Successful exsanguination tourniquet reanimation of a cardiac arrest patient with implanted defibrillator – a case report

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Short tittle: Exsanguination Tourniquet during CPR

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Background:

The key to successful cardioversion and return of spontaneous circulation (ROSC) in cardiac arrest is resumption of coronary blood flow (1,2). The extremity exsanguination device (HemaShock™, OHK Medical Devices Ltd., Israel), when applied to a limb (leg), compresses and constricts the blood vessels as it rolls up and displaces the blood to the central circulation and blocks the arterial flow into the limb (3, 4). Doing so increases venous return to the heart and diverts blood flow generated by CPR chest compression away from the legs.

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 upon their arrival to the scene. The patient was brought to ED by paramedics approximately 33 minutes after first 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. HemaShock™s 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 88.9 ± 13.8 bpm with blood pressure of $110.4 \pm 11.6/75.4 \pm 7.6$ mm Hg. Figure 1 shows the timeline of the patient's blood pressure and the HemaShock™ status until the patient was transferred to the ICU. The numbers indicate the timing of the AICD. 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 HemaShock™ placement with no conversion or pacing capture (Records 26 and 45 in Figure 2) and 4 additional times after HemaShock™ placement with transient paced capture (e.g. 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 HemaShock™s were applied (e.g. Record 95) with transient conversion, eventually leading to sustained ROSC 13 minute after HemaShock™ placement. records shown in Figures 2 and 3.

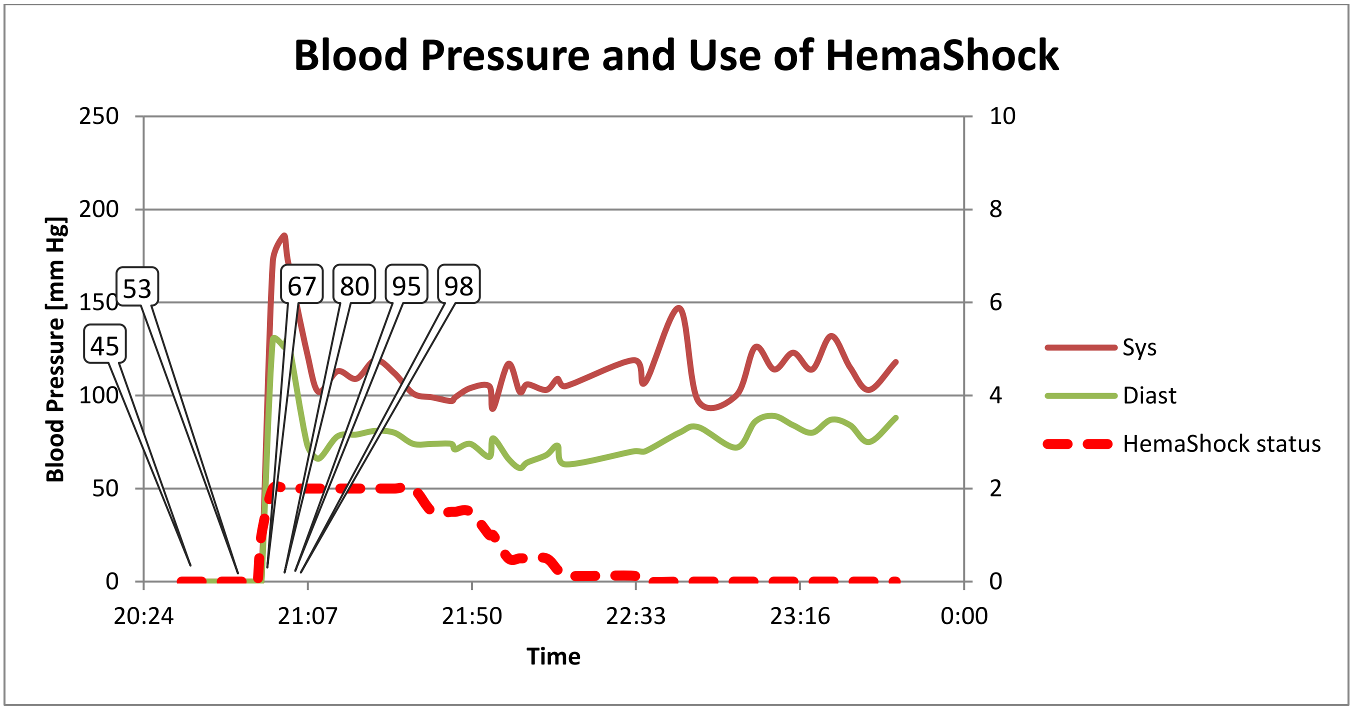

Figure 1: Timeline of the patient's blood pressure and the HemaShock™ status from the time of collapse until the patient was transferred to the ICU. The numbers indicate the timing of the AICD records shown in Figure 2 and 3.

