Successful exsanguination tourniquet reanimation of a cardiac arrest patient with implanted defibrillator – a case report and review of epinephrine vs. Mechanical Vasoconstriction

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Short tittle: Exsanguination Tourniquet during CPR

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Acknowledgements and conflicts: Prof. Noam Gavriely is an officer and shareholder of OHK Medical Device Inc.

http://www.resuscitationjournal.com/content/authorinfo

Word count 1918/2844

Abstract

The outcome of out-of-hospital witnessed cardiac arrest undergoing CPR is disappointing with only very few of the patients actually being alive and discharged from the hospital with intact neurological status 30 days after the arrest. We hereby describe a case of a 78 years old known cardiac patient with an implanted Medtronic defibrillator who sustained witnessed cardiac arrest. By-stander CPR was started promptly and evidently the internal defibrillator was activated multiple times. Continued CPR by paramedics included multiple external defibrillations and epinephrine injections, but no ROSC. The patient was transported to emergency department where an auto-transfusion tourniquet (A-TT) (HemaShock®, Oneg HaKarmel Ltd. Haifa Israel) was immediately applied to both legs. The A-TT is an elastic ring that is rolled up the limb to shift the blood from the limb to the core and prevent its re-entry to the limb. Within 4 minutes of the application the patient converted to ROSC, initially with very high blood pressure and tachyarrhythmia that stabilized within a few minutes. The patient was then transported to ICU in stable hemodynamic status to receive brain-preservation hypothermia for 7 days leading to cognitive recovery and rehabilitation. The entire duration of the arrest and CPR until the patient finally stabilized was recorded on the internal defibrillator and retrieved for analysis and documentation. The A-TT is routinely used in orthopedic surgery to create a bloodless surgical field. Physiologically it can be characterized as a “mechanical vasoconstrictor” that moves 95% of the blood from the limb to the core. As such, it can auto-transfuse over 1000 cc of blood from the two legs to fill up the heart chambers (pre-load) and block the flow to the legs, thereby causing total resistance to flow, diverting the cardiac output to the essential organs and increasing diastolic pressure and coronary perfusion pressure. These are, in fact, the intention behind using vasopressors during CPR, but the latter are associated with widely documented adverse effects including increasing resistance of the cerebral circulation and raising the O2 consumption of the heart muscle. This case indicates that there is a posiblity that a mechanical vasoconstriction in the form of the A-TT can improve survival of witnessed cardiac arrest. Clearly, additional controlled studies should be done in order to validate and optimize the use of A-TT during CPR.

Introduction:

The key to successful cardioversion and return of spontaneous circulation (ROSC) in cardiac arrest is resumption of coronary blood flow (1,2) by maintaining sufficient coronary perfusion pressure (CPP) (1,2). Increasing chest compression cardiac output requires higher venous return and chambers filling (pre-load), while raising peripheral vascular resistance and diastolic pressure (after-load). Both can be achieved by shifting the blood from the legs (auto-transfusion) and blocking its return to the legs (tourniquet). We hereby describe successful resuscitation of a patient using an elastic auto transfusion tourniquet device, (HemaShock®; Oneg HaKarmel Ltd. Haifa, Israel), which when applied to the legs, compresses and constricts all the blood vessels as it rolls up the leg and displaces the blood to the central circulation while blocking the arterial flow (3, 4). This case is unique since the patient had an implanted automatic defibrillator which recorded the electrical activity of the heart during the entire time from collapse to revival. The patient was subsequently treated by brain preservation and was discharged from the hospital in good neurological status.

