Assessment of the Theorized Risks of Conducted Energy Weapons through Literature Review of Runaway Pacemakers

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Abstract

Purpose: Fatalities following TASER activation are rare, though there are case reports documenting this phenomenon. One prevailing theory for the mechanism behind these deaths involves the TASER pacing the heart into a fatal arrhythmia. We conducted a structured review of runaway implanted pacemakers to assess whether this theory is supported by the literature.

Methods: This is a review of all available and applicable case reports on runaway pacemakers. All case reports where a patient experienced runaway pacing with a cardiac response of >100 BPM or VF or VT or a systole were included, excluding those cases that converted out of tachycardia. We recorded demographic data, in addition to cardiac parameters, interventions, outcomes, and duration of runaway pacing. Descriptive statistics are reported.

Results: We identified 39 case reports of runaway pacemakers, with 26 meeting study criteria. The mean patient age was 64. The mean heart rate was 196 bpm (range 95–400). There were 4 (15%) deaths in the 26 patients. All patients experienced runaway pacing for at least 20 minutes, many for over 24 hours. There were no cases of cardiac arrest that occurred with less than 20 minutes of cardiac pacing.

Conclusions: There was no published cases identified demonstrating that runaway pacemakers lead to cardiac arrest in less than 20 minutes. This is in contrast to case-reported TASER fatalities, which occur in less than 2 minutes. Thus, there appears to be no consistent data to support the published theory that TASERs cause death through a runaway pacing mechanism.

Keywords: TASER; Conducted Energy Weapons; Runaway Pacemakers; Ventricular Fibrillation; Ventricular Tachycardia; Cardiac Arrest

Introduction

Whether or not the use of less-lethal conducted energy weapons (CEW), such as the TASER electronic control device (ECD), can safely incapacitate a subject is still an ongoing debate. In 2008, Amnesty International, a non-governmental organization focused on human rights worldwide, published an article titled “Less Than Lethal” which reported that “more than 330 people ... have died during the years of 2001 and 2008 after being struck by police TASERs in the USA [1].”

The concern of risks associated with conducted energy weapons stems from how the devices work. They use compressed nitrogen gas to launch a pair of dart metal electrodes that can penetrate the subject’s skin or clothing in order to deliver rapid cycles of low amperage electricity. The subject experiences rapid muscular contractions, resulting in temporary incapacitation by neuromuscular dissociation. Given that the heart also runs on an electrical system that controls cardiac muscle contraction rates, there have been theories postulated that a CEW can possibly disrupt normal cardiac muscle contractions by over-pacing the heart. Swine models using CEW discharges have concluded that this type of cardiac capture is possible [2].

Since its introduction, there has been controversy regarding the safety of CEWs (including the TASER ECD). DP Zipes proposed that the TASER ECD may theoretically pace the heart at a very rapid rate, leading to decreased cardiac filling times and subsequent cardiovascular collapse. This theory involved the review of eight legal cases involving cardiac arrest and death following TASER ECD activation and is based on the medical parallel of faulty exogenous pacemaker devices leading to extremely rapid overdrive pacing, cardiovascular collapse and death. The Zipes publication refers to the relationship between TASER use and runaway pacemakers, but does not elaborate on the mentioned “outcome[s] of runaway pacemakers many years ago [3].”

Our study seeks to shed further light on the question of whether or not exogenous, runaway pacemakers can lead to cardiovascular collapse and death. If this phenomenon is possible, we hope to determine how long it takes for cardiac arrest to take place following the onset of rapid pacing. With this information, we seek to determine if the literature supports the published theory that TASERs cause death by pacing the heart into cardiac arrest.

Methods

This is a structured literature review on the outcomes of patients with runaway pacemakers. We utilized Pubmed and Google Scholar to conduct our search of all applicable literature from January 1960 to May 2016. The specific keywords employed included “runaway pacemakers” and “runaway pacing”. Following our primary search, we included all applicable references listed within our primary cohort of literature to assure that we included all associated materials on the topic of runaway pacemakers. We included all case reports, written in English, where we identified rapid exogenous pacing with an associated patient heart rate of >100 BPM or ventricular fibrillation (VF) or ventricular tachycardia (VT) or a systole. We excluded all case reports where patients experienced runaway pacing that spontaneously reverts back to normal sinus rhythm or bradycardia. We included several predictor and outcome variables including demographics, comorbid conditions, exogenous pacing rate, native heart rate, any physician interventions, duration of pacing, and final outcomes. Descriptive statistics are reported. As this is a literature review, it is exempt from IRB review.

Results

Through our literature search we identified 39 case reports from January 1960 to May 2016 [4–35]. Of the identified cases, 26
met inclusion criteria. All of the excluded cases were removed due to evidence that the patients experienced spontaneous reversion back to normal sinus rhythm or bradycardia. Among the 26 qualified case reports, the average age was 64.8 years (range 13-86). The average heart rate in beats per minute (BPM) was 196 ± 71 with a range of 95-400 BPM. Pre-existing health conditions within this group included: complete heart block and/or sinoatrial block, hypertension, sinus node dysfunction, bradycardia, sick sinus syndrome, cardiac enlargement, and Stokes-Adams attacks.