Hypothermia treatment was started within 33 minutes of ROSC. HemaShock™s removal started 44 minutes after they were placed. First HemaShock™ 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. The removal process took 37 minutes and total HemaShock™ time was 81 minutes. When the first HemaShock™ 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 flown to his home-town for continued rehab. 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 on 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.

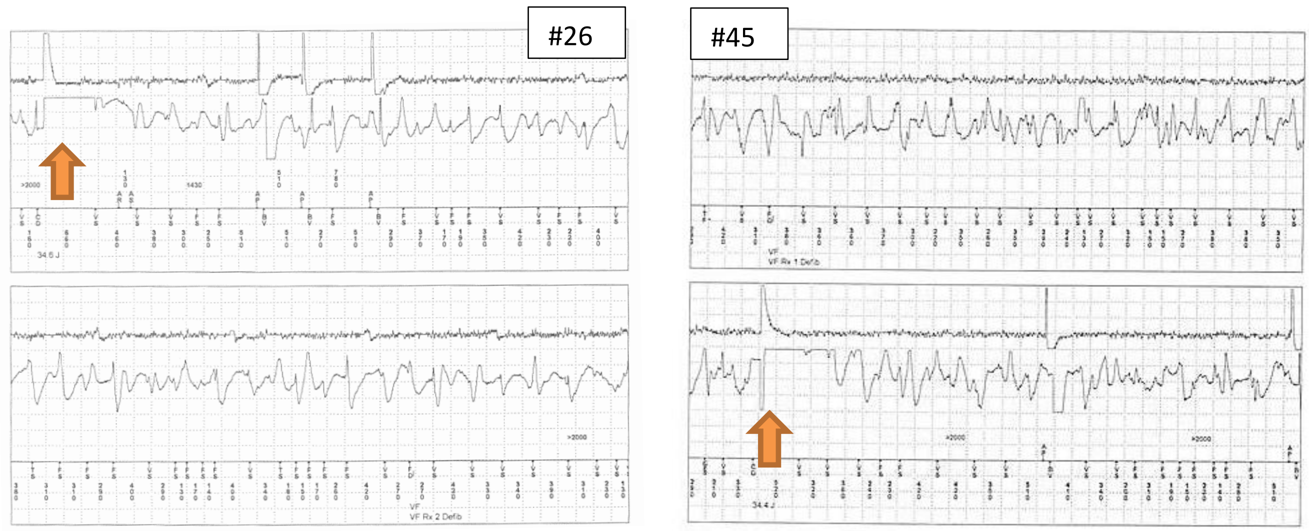

Figure 2 AICD records from before the application of the HemaShock™s. The arrows indicate shocks applied by the AICD. Note the lack of conversion or capture.

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 that inside the bone marrow and blocks arterial flow into the limb. It is estimated that about 500 cc of blood can be moved from each leg to the central circulation (3) in a normal individual. It is conceivable that during cardiac arrest, when the sympathetic system shuts down and vasodilatation occurs, the volume of blood in each leg may be even larger.

