DOI: https://doi.org/10.5114/ait.2019.87331

Cardiac implantable electronic device discharge during intrathoracic tumour radiofrequency ablation

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Anaesthesiol Intensive Ther 2019; 51, 3: 249–252

Dear Editor,

Techniques like radiofrequency (RF) ablation are emerging as new developments in the treatment and palliation of cancer. Cardiovascular implantable electronic devices (CIEDs) are increasingly used as treatment for the prevention of sudden cardiac death in the same patient population. CIEDs are indicated for primary prevention of sudden cardiac death in patients with prior myocardial infarction or systolic heart failure combined with decreased left ventricular ejection fraction. The devices are also indicated as secondary prevention for patients with documented cardiac arrest from sustained ventricular tachycardia or ventricular fibrillation. In many cases, a CIED is used as the first-line prophylactic therapy in patients demonstrating marked ventricular dysfunction [1]. CIEDs are permanent devices which utilise several lead options to promptly correct a patient's aberrant rate or rhythm [2].

Patients with CIEDs, however, are at a surgical risk due to procedural electromagnetic interference (EMI) of intraoperative devices [3]. CIEDs may detect EMI causing disruption of the device and resulting in the delivery of an inappropriate shock [4]. In pacemaker dependent patients, EMI may prevent the CIED from sensing asystole. Numerous studies and case reports suggest that RF ablation procedures are associated with a risk of EMI and may cause severe adverse outcomes. Here we present a case of a palliative tumour RF procedure in a patient with a CIED that resulted in an inappropriate delivery of a defibrillating shock. We also present a review of literature of similar cases previously reported.

CASE PRESENTATION

B.C. is a 62-year-old male with history significant for diabetes, paroxysmal atrial fibrillation, hypertrophic cardiomyopathy with moderate systolic dysfunction and diminished diastolic dysfunction, as well as prior ventricular tachycardia status post a single-chamber implantable cardioverter-defibrillator placed seven years prior. The patient presented for RF ablation of a right apical lung mass secondary to metastasis of pancreatic cancer. Preoperatively, his CIED was not interrogated nor deactivated. Following induction of general anaesthesia and onset of RF, ventricular bigeminy was noted on ECG; however, the patient remained haemodynamically stable. The patient was noted to experience a body convulsion; activation of the automated implantable cardioverter-defibrillator (AICD) was suspected and a magnet was placed over the device. No subsequent complications were noted. Upon postoperative interrogation of the AICD, it was noted that a 25J shock was delivered following two episodes of noise reservation and an episode of ventricular fibrillation at 292 bpm occurred, lasting one minute. The electrocardiologist deduced

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that the shock was delivered for suspected ventricular fibrillation, probably an artefact from the radiofrequency device. Post-surgical interrogation of the device also demonstrated normal function with acceptable lead measurements and battery status.

DISCUSSION AND REVIEW OF LITERATURE

Our patient had an implant of a single-chamber AICD in 2010 for prophylactic management of congestive heart failure with prior ventricular tachycardia. Since initial placement, he had undergone regular interrogations with no known events. He had not undergone any prior surgical interventions following placement of his CIED. Given that he was not pacemaker dependent for bradyarrhythmia, the decision was made not to reprogram his CIED to an independent setting prior to the procedure. Literature discussing the effect of radiofrequency procedures on implantable cardiac devices and optimal perioperative management is conflicting. In patients with CIEDs, EMI may result in inappropriate inhibition or triggering of pacemaker/defibrillator output, asynchronous pacing, reprogramming, or electrical component damage.