There were four deaths among the included case reports (15%). Among the case reports with fibrillation (7), there were 2 deaths. Those with a cardiac response rate of 141-400 BPM (18) had 17% mortality. Figure 1 provides a visual graph of the 26 cases organized by increasing heart rate. Bars in red indicate a death. Table 1 provides a data table of all 39 case reports. The 26 case reports that were included in the analysis are noted with an **.

The four cases that resulted in death had a variety of etiologies. Case 8 involves an 81-year-old woman suffering from 2nd degree sino-atrial block. She had an average exogenous runaway pacemaker rate of 230 BPM full cardiac capture. She was admitted with clinical cardiac arrest. She failed to resuscitate due to cerebral anoxia. She was estimated to have experienced runaway pacing for over 20 minutes prior to cardiac collapse and death [9]. Case 17 involves a 50-year-old man with bradyarrhythmia and cardiac enlargement. He had a runaway pacemaker rate that ranged from 100-300 BPM, with complete cardiac capture. Ventricular tachycardia and ventricular fibrillation were noted in his case report. Pacemaker extraction was not feasible during ventricular tachycardia sessions for technical reasons. He was estimated to have experienced runaway pacing for over 11 hours [17]. The last case, case 33, involves a 73-year-old male with chronic congestive heart failure and complete A-V block. He had a runaway rate of 260 BPM and experienced periods of ventricular fibrillation. His runaway pacing lasted over 20 minutes prior to cardiovascular collapse and death [29].

Through this literature review we found that all episodes of exogenous runaway pacing lasted 20 minutes of more, with several cases extending beyond 24 hours. We identified no cases where a patient experienced cardiac arrest from runaway pacing in the time frame of less than 20 minutes.

**Discussion**

In making inferences from the literature review, one must consider the characteristics that describe these cases: the high average age and the variety of ill heart conditions. Despite these significant issues, a majority of these patients survived long periods of time with runaway pacing. Most of the study participants were of advanced age with significant co-morbidities and many had cardiac disease significant enough to warrant pacemaker placement. There was an overall 15% mortality among the 26 cases. None of the cardiac arrests, however, took place in less than 20 minutes.

This is in contrast to the population involved in the case series by Dr. Zipes, which describes 8 cases of cardiac arrest following TASER activation [3]. None of these subjects were reported to have significant cardiac disease and their ages ranged from 16 to 48 years, with all but one under the age of 34 years. None of these individuals were found to be on illicit drugs that classically cause cardiac instability (e.g., methamphetamines, cocaine, etc). The majority of these patients had a short period of TASER ECD activation, with only two having continuous TASER ECD activations of 30 seconds or longer. These included a 17 year old male who experienced TASER activation for 37 seconds and a 24 year old male who experienced activation for 49 seconds. Only one individual had repeated TASER ECD activations of time duration of over 60 seconds total activation.

