Third-degree burns caused by transcutaneous pacing for third-degree heart block

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Introduction

Since the first report of external electrical stimulation of the heart 70 years ago,[1] transcutaneous pacing and defibrillation have become indispensable tools in the management of patients with both bradyarrhythmias and tachycarrhythmias.[2] The most common adverse event resulting from the use of transcutaneous electrodes is first-degree skin burns from defibrillation. While there exists an extensive body of literature on burns from defibrillation,[3] there are only a handful of reports of burns caused by transcutaneous pacing, with most of these observations occurring in the neonatal population.[4–6] Here, we report on a case of third-degree burns from extended transcutaneous pacing and discuss both the mechanisms and approaches to minimize the risk.

Case report

A 66-year-old white man with a history of coronary artery disease, type 2 diabetes, normal body mass index (24), and hypertension presented to the emergency department in the late evening with weakness and fatigue with associated episodes of transient loss of consciousness with tonic-clonic movements. Electrocardiography demonstrated sinus rhythm with complete heart block and a ventricular escape rhythm at 23 beats per minute. Initial management included atropine and a dopamine infusion, without effect, so pacing pads were applied and transcutaneous pacing was initiated. He was hemodynamically stable but became combative, so he was sedated and intubated. Nine hours after transcutaneous pacing was started, he was brought to the electrophysiology laboratory, where a permanent pacemaker was placed. After removing the temporary pacing pads (Zoll OneStep CPR Complete; Zoll Medical, Chelmsford, MA), staff noted 4 full-thickness burns on his chest wall (Figures 1 and 2).

KEYWORDS Burn; Current density; Electrode; Pacemaker; Transcutaneous pacing
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Discussion

Our patient had an unexpected complication of life-saving transcutaneous pacing. A review of the literature was performed by querying PubMed with the following search strings: “transcutaneous AND burn,” “pacing AND burn,” and “pace AND burn,” yielding a total of 285 published articles. The abstracts were reviewed by 1 author (M.J.S.) and eligible reports are included here (Supplemental Table).

Pediatric and neonatal patients are at particularly high risk of pacing-induced burns owing to thin skin and limited body surface area. A neonate weighing 2 kg with complex congenital heart disease required high-output pacing at 140 mA for adequate capture owing to profound lactic acidosis; after 12 hours of pacing, full-thickness burns requiring surgical repair were noted.[4] Nine hours of pacing in a 1.1 kg neonate led to large, third-degree burns requiring W-plasty surgical repair.[5] A 7-week-old neonate developed a second-degree burn on the back and a third-degree burn on the chest after 45 hours of pacing.[6] A 5-year-old boy weighing under 15 kg with a history of complex congenital heart disease developed full-thickness burns after only 55 minutes of transcutaneous pacing at 60 mA output.[7] The fact that the pacing electrode was placed over a prior surgical scar may have contributed in this case because of the decreased blood flow in the region of the scar, limiting heat dissipation.

Pacing burns in adult patients are rarely reported and the proposed explanations for this complication vary by case. In a recent report, 12 hours of transcutaneous pacing at 80 mA output led to third-degree burns; this was attributed to inadvertent displacement of the anterior electrode patch.[8] As little as 2 hours of transcutaneous pacing may be sufficient to lead to full-thickness burns, as illustrated by an earlier report.[9] The fact that the anterior electrode patch was applied underneath heavy breast tissue was proposed as an explanation. Another case of pacing-induced burns was believed to be explained by severe obesity (body mass index of 58).[10] Malfunction of the external pulse generator can lead to skin

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KEY TEACHING POINTS

- Transcutaneous pacing can cause thermal burns with prolonged use.
- Transcutaneous pacing should be viewed as a bridge to a transvenous approach, which should be pursued as soon as is feasible.
- Applying excessive pressure to carefully engineered electrodes may hinder their function in achieving maximal current distribution.

burns via electrolysis if a leakage current is continuously applied at the skin electrode patch during cardiac surgery.[11] Inadequate electrolytic gel at the electrode–tissue interface was likely contributory in a case of pacing-induced burns in which the transcutaneous pacing pads were reused in a Malaysian hospital.[12]

Proposed mechanisms

As transcutaneous pacing is frequently utilized clinically without complications, we sought to determine the root cause of this complication. We hypothesize that 1 of the contributing factors in our case may have been excessive pressure on the electrodes. Because the patient was dependent upon transcutaneous pacing for perfusion and was being transported between hospitals, medical personnel applied more than a dozen strips of tape across the patient's chest. We suspect that this pressure damaged the patch electrode and that this led to the skin burns.