Case description:

A 78 years old male collapsed in witnessed arrest in a restaurant. The patient had cardiac history of MI, chronic atrial fibrillation, cardiomyopathy, S/P triple bypass surgery, multiple coronary stents, aortic valve replacement, inferior vena cava filter and AICD. Bystander CPR was started immediately followed by paramedics ACLS. The patient was brought to ED by paramedics approximately 33 minutes after collapsing with on-going CPR, multiple IV doses of epinephrine, IV Amiodarone, and multiple AICD shocks and external defibrillation attempts. Upon arrival the patient was in VF, comatose, with dilated pupils. Auto-transfusion tourniquets (A-TT) were placed on both legs immediately upon arrival to the ED. The patient was then defibrillated successfully with achievement of ROSC within 4 minutes of ED arrival, initially with extreme tachycardia and very high blood pressure followed within 8 minutes by sustained and effective cardiac rhythm at 89$\pm$14 bpm with blood pressure of 110.$\pm$12/75$\pm$8 mm Hg. Figure 1 shows the timeline of the patient's blood pressure and the A-TT placement status until the patient was transferred to the ICU. The numbers in the Figure correspond to the timing of the AICD records shown in Figures 2 and 3.

The AICD (Medtronic Protecta XT CRT-D) record showed persistent VT/VF pattern at 150 to 273 waveforms per minute (Figure 2). The AICD discharged 10 times prior to A-TT placement with no conversion or pacing capture (Records 26 and 45 in Figure 2) and 4 additional times after A-TT placement with transient paced capture as seen in records 67 and 80. In addition, external cardioversion shocks at 200J were given multiple times before ED arrival with no conversion and additional 4 external shocks were given after the A-TTs were applied as shown in record 95, this time with transient conversion, eventually leading to sustained ROSC 13 minute after A-TT placement.

Hypothermia treatment was started within 33 minutes of ROSC. A-TT removal started 44 minutes after they were placed. First A-TT was rolled down to knee level, and then removed followed by the second one being rolled to knee level and then to ankle and then removed completely. The removal process took 37 minutes and total A-TT time was 81 minutes. When the first A-TT was rolled down from the thigh to the knee, supplemental bolus of IV NS was given to avoid sharp drop in blood pressure. The patient was maintained in brain-ischemia protection protocol for 7 days and gradually regained consciousness with meaningful communication and cognition over the subsequent week. Rehabilitation was started and after a month in the hospital the patient was discharged and flown to his home-town for continued rehabilitation in good neurological status. The patient eventually succumbed to MRSA infection of a bed sore 3 months after the reported cardiac arrest episode.

Discussion

This case is unique for a number of coinciding factors: a witnessed cardiac arrest event in which multiple AICD and external shocks failed to convert a shockable rhythm until more than 30 minutes later when exsanguination tourniquets were placed on the patient's legs. Subsequent shocks were then effective, first transiently and within ~8 minutes to sustained ROSC. Despite the prolonged >30 minutes of arrest and fixed dilated pupils upon arrival to the ED, brain preservation protocol was promptly initiated, leading to the patient regaining physical and cognitive functionality to the point where he could be discharged. The fact that the entire acute event was recorded by the AICD adds to the uniqueness of this case presentation. The ultimate fate of the patient who succumbed to MRSA infection of a pressure sore 3 months after the event provides a perspective of the relative importance of basic nursing care vs. advanced technology. The following is a systematic discussion of the history, physiology, and clinical background of the use of means to shift blood from the periphery to the central circulation during CPR as well as certain aspects of this particular case.

Pathophysiological considerations

The exsanguination tourniquet used as a last resort measure in this case is routinely used in orthopedic limb surgery to effect bloodless surgical field (5). It evacuates all the blood in the limb except the blood inside the bone marrow and blocks arterial flow into the limb. As such it is an ultimate mechanical vasoconstrictor, exclusively focused to the limb. It has been shown that about 500 cc of blood can be shifted from each leg of a normovolemic adult to the central circulation (3). It is conceivable that during cardiac arrest, when the sympathetic system shuts down and vasodilatation occurs, the volume of blood accumulating in each leg may be even larger. As such, applying the A-TT to a leg can quickly (i.e. in less than 30 seconds) displace more than a pint of whole blood with intact oxygen carrying capacity from each leg. The blood then feeds into the heart and central circulation to enhance venous return, increase end-diastolic volume of the heart and stressed volume of the central circulation. A recent porcine study where surrogates of the A-TT were used – simultaneous placement of Esmarch bandages on all 4 limbs (6) showed significantly higher Coronary Perfusion Pressure (CPP), Cerebral Blood Flow (CBF), and ETCO2 during mechanical chest compression of induced VF pigs treated with the limb binding vs. those who were not. This study recreated the Woodward Maneuver where Esmarch bandages were used to restore heart volume in a child in cardiac arrest during open chest cardiac massage (7).