To date, techniques for managing risk of RF in patients with CIEDs have evolved mostly through case study findings. The largest study examining the effect of RF on CIED function included 22 patients. Skonieczki *et al*. conducted a retrospective study of RF and microwave ablative procedures, for the management of lung, kidney, liver, and bone tumours, in 19 patients with permanently implanted cardiac devices. The group assessed malfunction of CIEDs during or after the thermal ablation procedures [5]. For all of the observed cases, cardiologists performed pre- and post-procedure interrogations of the implanted devices. Baseline cardiac device functions were determined prior to each procedure. Immediately prior to each ablation, pacemaker functions were changed to automatic pacing and defibrillator modes were disabled. During 20 of the 22 sessions, no EMI was detected in the continuous electrocardiogram tracings or in pacemaker functions. In two RF sessions, significant changes occurred in pacemaker parameters. In one patient, the energy emitted by the RF electrode reset the device from ventricular pacing without sensing to ventricular pacing with sensing. This alteration had the capacity to inhibit pacemaker function based on sensed electrical activity, although the patient remained in normal sinus rhythm throughout the procedure. In a second patient, the implanted device underwent four brief episodes of inhibition during RF application wherein the ECG tracings recorded atrial high rates. In all 22 cases, patients remained in sinus rhythm throughout the ablation, and post-procedure interrogations of each CIED revealed no damage to electrical components, with all devices successfully being returned to their original settings.

In addition to this study, five published cases describe the impact of tumour ablative RF procedures in patients with CIEDs.

Case 1

A 67-year-old male patient underwent RF ablation for squamous cell carcinoma of the lung [6]. The patient had prior placement of a biventricular pacemaker as treatment for non-ischaemic cardiomyopathy with severe left ventricular dysfunction and congestive heart failure. He was known to be pacemaker dependent and thus, prior to the procedure, the device was reprogrammed to an independent mode. Two RF ablations were performed, during which the pacemaker captured the left pectoralis major muscle in synchrony with the QRS complex, resolving with discontinuation of ablation. Post-procedural interrogation of the device determined that the device had undergone an electrical reset, which can occur when a pacemaker senses a large amount of electric energy. In this particular implanted device, manufacturer guidelines specified that electrical activity could be sensed at over 15 cm from its leads and that there is a risk of electric reset due to activity within 15 cm. EMI occurred for this patient because the lung lesion was 9.0 cm from the nearest pacing lead and 11.5 cm from the pacing unit in the chest wall, while the side of the insulated RF probe was only 2.4 cm from the nearest pacing wire adjacent to the superior margin of the implanted pacer.

The cause of pectoral stimulation may have been transient unipolar pacing, which had been activated after electrical reset, and can transiently reprogram the atrial and ventricular leads from bipolar to unipolar. The issue concerning unipolar pacing is that the pacemaker generator itself becomes part of the electrical pacing circuit, and at high pacing outputs, as during electric reset, underlying muscles can be captured. In this case, unipolar pacing occurred only during RF delivery, although the device setting remained bipolar during the post-procedural interrogation. The elective replacement indicator on the battery was thought to be due to the sensing of electrical energy preventing a normal reading of the battery voltage during and immediately after RF delivery.

In this case, the patient did not exhibit any symptoms of the effects of RF on the device during the procedure. The CIED was reprogrammed to its original settings during the post-procedural interrogation, and these settings persisted without complications. This case demonstrated that RF ablation near a CIED can cause electric reset of the device despite preventative pre-ablation reprogramming.

Case 2

A 73-year-old male patient with a CIED for ventricular tachycardia underwent nephron-sparing RF ablation of renal-cell carcinoma [7]. During the procedure a magnet was used to disable defibrillator function. The distance from the tumour to the ventricular pacing lead was approximately 18 cm. No EMI was noted during the procedure and no change in the previously programmed settings was evi-

dent during the post-procedural interrogation of the device. Mahneken *et al*. hypothesised that the 18-cm distance between the RF probe and ventricular pacing lead may alone have been sufficient to allow safe performance. In discussing their precautions, the authors noted that they used a magnet to inhibit the defibrillator function. Rate response mode was switched off to reduce the risk of accidental stimulation. They noted that in cases where the pacemaker is programmed in VOO mode, an external pacemaker should be made available due to the risk of "R-on-T" phenomenon. Additionally, if the patient is pacemaker dependent, the device should be reprogrammed to an asynchronous mode before the ablation and peripheral pulse should be monitored throughout the procedure to prevent failure of asystole detection.

Case 3

A 52-year-old patient with an abdominally placed CIED underwent RF treatment for hepatocellular lesions [8]. The patient had a history of sinus node dysfunction, which was treated with a ventricle-paced, ventricle-sensed (VVI) pacemaker. Of note, his device had a unipolar ventricular lead. Prior to the procedure the CIED was programmed to VOO mode. No EMI was noted during ablation of either lesion; however, stimulation artefacts were clearly visible on ECG. Interrogation of the device after each set of RF pulses did not show significant differences in the battery or electrode status.

