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REVIEW ARTICLE

Remember by heart – the importance of post-mortem cardiac implantable electronic device analysis

Szymon Rzepczyk, Marcin Migiel, Bartosz Bijata, Paweł Świderski

Department of Forensic Medicine, Poznań University of Medical Sciences, Poznań, Poland

Abstract

In recent years, the number of patients with a cardiac implantable electronic device (CIED) has been steadily increasing. Implantable cardioverter-defibrillators (ICDs) are currently one of the primary methods of preventing sudden cardiac death (SCD) in patients at risk. A post-mortem CIED examination, which these days is performed very rarely, as well as the analysis of the recordings may provide key information regarding the circumstances of the patient's death. This applies to both the potential impact of a defect or damage to the device in an event of the owner's death and the forensic analysis of the circumstances of death, especially when traditional post-mortem diagnostics do not provide a clear diagnosis. In addition, using the data stored on the device, it is possible to identify the corpse and precisely determine the time of death, which is crucial for the conducted expertise. Since it is a quick, cheap and widely available procedure, CIED analysis should be incorporated as a routine element of post-mortem diagnostics.

Keywords: cardiac implantable electronic device · ICD · sudden cardiac death · post-mortem examination · diagnostic difficulties

Citation

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Corresponding author:
Szymon Rzepczyk, Department of Forensic Medicine, Poznan University of Medical Sciences, Poznań, Poland
e-mail: szymon.rzepczyk@interia.eu
Available online: www.ejtcm.gumed.edu.pl

Introduction

Implantable cardioverter-defibrillator (ICD) is an advanced medical instrument of the cardiac implantable electronic device (CIED) type, which plays a key role in the prevention of sudden cardiac death (SCD) in patients with certain cardiac arrhythmias [1-3]. Its main purpose is to detect and terminate ventricular arrhythmias or bradycardia and to provide resynchronization pacing [4]. This therapy is considered in the context of primary and secondary prevention of SCD [5-7]. Secondary prevention includes cases of patients who were successfully resuscitated after cardiac arrest due to ventricular fibrillation (VF) or ventricular tachycardia (VT), after 48 hours of acute coronary syndrome and have been assessed to benefit from the therapy for at least one year in good condition. Primary prevention is for patients with chronic symptomatic heart failure (NYHA II-III) and low left ventricular ejection fraction (LVEF ≤ 35%) for whom three months of optimal pharmacotherapy did not bring improvement in these parameters and are expected to benefit from the therapy for at least one year in good condition [8]. Besides ICDs, permanent pacemakers (PM), also classified as CIEDs, are among the devices used to improve the quality of life and survival time of patients with cardiac problems [9]. PMs are devices used to electrically stimulate the heart's rhythm, especially when dysfunction of the impulse-conducting system occurs, e.g. advanced atrioventricular blocks, causing hemodynamic heart failure [10].

Cardiac Resynchronization Therapy (CRT) is another electronic device permanently implanted in patients with heart failure [11]. Resynchronization therapy improves heart function and the well-being of patients, reduces the severity of symptoms, and decreases morbidity and mortality. There are two main types of CRT devices: a resynchronization stimulator with a defibrillator function (CRT-D, cardiac resynchronization therapy-defibrillator) and resynchronization stimulator without a defibrillator function (CRT-P, cardiac resynchronization therapy-pacemaker) [12]. In recent years, an increase in the number of ICD and other CIEDs implantations has been observed worldwide [13-16]. According to epidemiological data, over 200000 ICD implantations are performed per year [17]. Due to the clear trend in the number of CIED implantations, it is important to explore its the role in the post-mortem examination. Such studies are a key element in evaluating the effectiveness of therapy (not only in the context of preventing SCD), but also in identifying potential problems with these devices. The knowledge gathered as a result of post-mortem examinations improves the procedures of implantation, programming and supervision of ICDs, contributing to the improvement of the quality of life of patients with cardiac arrhythmias [18]. Currently, the obligation to extract CIED from the body only applies to cases where cremation is planned (for safety reasons, including the risk of explosion due to high temperature). Furthermore, explantation of the device during autopsy and postmortem analysis of its recordings is rare and applies mainly to forensic examinations, while the device itself is usually treated as medical waste [19-21].

CIED flaws and malfunctions

Despite the high efficacy demonstrated by implantable cardioverter-defibrillators, it is imperative to acknowledge the potential existence of operational imperfections within these devices. This acknowledgment underscores the significance of considering the presence of defects that might impact the seamless functioning of CIEDs despite their overall effectiveness. These may include electrode failures or displacements, abnormalities regarding arrhythmia detection and treatment, mechanical failures of the control unit and pulse generator, or improper programming of the device and software errors, including spontaneous reset or shutdown [22-23]. These defects can lead to inappropriate therapy or the lack of it in critical situations, which in turn may result in a threat to the patient's life [24-25]. The analysis of the literature shows that many technical defects of the ICD are not recognized during the life of the patient, which may contribute to their death [26]. A post-mortem examination conducted on 262 CIEDs showed device malfunction resulting from its defect or damage in as many as 15% of cases [27]. Additionally, in more than 3% of cases the flaw of the device was a potential threat to the patient's life [28]. The most common failure was battery depletion, although there were also cases of damaged electrodes, as well as errors in the software or infection at the implantation site [27]. Thanks to post-mortem CIED analysis, it is possible to identify defects in the device, which enables modification of subsequent therapies and potentially saving the lives of future patients with similar devices. There is also a risk of misdiagnoses of arrhythmias or false alarms, which can lead to unnecessary pacing. Inadequate ICD interventions, (to rhythms other than VT or VF) occur most often in the case of atrial fibrillation (AF) with rapid ventricular action, sinus tachycardia or supraventricular tachycardia (SVT). This flaw is a result of the difficulty in differentiating the various types of arrhythmias and accurately identifying which of them are in fact life-threatening. This can lead to unnecessary electric shocks, even repeated several times, which is not only unpleasant for the patient, but also increases the risk of complications [29-32].