To deliver energy sufficient to depolarize myocardium, current must be passed between 2 skin electrodes. Heating at the electrode–tissue interface is proportionate to the local current density.[13] Thus, tissue heating is minimized by several design features aimed at maximizing the effective surface area of the electrode–tissue interface, including the use of large electrode patches and the incorporation of an electrolyte-impregnated conductive gel,[14] which bridges the gap between the electrode surface and the skin. One case of pacing-induced burn was attributed to reuse of disposable electrodes, leading to inadequate electrolyte gel at the tissue–electrode interface, with a consequent increase in current density.[12]

However, in vitro and theoretical studies have demonstrated that, even with uniform electrode–tissue conductivity via an electrolytic gel, there remains substantial heterogeneity of current density distribution, with current density decreasing roughly with the square of distance from the source.[15] In effect, this leads to the bulk of current passing from the electrode to the tissue immediately underneath the button electrodes.[16] Contemporary temporary transcutaneous pacing electrodes incorporate a current redistribution layer composed of a polymeric sheet of dielectric material between the button electrodes and the patient-facing surface to

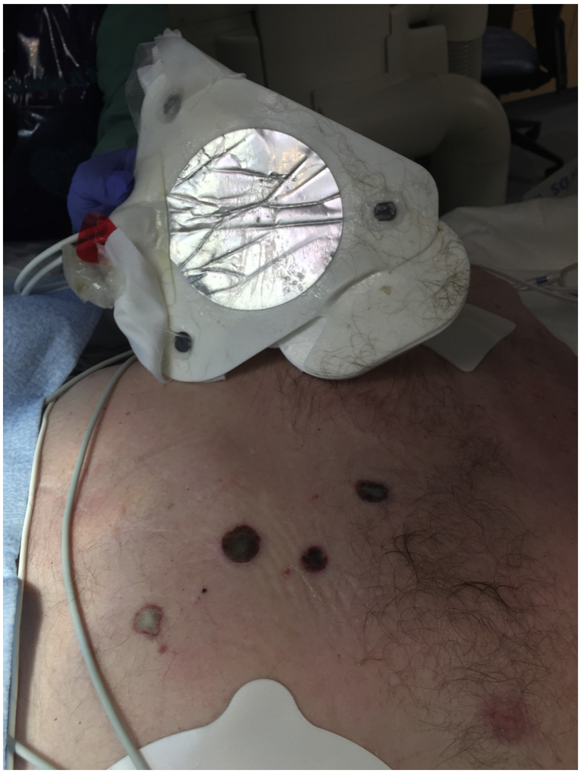

Figure 1 The burns were initially seen at the time of removal of the transcutaneous pacing pads immediately prior to permanent pacemaker implantation.

homogenize the local current densities under the entire electrode.[17] However, the proper functioning of this layer is dependent on the integrity of the electrically insulating dielectric layer.[18] We suspect that in our case the pressure from the tape caused the button electrodes to crush the dielectric layer underneath them, leading to loss of the current-dispersive properties of that layer with the resulting high current density immediately under the button electrodes, causing conductive heating and tissue necrosis.

Interestingly, there were no burns on the patient's back. Examination of the posterior patch electrode disclosed a different design—whereas the anterior patch electrode includes both a central, broad electrode and 3 smaller button electrodes that are used for both energy delivery and sensing of cardiac activity (Figure 3), the posterior patch includes only a planar electrode made of tin bonded to a flash-spun high-density polyethylene fibrous matrix.[19] This alternative electrode construction with an increased surface area and without areas vulnerable to crushing of the dielectric layer under button electrodes likely led to local current density that was sufficiently low to avoid thermal injury.

Finally, technical considerations aside, the fact that the patient was intubated and sedated precluded his communicating any pain that he may have been experiencing. When patients are in this state, additional consideration should be made to minimize the risk of pacing-induced burns by utilizing appropriate pacing output safety margins and expediting placement of a transvenous pacing wire.