Case 4

A 62-year-old male patient with a permanent CIED to treat intermittent complete heart block underwent hepatic RF for metastatic disease [9]. The patient was pacemaker dependent and was reprogrammed to asynchronous ventricular pacing prior to the procedure. RF was delivered for more than 17 minutes at a distance of 14 cm from the tip of the delivery electrode to the pulse generator and 7 cm from the ventricular pacing lead. EMI was not noted at any point in the procedure.

Case 5

A 65-year-old patient with hepatic metastasis of renal carcinoma underwent hepatic RF ablation [9]. The patient's dual-chambered pacemaker was programmed to DDDR with a rate of 60–130 bpm. Ablation was performed on both lobes of the patient's liver for a total of 97 minutes within a distance of 5–8 cm of the pacer lead positioned in the right ventricle. Continuous electrocardiographic monitoring showed that the patient remained in normal sinus rhythm, and no abnormalities of CIED function were noted during the RF procedure.

Literature discussing the effect of radiofrequency procedures on CIEDs is conflicting. Although there seems to be a clear association of EMI produced by RF, it is not evident what specific guidelines should be followed for the prevention of resultant adverse events. The matter is further complicated by cardiac device specifications and individual patient settings. Guidelines published in 2011 summarised that provisions to be taken to help mitigate this risk may include turning off defibrillator function, reprogramming to automatic pacing modes, and making available external defibrillation in case of ventricular tachycardia [4]. Pre- and post-procedural interrogation of implanted devices is important to detect aberrant AICD function, which may result following EMI caused by an RF procedure. CIEDs which utilise a unipolar sensing lead have a greater susceptibility to EMI because of a greater distance between the cathode (myocardial electrode) and the anode (extra-cardiac pulse generator). Patients who are pacemaker dependent represent a "worst case scenario" because EMI may cause the failure to recognise asystole. In such cases it is important to deactivate sensing function and reprogram to VOO prior to the procedure. Although setting to asynchronous mode is recommended, no controlled trials have been performed assessing the benefit, and, moreover, published cases report EMI continuing to affect reprogrammed devices. In most instances, if the patient is not pacemaker dependent, the pacemaker probably does not need to be programmed to asynchronous pacing mode prior to the procedure; however, rate-adaptation should be disabled for the duration of the ablation.

The distance of the RF electrode to the lead system and the RF power output used may be the greatest contributors to the severity of EMI and resultant device malfunction. The effect of radiofrequency ablation on CIEDs has been studied experimentally. Though EMI was observed with power outputs as low as 15 watts, in this study no subsequent device malfunction occurred when RF was performed outside the range of 4 cm [10]. Important to note, however, is that modern radiofrequency ablation systems used in the ablation of tumours are capable of producing 250 W and may thus impact an AICD at a significantly greater distance [11]. Though this is probably specific to each manufacturer, lesions within 15 cm of the device may pose greater risk for EMI. When managing perioperative patients with AICD, anatomy of the procedure is thus important for understanding the risks associated with the procedure. Guidelines published in 2011 advise direct contact between the RF electrode and the cardiac device system and moreover to minimise the distance of the RF current path from the device [4].

CONCLUSIONS

Unfortunately, CIED mismanagement during surgery continues to be a ubiquitous issue, and this should be recognised and brought to light. Our presented case and previously reported cases underscore that while there are no clear guidelines for patients with implanted cardiac devices undergoing RF, these patients must be electrocardiographically monitored throughout the procedure and individually assessed for interference. Despite considerations and precautions, significant risk is maintained

in the event of EMI causing intraoperative reprogramming, as has been reported. A clinical study is required to assess the risk of EMI generated by modern tumour radiofrequency ablative techniques having a negative effect on cardiac device function. While an inherent risk is likely to exist in the setting of a CIED, more evidence is needed to determine complication rates of tumour RF in patients with CIEDs, and more concrete operative precautions to be taken in these individuals.

ACKNOWLEDGEMENTS

1. Source of funding: none.
2. Conflict of interest: none.

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