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**Figure 1**: Red bars indicate death. Numbers under bars do not indicate corresponding case report.
<table>
<thead>
<tr>
<th>Year</th>
<th>Duration of Runaway</th>
<th>Outcome</th>
<th>Intervention(s)</th>
<th>Pre-Existing condition(s)</th>
<th>Sex</th>
<th>Age</th>
<th>Runaway Rate (impulses/min.)</th>
<th>Cardiac Response Rate (beats/min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1977</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>84</td>
<td>73-500</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>1994</td>
<td>3 days</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>67</td>
<td>60-2000</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>1944</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>-</td>
<td>M</td>
<td>78</td>
<td>2000</td>
<td>40-60</td>
</tr>
<tr>
<td>4</td>
<td>1944</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>2000</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction, Defibrillation</td>
<td>M</td>
<td>55</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>2005</td>
<td>3 days</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>79</td>
<td>168</td>
<td>165</td>
</tr>
<tr>
<td>7</td>
<td>1980</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>76</td>
<td>1180</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>1982</td>
<td>&gt;20 min</td>
<td>Died</td>
<td>PM extraction, Magnet, Defibrillation</td>
<td>M</td>
<td>81</td>
<td>210-240</td>
<td>210-240</td>
</tr>
<tr>
<td>9</td>
<td>1982</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>63</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>10</td>
<td>1983</td>
<td>&gt;60 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>M</td>
<td>72</td>
<td>-</td>
<td>300</td>
</tr>
<tr>
<td>11</td>
<td>1980</td>
<td>&gt;120 min</td>
<td>Survived</td>
<td>External PM overdrive stimulation at 170/min, PM extraction</td>
<td>M</td>
<td>64</td>
<td>140</td>
<td>85</td>
</tr>
<tr>
<td>12</td>
<td>1990</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>71</td>
<td>140</td>
<td>68</td>
</tr>
<tr>
<td>13</td>
<td>1995</td>
<td>&gt;60 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>70</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td>14</td>
<td>1997</td>
<td>&gt;80 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>86</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>15</td>
<td>1963</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>59</td>
<td>163</td>
<td>163</td>
</tr>
<tr>
<td>16</td>
<td>1963</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>External Pacemaker, PM extraction</td>
<td>M</td>
<td>33</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>17</td>
<td>1963</td>
<td>&gt;24 min</td>
<td>Died</td>
<td>Procaine amide and quinidine</td>
<td>M</td>
<td>50</td>
<td>100-300</td>
<td>100-300</td>
</tr>
<tr>
<td>18</td>
<td>1964</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>80</td>
<td>0-750</td>
<td>140-168</td>
</tr>
<tr>
<td>19</td>
<td>1964</td>
<td>&gt;3 hrs</td>
<td>Survived</td>
<td>External cardiac massage, D.C. countershock, Portable external-internal pacemaker unit, PM extraction</td>
<td>M</td>
<td>80</td>
<td>80-150</td>
<td>80-150</td>
</tr>
<tr>
<td>20</td>
<td>1965</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>External cardiac massage, endotracheal ventilation, defibrillation 50 watt-seconds direct current, PM extraction</td>
<td>M</td>
<td>64</td>
<td>100-288</td>
<td>100-288</td>
</tr>
<tr>
<td>21</td>
<td>1969</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction</td>
<td>M</td>
<td>72</td>
<td>64-400</td>
<td>64-160</td>
</tr>
<tr>
<td>22</td>
<td>1999</td>
<td>&gt;3 hrs</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>M</td>
<td>85</td>
<td>2400</td>
<td>62.5</td>
</tr>
<tr>
<td>23</td>
<td>2000</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>76</td>
<td>2600</td>
<td>65</td>
</tr>
<tr>
<td>24</td>
<td>1979</td>
<td>&gt;72 hrs</td>
<td>Survived</td>
<td>PM extraction, Defibrillation, Magnet, Pacing Overdrive to 150</td>
<td>F</td>
<td>47</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>PM extraction, Magnet</td>
<td>F</td>
<td>76</td>
<td>180-185</td>
<td>180-185</td>
</tr>
<tr>
<td>26</td>
<td>2003</td>
<td>&gt;20 min</td>
<td>Survived</td>
<td>Coronary artery bypass grafting, Mechanical mitral valve replacement after juvenile acute rheumatic disease, tricuspid valve repair, diabetes mellitus, polymyalgia rheumatic, sick sinus syndrome</td>
<td>M</td>
<td>71</td>
<td>185</td>
<td>185</td>
</tr>
</tbody>
</table>
time. This occurred in a 33 year old male who received 13 short duration TASER ECD activations over a three minute period, totaling 62 seconds of total activation time. The previously reported theory proposes that the heart is paced by the TASER in a similar manner to how the heart is paced by a runaway pacemaker (the ECD acting much like a transcutaneous pacer), eventually causing cardiac collapse and death. Our data, which suggests that patients sustain cardiac arrest only after long periods of runaway pacing, appears to contradict this theory in that the reported deaths following TASER activation generally occurred after short duration activations (as short as 5 to 11 seconds in 3 of the Zipe’s case reports). Also, although many of the patients presented in the Zipes paper were ultimately found to be in Vfib or Vtach prior to death, there is no evidence that rapid pacing preceded any of these arrhythmias. Furthermore, the reported deaths due to runaway pacemakers generally occurred in elderly cardiac patients, while the deaths following TASER activation almost all occurred in young, healthy males. These findings suggest an alternative, yet unknown, etiology of the deaths following TASER ECD activation.

**Study Limitations**

The limitations of this study include it being retrospective in nature and being restricted to the clinical data provided in the case reports. In some cases, exact duration of the runaway pacemaking cannot be determined, but estimations of minimal durations of time were performed. There is the possibility of having missed some papers in our search, but in reviewing two search engines and all of the references of each of the papers reviewed, we are confident that this number would be very low and certainly would not provide overwhelming data to modify our conclusions. The aim of our study was not to explore the pathophysiology behind ECD related deaths. This study explored the validity of one proposed mechanism for these deaths: that an ECD discharge could rapidly pace the heart into cardiac arrest. The actual cause of these fatalities remains unclear and is an area for further study.

**Conclusions**

There were no published cases identified demonstrating that runaway pacemakers lead to cardiac arrest in less than 20 minutes, even in a population of elderly cardiac patients. This is in contrast to case-reported TASER fatalities, which occur in less than 2 minutes. Thus, there appears to be no consistent data to support the published theory that TASERs lead to death through a runaway pacing mechanism.
Conflict of Interest
None of the authors have conflicts of interest.

References