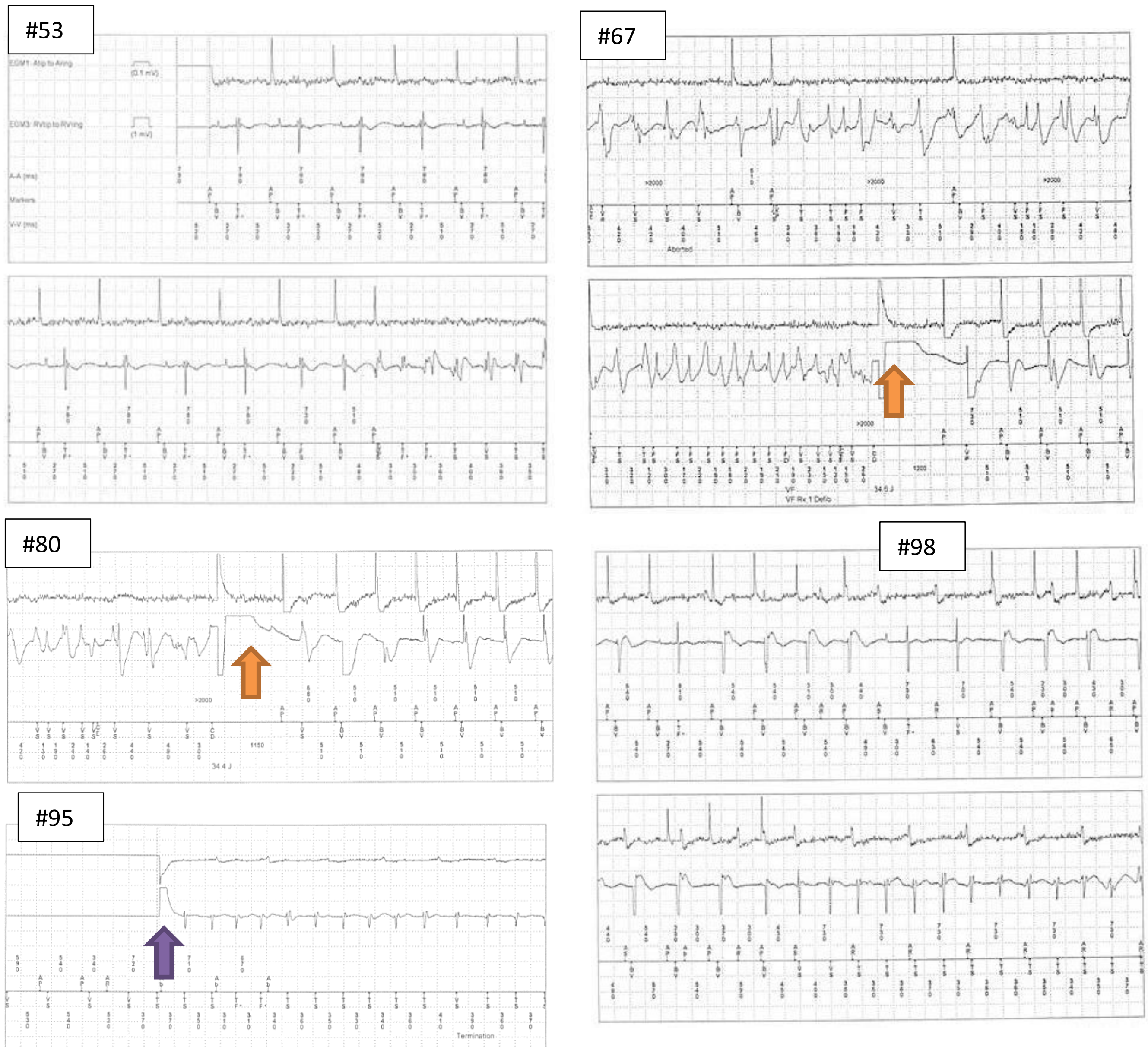

Figure 3 AICD Records from after the HemaShock™s were applied. The numbers indicate the times shown in Figure 1. Brown arrows show the shocks of the AICD. Blue arrow indicate an external defibrillator shock. Note the return to regular (paced and un-paced) electrical activity, which was initially transient and from record 98 on was sustained.

As such, applying the HemaShock™ to a leg can quickly (i.e. in less than 20 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, end diastolic volume of the heart and stressed volume of the central circulation. A recent porcine study where surrogates of HemaShock™ were used – 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 HemaShock™ 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. However, the shifting of blood and increase of pre-load is not the only effect of the HemaShock™. Its use also prevents blood from feeding into the treated limbs. This clearly 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 HemaShock™ use 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 an 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 shifting upwards the abdominal content. The logistics and time for applying these devices 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 success of these newer methods in improving ultimate CPR outcome is of interest.

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. 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 as well as to the gut, kidneys and liver. This may almost exceed the half-life of adrenaline in the body. 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 may speculate that the multiple doses of Adrenaline given to this patient contributed to these observations.

Comments on this case

The fact that ROSC occurred within seconds from applying the HemaShock™ 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 shock prior to HemaShock™ placement and repeated conversion after it was placed is compelling. Since this case the HemaShock™ has been used in several additional patients who were brought to the ED after witnessed arrest (all with down time greater than 30 minutes) and some of them reverted to ROSC, but in all of them hypoxic brain damage was severe leading to their demise within several days. In our view the HemaShock™ should be placed on cardiac arrest patients as soon as possible, provided that this is proven in a prospective study to improve the patients' ultimate outcome.

The HemaShock™ 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 HemaShock™ in cardiac arrest is discussed here. In patients with severe shock other instructions apply to the HemaShock™ application. The removal of the device is common to all cases and 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 the best available way. Nevertheless, the patient arrived to the ED with dilated unresponsive pupils. However, apparently the ischemic brain damage was transient and reversible and the prompt initiation of brain preservation hypothermia protocol soon after ROSC 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 HemaShock™ as an added link in this chain should be critically studied, optimized and if proven useful, meticulously implemented.

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