CASE REPORT

Disaster and Emergency Medicine Journal
2022, Vol. 7, No. 1, 63–69
DOI: 10.5603/DEMJ.a2021.0030

ISSN 2451–4691, e-ISSN 2543–5957

GLOBAL CASUALTY CARE IN OPERATION AREA (CARDIOPULMONARY RESUSCITATION AND DAMAGE CONTROL SURGERY)

Shibu Sasidharan[1], Shyam Krishna[1], Aanchal Varma[1], Babitha Shibu[2], Harpreet Dhillon[3]

[1]150 GH, Jammu, India
[2]Ojas Alchemist Hospital, Panchkula, India
[3]Military Hospital, Jammu, India

Abstract

Urgent surgery should not be performed preferably for at least 72 hours after a cardiac arrest to minimize the risk for additional perfusion-related organ injury. However, in peculiar circumstances, especially in a military setting, emergency surgery may be necessary in selected patients to save health and life. A previously healthy 34-year-old soldier developed multiple splinter injuries and mangled injury to his right arm after a missile attack. Due to heavy shelling and enemy fire, he bled profusely and could not be immediately evacuated to the medical aid post. After reaching the first-aid post, he was navigated through various medical echelons before reaching our center (Level III) where he was resuscitated and limb-salvage surgery was done. En route to the hospital, he suffered a cardiac arrest, was resuscitated, and had the second arrest on arrival. He was revived within 3 minutes and rushed to the operation theatre, where damage control surgery was done, including a brachial artery anastomosis. After the initial surgery, he was air-evacuated to the nearest tertiary center, where he was further managed by the vascular surgeon and cardiologist and made a full recovery. Immediate hemostasis of culprit injury is mandatory to make fluid resuscitation effective. Administering effective CPR, volume replenishment using crystalloids and whole blood, balanced anesthesia, damage control surgery, and teamwork can save patients' limbs and lives.

KEY WORDS: cardiopulmonary resuscitation, CPR, military medicine, hypovolemic shock, Damage control surgery

Disaster Emerg Med J 2022; 7(1): 63–69

INTRODUCTION

The casualties on a battle-front are very different from what we see in the routine day-to-day practice of medicine.

Orthopedic trauma is the most common type of injury seen in battlefield medicine [1]. The upper extremity is very commonly affected, ranging from a fingertip injury to complex injuries including amputation, mangled limbs, and injury to the brachial plexus. For a successful outcome, a swift multidisciplinary approach is necessary as delay can result in severe dysfunction [2].

After a cardiopulmonary arrest (CPA) secondary to traumatic injury, the overall survival rate is only 2.2% [3]. Furthermore, only 0.8% of those suffering from traumatic CPA are spared from neurological disability [4]. The rates go further lower for a patient undergoing surgery post-cardiac arrest due to hypoxic-ischemic events due to CPA. Hence, such

ADDRESS FOR CORRESPONDENCE:
Shibu Sasidharan, Department of Anaesthesiology and Critical Care, 150 GH, Rajouri, Jammu and Kashmir, India
e-mail: shibusasi@gmail.com
Received: 8.07.2021 Accepted: 7.09.2021 Early publication date: 15.12.2021

cases are a challenging test for any anesthesiologist, intensivist, or emergency physician [5].

Cardiac arrest/mortality due to hemorrhagic shock are common in battlefield medicine and have been well reported. However, to the best of our knowledge, this is the first reported case of successful surgical outcome in a post-cardiac arrest patient in hypovolemic shock, in a war zone from Southeast Asia, without any cardiac or neurological sequelae. Our report has been reported in line with the CARE reporting criteria.