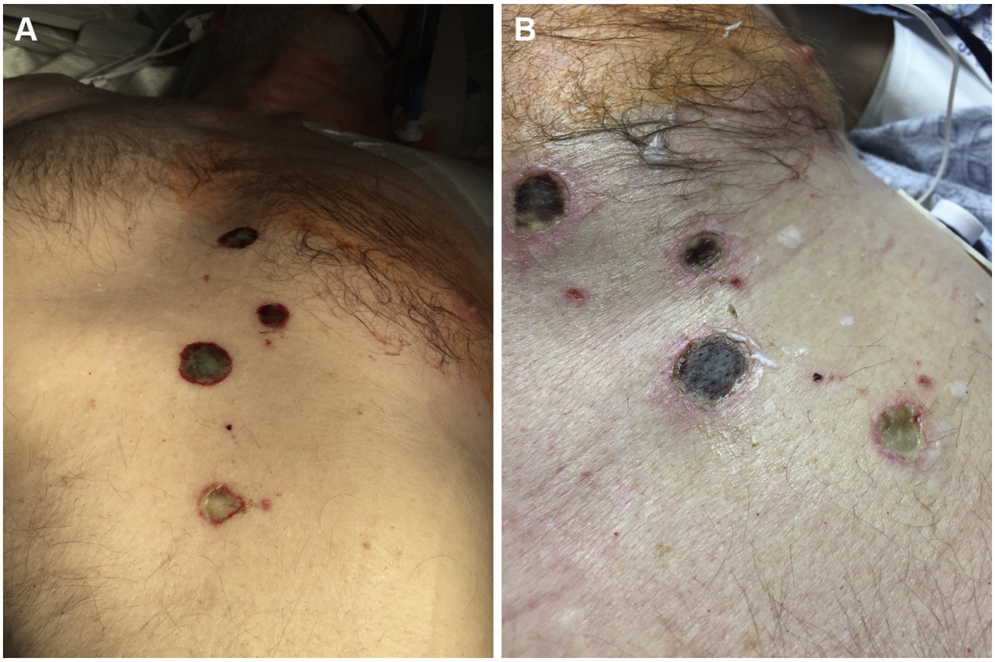

Figure 2 Close-up view of the burns immediately after permanent pacemaker implantation (at left) and on hospital day 3 (at right), demonstrating full-thickness eschar with surrounding erythema.

Conclusions

In this report, we propose a mechanism for the third-degree burns that are an infrequent but severe complication of transcutaneous pacing, in which heterogeneity of current distribution may be caused by breakdown of the dielectric layer of the electrode patch and loss of its current-dispersive properties, resulting in local high current density and thermal burns.

In addition, this case serves as a reminder of 3 key clinical teaching points. First, though transcutaneous pacing can be a life-saving intervention, it is not without possible side effects. Second, transcutaneous pacing should be viewed as a bridge to a transvenous approach, which should be pursued as soon as is feasible. Finally, applying excessive pressure to carefully engineered electrodes may hinder their function in achieving maximal current distribution.

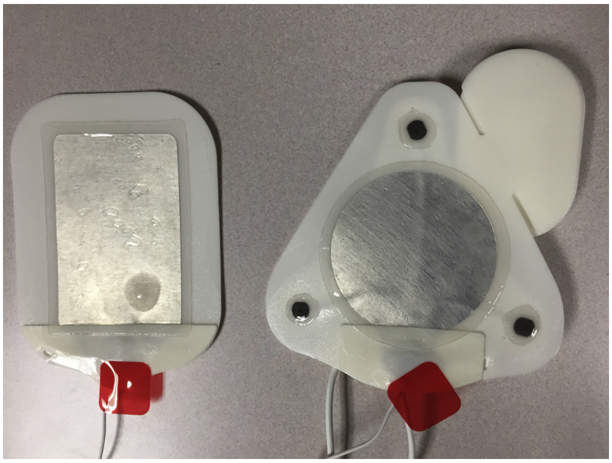

Figure 3 Comparison of the posterior (left) and anterior (right) patch electrodes. Note that the anterior patch electrode has multiple components, including a central, broad electrode for pacing, 3 button electrodes for sensing and pacing, and a heterogenous distribution of electrolyte-impregnated conductive semisolid.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2020.05.006.

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