The effect of the A-TT can be viewed as a "mechanical vasoconstrictor" whose effect is focused and limited to the extremities. Chemical vasoconstrictors (8-12) are routinely used during CPR to achieve a similar effect, although distributed and less than maximal and has been repeatedly shown to reduce cerebral blood flow and neurological outcome. However, the shifting of blood and increase of pre-load is not the only effect of the A-TT. Its use also prevents blood from feeding into the treated limbs. This promptly increases peripheral resistance, and redirects the less than optimal cardiac output achieved with CPR to the essential organs. In fact in the J Resuscitation porcine study (6) it was shown that the diastolic pressure was 14-17 mm Hg higher in the limb binding group and CPP was 10-14 mmHg higher. It is our speculation that effecting sufficient coronary blood flow is what facilitated ROSC in this case (1,2).

Experience with the use of tourniquets in orthopedic surgery (5) and in prevention of bleeding in penetrating limb trauma facilitated setting the time limit of uninterrupted application of the A-TT to 120 minutes, but it is prudent to start removing it as soon as possible after ROSC was achieved and do so gradually while monitoring hemodynamic parameters.

History

The first mention of expelling blood from the limbs and restricting its re-entry during cardiac arrest was by Woodward in 1952 (7). He described a case of a 4 years old child who had cardiac arrest during orthopedic surgery. Attempt to perform internal cardiac massage failed until Esmarch bandages were applied to the legs from toes to groin, leading to "more than doubling the size of the heart and spontaneous (temporary) return of heartbeat". This is now called by some "Woodward Maneuver", but it should not be confused with just elevating the legs.

Studies done in the 1980's with MAST anti-shock trousers and Abdominal Binding during CPR did not have an overall beneficial effect on the measured parameters nor on the outcome (13-19). The general perception is that their use restricted respiration by compressing the lower ribs and upwards shifting of the abdominal content. The logistics and time delay for applying the MAST were a likely additional factor in their not becoming a standard of care.

The logic of trying to shift blood from the widely dilated periphery to the core prompted the invention of Compression-Decompression CPR devices (20) as well as the inspiratory impedance threshold valve (21-23). Both methods attempt to maintain negative intra thoracic pressure in order to induce a pressure gradient along the vena cava(s) in order to increase venous return and end diastolic volume. The debatable success of these methods in improving ultimate CPR outcome is most likely due to difficulty to suck fluids through soft-wall collapsible blood vessels (i.e. "Starling resistor").

Vasopressors such as epinephrine, norepinephrine and vasopressin are being used routinely in CPR. Controversies around the use of these drugs continue (24-25), but the current standard of care and AHA ACLS directives are to use them since their use increases the rate of ROSC 2-3 fold. It should be noted that with the reduced cardiac output during CPR circulation time may take as much as 4 minutes for a dose of Epinephrine to reach from a peripheral vein injection site to the arterial and venous vessels of the limbs but less so to the heart, brain gut, kidneys and liver. This may exceed the half-life of adrenaline in the body, so that their constricting effect is greater on the brain and the central organs than on the periphery. In addition, the excitatory effect of these drugs on the heart contractility and its energy consumption are of interest beyond the scope of this discussion (24-25). However, we noted the exceedingly high blood pressure immediately after ROSC (Figure 1) and the initial undulation between effective and ineffective contractions (Figure 3) and we speculate that the multiple doses of Adrenaline given to this patient contributed to these adverse effects.