Case summary

In a forward location of the battle, a 34-year-old soldier suffered multiple injuries and a mangled right upper limb after a missile explosion following enemy action. The time of injury was 19:30. The combat life-saver nearest to him immediately applied a compression bandage using shell dressing on the mangled arm and started dragging him to the rear. Enemy exchange of fire made evacuation from the forward post difficult and time-consuming. The patient could reach the aid-post (Level V) only by 21:45 (with a shell dressing in situ), where a combat-medic attended him. On arrival at the post, the casualty was conscious and alert with the following vitals — HR 148 bpm; NIBP 106/76 mm Hg; SpO_2: 99%; Afebrile; ECG: sinus tachycardia. Two large-bore (16G) intravenous (i.v.) access was secured (left arm, right foot), and a tourniquet was secured below the axilla. The shell dressing, which was completely soaked with blood, was then removed and reapplied. The casualty was given Tetanus prophylaxes, Morphine (5 mg i.v.), and iv fluids (RL — 1 liter and then infusion, to maintain a MAP > 65 mm Hg). After the initial resuscitation, at 22:30, the casualty was further moved to the higher echelon of medical care (Level IV), where a surgeon now attended to the casualty. The secured tourniquet was reassessed, iv analgesics (Paracetamol 1000 mg slow i.v.) continued, and antibiotics were started. Cleaning and thorough irrigation of the wound was done. An attempt was made to put a temporary shunt, which was unsuccessful. Bleeding was now controlled to a great extend with the dressing and compression bandaging. A urinary catheter was also inserted. By 23:50, the casualty was pale and hypotensive with tachycardia (NIBP 90/70 mm Hg, HR140 bpm). Blood transfusion was started (350 mL whole blood, using a walker donor), and the casualty was thereafter evacuated to the closest military hospital (Level III) for further management. Vitals at the exit from Level IV hospital — HR-120 bpm, NIBP – 110/78 mm Hg, SpO2 – 100%, GCS – 15/15.

At 01:50, en route to the hospital (almost 2 hours into the journey), the casualty had bradycardia and suffered a cardiac arrest. CPR was administered by the para-medic staff accompanying the casualty. Atropine 0.6 mg, followed by Adrenaline 1 mg iv, was administered. Crystalloid bolus (RL) of 500 mL was also given, along with passive leg raising (PLR). The casualty achieved a return of spontaneous circulation (ROSC) within 2 minutes (At 01:55, HR 88 bpm, NIBP 100/60 mm Hg). The casualty reached the hospital navigating the difficult mountainous terrain by road at 03:30, accompanied by the paramedics. So far, 3L of RL and 350 mL of whole blood had been transfused. Urine output was 60 mL over 3 hourshours. On arrival, the vitals were: HR 72 bpm, NIBP 90/60 mm Hg, the patient appeared pale and drowsy. While the casualty was being wheeled into the hospital, he suddenly became unresponsive, with no pulse. Emergency resuscitation as per ACLS protocol was started, and the casualty was revived in less than 3 minutes (CPR and Inj Adrenaline 1 mg were administered i.v. stat). He was infused with another 500 mL of bolus RL, and PLR was done. 10 mg/kg CaCl2 and MgSO4 1 gm were infused i.v. He regained consciousness, was responsive, and his vitals were now NIBP 90/60 mm Hg and HR 90 bpm. Noradrenaline infusion was started via the peripheral line to maintain a MAP > 65 mm Hg. As soon as the casualty achieved ROSC, his blood samples were taken for laboratory tests and ABG; a chest radiograph was taken and quickly shifted to the operation theatre, where the radiologist did doppler studies. ABG at 03:45 showed O_2 saturation (O2Sat) 95%, pH 7.33, pO_2 88 mm Hg, pCO_2 52 mm Hg, bicarbonate (HCO_3) 21 mmol/L, base deficit (BD): -2 mEq/L and lactate: 2.4 mmol/L. Pre-op doppler showed negligible flow in the brachial artery at the area of injury. Doppler studies distal to injury showed no vascular flow. SpO2 on the fingers of the mangled arm showed no reading. The surgical plan was designed to immediately operate the casualty and remove the splinters and attempt to re-vascularise the limb through anastomosis in order to save the limb. After a quick pre-anesthesia evaluation, the casualty was accepted in ASA IV (E), and general anesthesia was administered with invasive monitoring. Left radial artery was cannulated for arterial wave monitoring, and left internal jugular vein was cannulated