There have also been cases of death of patients with ICDs, which were directly caused by a pacemaker dysfunction [28] and traffic accidents resulting from loss of consciousness after receiving a stimulation [33]. In cases of death of patients with CIED, the possibility of infection and infection of the device should also be considered in the post-mortem diagnosis.

Despite their infrequent occurrence, such events carry a high mortality rate [34-35]. Then, it becomes particularly important to examine the device pocket in situ during the post-mortem examination and the histopathological examination together with the analysis of the patient's medical records [36]. These results underline the importance of the forensic aspect of such cases and the need to discuss and question the natural cause of death in such cases. What is more, inclusion of ICD analysis during a routine autopsy becomes an important issue, as it may reveal a cause of death different from what was originally assumed. Moreover, the integration of comprehensive scrutiny of implantable cardioverter-defibrillators (ICDs) within the framework of routine post-mortem examinations assumes paramount significance, as it holds the capacity to elucidate an underlying cause of death that diverges from the initial hypotheses.

Forensic medicine

The reading and analysis of data recorded by CIED's provides key information for the conducted forensic medical examination [37-40]. This is particularly important in the case of unknown circumstances of the event or lack of witnesses [41]. One of its basic advantages is the possibility of identification of corpses, which is particularly important in the case of mass events, significant body damage, advanced decomposition or inability to be identify using commonly used methods, such as dental analysis or fingerprints [42]. Body identification is possible by reading the patient's data uploaded during device preparation before implantation. In the event of damage preventing the download of data, it is possible to determine the patient's identity indirectly, by reading the serial number placed on the device's case [43]. The analysis of the information recorded by the CIED also enables determination of the precise time of death, which is crucial information for the investigation, allowing, among other things, to identify the perpetrator [44-46]. Confirmation or exclusion of a suspect's alibi is one of the key pieces of information for an investigation. Moreover, determination of the exact time of death is possible even in the case of a long time since death [47]. In this case, one should also remember about possible time shifts resulting, for example, from changing the time zone, and to correlate the time shown by the device with the real time.

An autopsy remains the gold standard for determining the cause of death but in sometimes it does not provide a clear conclusion as to its circumstances [48]. In such cases, it is required to perform additional tests, which may be post-mortem analysis of the CIED record. Post-mortem reading of the data recorded by the CIED helps to determine the cause and mechanism of death by analyzing the electrophysiology and rhythm of the heart [39, 49]. This is particularly important in unclear cases when traditional post-mortem diagnostics do not show significant changes that could have led to death [18, 50]. Such situations include, among others, sudden cardiac death as a result of cardiac arrhythmias in the functional mechanism, which may not cause any specific changes that can be visualized during an autopsy [51-53]. It is also important in the case of poisoning or overdose of drugs that may not leave macroscopically visible changes during post-mortem examination but may affect the cardiac function. In addition, reading a time-correlated heart rate record from the CIED allows a reliable determination of the sequence of events and the cause of death in cases, where potentially fatal events occur suddenly, e.g. a car accident or a fall due to loss of consciousness resulting from cardiac arrhythmias [54-56]. Moreover, the analysis of the record allows to determine the patient's condition in the period immediately prior to death and determine whether the death was sudden or preceded by agony and to determine the manner of death [57]. It is essential to correctly separate the lifetime record from the artifacts created after death, e.g. as a result of body transport or medical rescue operations. The impact of the low temperature in which the corpse is stored in the mortuary on the operation and recording of the device should also be taken into account. Another important aspect is the possibility of damage to the CIED as a result of violence, which can be life-threatening.

Conclusions

Post-mortem analysis of data recorded by CIEDs is an important addition to the traditional post-mortem examination, often providing crucial information for expert opinion on the time and circumstances of death, as well as identification of the body. Since it is a quick, cheap and widely available procedure, CIED analysis should be incorporated as a routine element of post-mortem diagnostics. Cooperation between forensic medicine specialists and cardiologists seems to be of key importance in order to assess the record and its interpretation in the context of the patient's available medical documentation as accurately as possible. This procedure would allow for a reliable assessment of the circumstances of death and identification of any defects or faults of the device, which is of key importance for the legal and medical proceedings and for improving the safety of future patients using CIEDs. It is necessary to conduct further research on post-mortem CIEDs analysis, determining the frequency of occurrence of potentially life-threatening events caused by malfunctioning of the device, which will also enable safety-improving design modifications. In addition, routine post-mortem examination of CIEDs will help to determine the cause of death in cases when the traditional post-mortem examination is inconclusive. Consideration should also be given to the CIED feature that allows transferring the recorded data from the device to an external server in order to prevent record loss.

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Conflicts of interest

All authors declare that they have no conflicts of interest.

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