Comments on this case

The fact that ROSC occurred within a short time from applying the A-TT on this patient should be viewed as coincidental until more data is collected and analyzed from a larger number of patients. However, the fortuitous availability of the AICD (26) recording that showed absolutely no effect of the cardioversion shocks prior to A-TT placement and repeated conversion after it was placed is compelling. Since this case, the A-TT has been used in eight additional patients who were brought to the ED after witnessed cardiac arrest (all with down time greater than 30 minutes and dilated pupils) and six of them reverted to ROSC, but in all of them hypoxic brain damage was severe, leading to their demise within 22 min to 12 days later. In our view the A-TT should be placed on the cardiac arrest patients as soon as possible, provided that this is proven in a prospective study to improve the patients' ultimate outcome.

The A-TT should not be placed on a leg that has known DVT in it. It is not contraindicated to place it on the other leg or on the arms. Only the use of the A-TT in cardiac arrest is discussed here. In patients with severe shock other instructions apply to the A-TT application. The removal of the device in all cases should always be done by rolling it down gradually and in steps while monitoring the patient's hemodynamic status.

Conclusions

ROSC was achieved in this case after more than 30 minutes of CPR with multiple internal and external defibrillation attempts. CPR was carried out from the very beginning by trained individuals (first an MD bystander and then by paramedics), presumably doing so in an optimal way, but with no ROSC. The placement of the A-TT upon arrival to the ED coincided with prompt ROSC that was sustained. The patient arrived to the ED with dilated unresponsive pupils. However, apparently his ischemic brain damage was transient and reversible and the prompt initiation of brain preservation hypothermia protocol soon after ROSC was effective was effective. As always, the successful care of the near-death patient is the result of combining many elements. As with the AED, some 15 years ago, the addition of the A-TT as an added link in this chain should be critically studied, optimized and if proven useful, meticulously implemented.

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Figure Legends

Figure 1

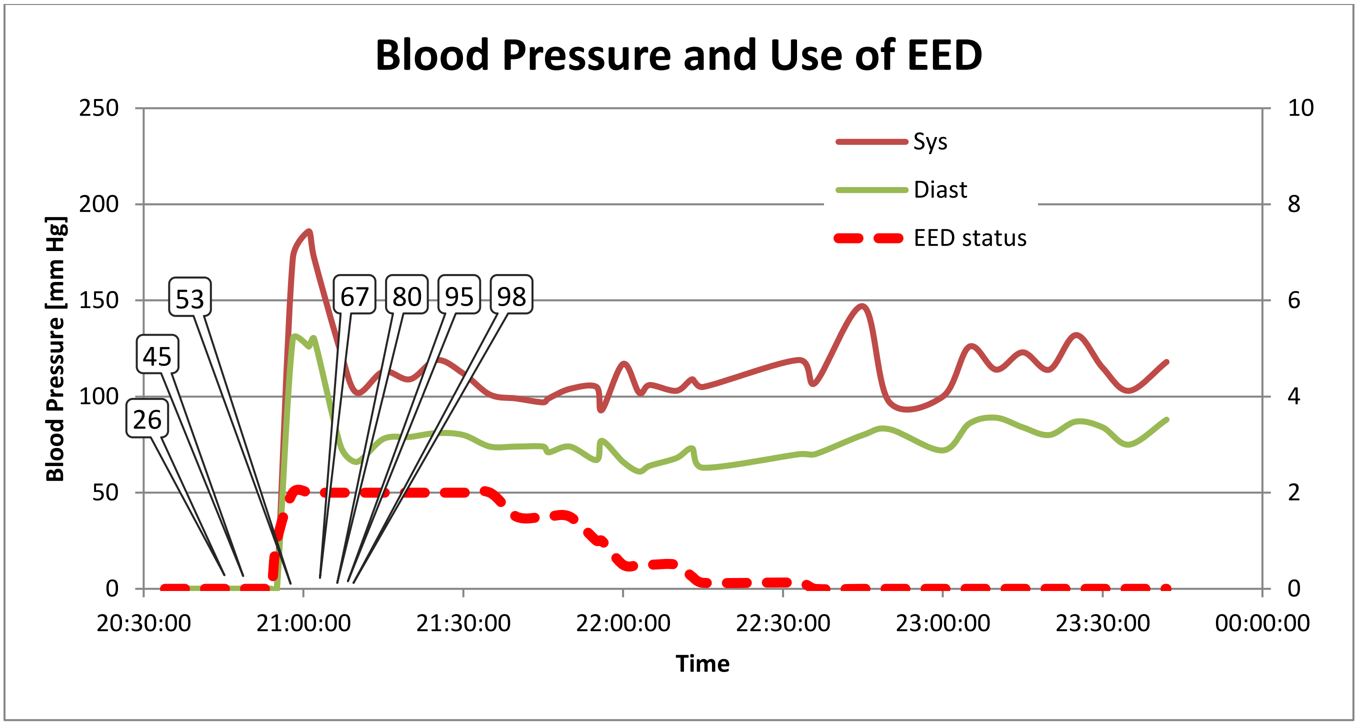
Timeline of the patient's blood pressure and the EED status from the time of collapse until the patient was transferred to the ICU. The numbers indicate the timing of the AICD records shown in Figure 2 and 3.