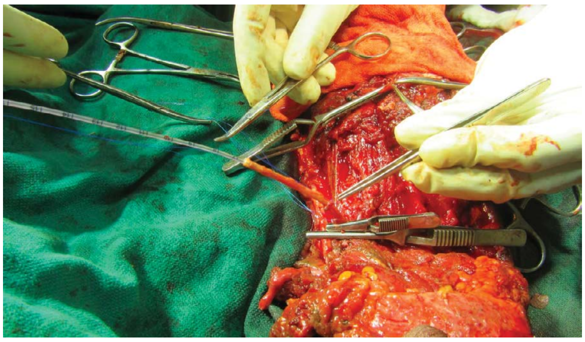

FIGURE 1. Anastomosis of the vessels in progress

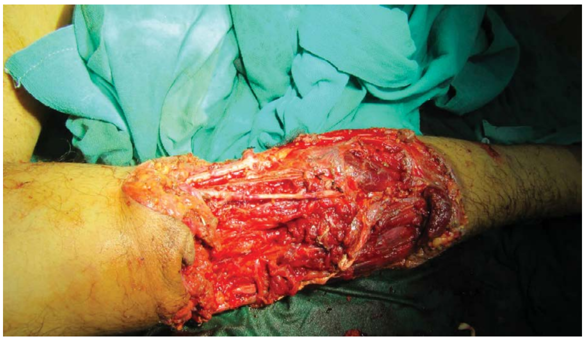

FIGURE 2. Anastomosis completed and patent vessels

with a 7.5 Fr triple lumen central venous catheter. The patient was kept warm, and the temperature was monitored using a nasopharyngeal probe, and a bladder catheter monitored urine output.

Vitals at induction were: HR 152 bpm, NIBP 90/70 mm Hg, SpO_2 99%. Induction was done using Inj. Ketamine 40 mg slow i.v. and Inj Fentanyl 140 mcg i.v. Volatile anesthesia was started using Isoflurane, and Inj Vecuronium 7 mg iv was given for muscle relaxation.

The airway was secured using 8 mm ID PVC ETT. Anesthesia was maintained by volatiles N20 and Isoflurane to achieve a MAC-1. The maintenance fluid given was RL, and MAP was kept at 65 mm Hg. Blood transfusion with whole blood was started with whole blood. Intra-op casualty developed hypotension, and hence Inj Noradrenaline infusion doses were escalated to titrate to a MAP > 65 mm Hg. By now, his lab results had come. Hemoglobin was 6.2 g/dL (normal: 14–15 g/dL), hematocrit level was 16.9% (normal: 45%); prothrombin time (PT) 15.1% (normal: 11–13%); and partial thromboplastin time (PTT) was 49 seconds (normal: 21–34 seconds). ABG at 04:30 showed O_2 saturation (O_2Sat) 95%, pH 7.36, pO_2 98 mm Hg, pCO_2 38 mm Hg, bicarbonate (HCO_3) 23 mmol/L, and lactate: 1.8 mmol/L. His vascular anastomosis of the brachial artery was done after taking graft from the right great saphenous vein, and debridement of the mangled arm was done (Fig. 1). Doppler studies showed that the graft was not successful, and hence another graft taken from the right sephano-femoral junction and anastomosis was done using prolene 5-0. Doppler confirmed perfusion and SpO_2 on the finger probe showed 98% saturation. The dressing was done, and the limb was immobilized. Plaster-of-Paris (POP) slab was applied after achieving hemostasis. Inj Heparin 1500U i.v. was administered stat, and 2.5 L RL and two packs of whole blood were given intra-op. Inj calcium gluconate 10% (10 mL) was given as a slow infusion. The radiologist, intra-op, constantly carried out Doppler studies at various intervals to ascertain the patency of the graft using dynamic studies. The flow was achieved, and the circulation was checked using the finger prick test. After anastomosis was done (Fig. 2), multiple splinters were removed from various sites of the body (none of which were contributing to major blood loss). ABG at 05:15 showed O_2 saturation (O_2Sat) 99%, pH 7.38, pO_2 96 mm Hg, pCO_2 35 mm Hg, bicarbonate (HCO_3) 24 mmol/L, and lactate: 1.7 mmol/L. Noradrenaline was now being infused at a dose of 1 mcg/kg/minute.

