibrillation needs an increased defibrillation threshold, making the anti-ischemic therapy a priority.

Also, the Class I antiarrhythmic agents and Amiodarone (a Class III agent), are known to increase the defibrillation threshold<sup>13,14</sup> therefore interacting with the defibrillation efficiency; changing the antiarrhythmic therapy may solve the problem.

## CONCLUSION

In conclusion, the archived electrograms recorded in the ICDs can bring valuable information about the evolution and the prognosis of the patient and on the device itself.

Current ICD algorithms discriminate VT from SVT on the basis of passive analysis of detected rhythms with positive predictive values of greater than 90%.

Still, malfunctions and errors of programming may interfere with the correct analysis of the archived electrograms, requesting specific solutions.

**Conflict of interests:** none declared.

## References

1. Mark A. Wood, Charles Swerdlow, Walter H. Olson. Sensing and Arrhythmia Detection by Implantable Devices. Clinical and Cardiac Pacing and Defibrillation. 2nd Edition. Eds. Kenneth Ellenbogen, G. Neal Kay, Bruce Wilkoff. W. B. Saunders Company, 2000, 68-126.
2. Reiter MJ, Mann DE. Sensing and tachyarrhythmia detection problems in implantable cardioverter defibrillators. *J Cardiovasc Electrophysiol*, 7: 542-558, 1996.
3. Paul VE, O'Onunain S, Malik M ET AL. Temporal electrogram analysis: Algorithm development. *PACE*, 13: 1943-1947, 1990.
4. Wilkoff B, Gillberg J, Hillman S, Larsen J. Clinical Experience with detection of spontaneous ventricular arrhythmias by a new dual chamber defibrillator in a multicenter study. *Circulation*, 98: 1507, 1998.
5. Michael O. Sweeney. Antitachycardia Pacing for Ventricular Tachycardia Using Implantable Cardioverter Defibrillators. *Pacing Clin Electrophysiol* 2004; 27(9).
6. Fisher JD, Kim SG, Matos JA, et al. Comparative effectiveness of pacing techniques for termination of well-tolerated sustained ventricular tachycardia. *PACE* 1983; 65: 915-922.
7. Malini Madhavan, Paul A. Friedman. Arrhythmia Management Devices. Optimal Programming of Implantable Cardiac-Defibrillators. *Circulation*, 2013; 128: 659-672.
8. Kelly PA, Mann DE, Damle RS, Reiter MJ. Oversensing during ventricular pacing in patients with a third-generation implantable cardioverter-defibrillator. *J Am Coll Cardiol*. 1994 Jun;23(7):1531-4.
9. Konstantinos Gatzoulis, Ioannis Gialafos. Dual Chamber Antitachycardia Cardioverter Defibrillators. Another Step for the Treatment of High Risk Patients. *Hellenic J Cardiol* 44: 71-79, 2003.
10. Dietmar Wietholt, Michael Block et al. Clinical experience with antitachycardia pacing and improved detection algorithms in a new implantable cardioverter-defibrillator. *JACC*, Volume 21, Issue 4, 15 March 1993, Pages 885-894.
11. Mauro Biffi. ICD programming. *Indian Heart J*. 2014 Jan; 66(Suppl 1): S88-S100.
12. Marek Banaszewski, Janina Stępińska. Right heart perforation by pacemaker leads. *Arch Med Sci*. 2012 Feb 29; 8(1): 11-13.
13. Dopp AL, Miller JM, Tisdale JE. Effect of drugs on defibrillation capacity. *Drugs*. 2008;68(5):607-30.
14. Bollmann A, Husser D, Cannom DS. Antiarrhythmic drugs in patients with implantable cardioverter-defibrillators. *Am J Cardiovasc Drugs*. 2005;5(6):371-8.