Figure 2

AICD records from before the application of the EEDs. The arrows indicate shocks applied by the AICD. Note the lack of conversion or capture.

Figure 3

AICD Records from after the EEDs were applied. The numbers indicate the times shown in Figure 1. Brown arrows show the shocks of the AICD. Blue arrow indicate an external defibrillator shock. Note the return to regular (paced and un-paced) electrical activity, which was initially transient and from record 98 on was sustained.



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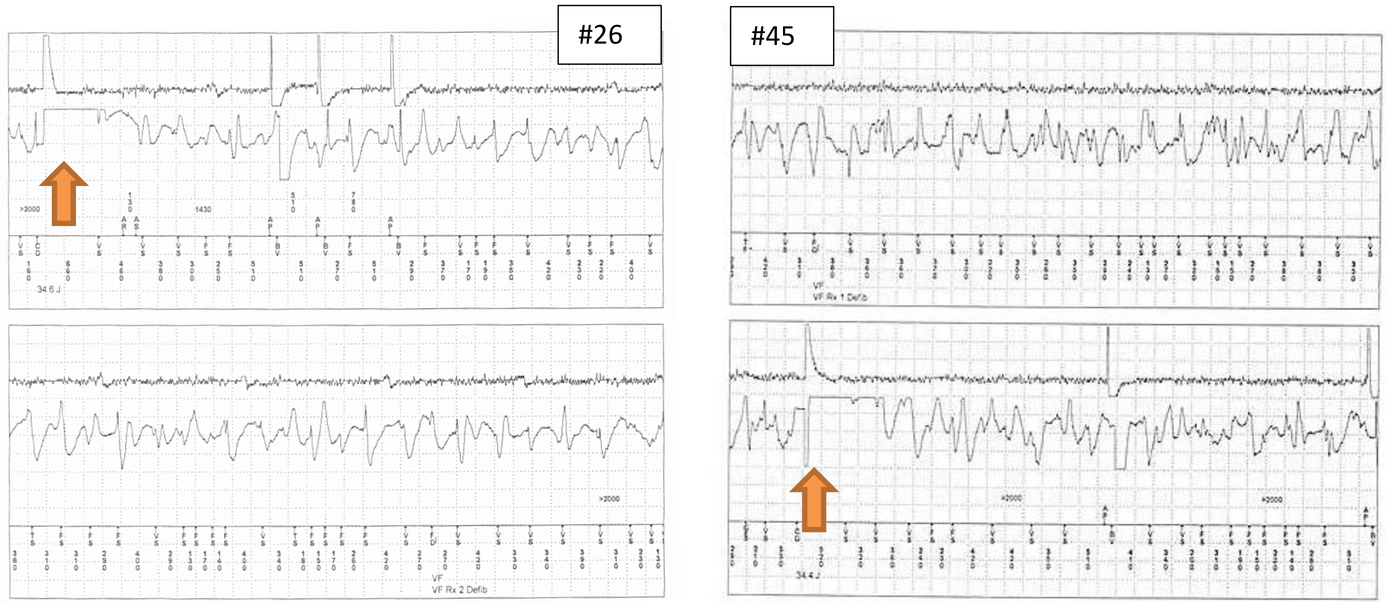

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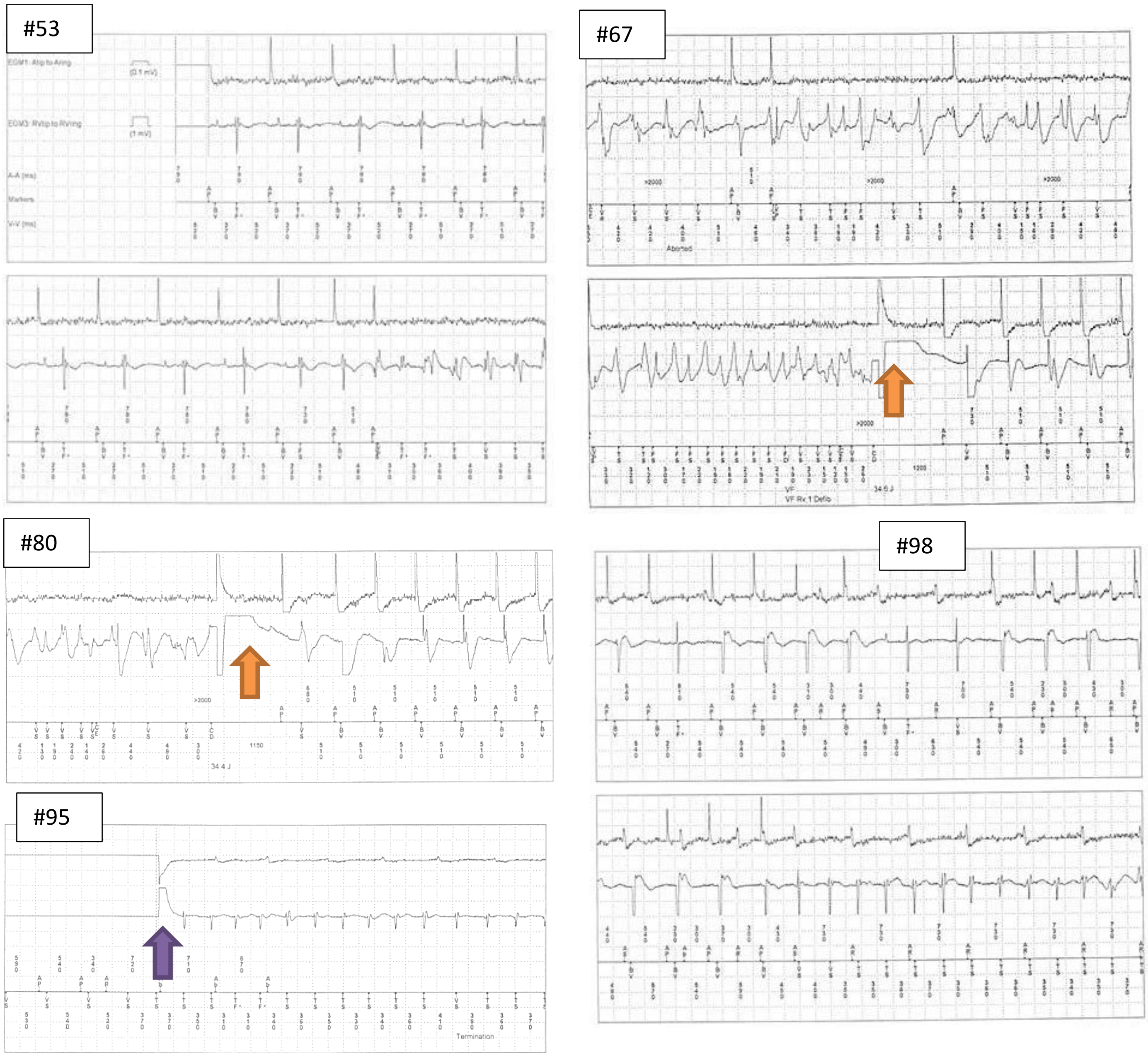

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