The total duration of surgery was 1.5 hours, total fluids given 6.5 liters RL and 750 mL whole blood, total blood loss intra-op — 150 mL. Peri-operative normothermia of 36.5 C was kept constant. TOF value was > 0.9. In view of the above, he was extubated on the table and shifted to the ICU for observation and further management. The casualty was transferred the following day by air to the Level II center, where further evaluation and treatment by the vascular surgeon and cardiologist (for graft and cardiac evaluation, respectively). On day 7 of injury, the casualty was discharged with his limb salvaged.

DISCUSSION

Trauma centers and military hospitals worldwide have various designations to identify the level of care available at a hospital. There are five levels of care (also known as "roles"), previously referred to as echelons by NATO and ABCA (USA, Britain, Canada, Australia) countries. Levels should not be confused with the American College of Surgeons use of the term in US trauma centers. Different levels denote differences in capability rather than the quality of care. Each level has the capability of the level forward of it and expands on that capability. Soldiers with minor injuries can be returned to duty after simple treatments at forward locations, and all others are prepared for evacuation with medical care to a higher level.

When the casualty arrived at our facility in the Level III hospital, 8 hours had already elapsed after a missile blast injured the casualty. By the time he reached our center, he had already lost much blood despite the tourniquet and pressure dressing and had 2 episodes of cardiac arrest. Though recent cardiac arrest and severely depleted reserves, as seen in shock, are a clear contra-indication to emergency surgery, this casualty was taken up for surgery to control the bleeding and to attempt to salvage his limb, which was severely hypo-perfused.

This timely surgical action and optimal anesthesia management helped save the life and the limb of the casualty and is described in detail in the paragraphs below.

Control of hemorrhage is the most crucial step to prevent morbidity and mortality on the battlefield. Bleeding that is not controlled by direct pressure should use extremity tourniquets for the same to reduce complications. Pneumatic tourniquets (PTs) are most commonly used to control bleeding during upper-limb surgery [6]. Standard PTs are inflated to pressures < 250 mm Hg for not more than 2 hours and are placed 5 cms proximal to the open wound. These are useful in injuries distal to the axilla only [7–9].

The most common tourniquets used on the battlefield are windless style Combat Application Tourniquet (CAT) or Special Forces Tactical Tourniquet (SOFT-T wide). These tourniquets can be applied by one hand if need be. Hemostatic dressing and continuous pressure are advised if the wound is at the axilla (junctional wounds). Junctional tourniquets are presently available commercially, but there is insufficient evidence to embrace their use. In our casualty, a CAT tourniquet was secured at the Level IV hospital for hemostasis [10].

In the medical aid posts, blood transfusion is done via blood donation from a walking blood donor who is part of the walking blood bank (WBB). WBB is the source of whole blood on the battlefield. Using very basic equipment, by a sterile technique, blood is drawn from the soldier donating blood and is directly transfused to the recipient [11]. This whole blood serves two purposes: transfusing all blood components and keeping the casualty warm (if passed through a fluid warmer). Hypothermia is one of the significant causes of death in trauma [12]. Our casualty was transfused with whole blood via WBB at the Level 4 center. This transfusion assumably bought the well-needed time and reserves for the casualty to endure the remaining journey. However, the American Association of Blood Banks discourages the use of a WBB program for general civilian use [13].

Passive leg raising (PLR) is the maneuver of lifting the legs in the event of circulatory collapse. It is a time-tested rescue maneuver used by first-aid rescuers for many years. PLR increases cardiac preload and is used as a test for monitoring functional hemodynamic and assessing fluid responsiveness. Lifting the legs passively induces a gravitational transfer of about 150 mL of blood from the legs to cardiac cavities [14].

On a battlefield, evacuation is a major consideration. Unfavorable terrain and the possibility of enemy fire can further compromise movement, as with our casualty. Hence, battlefield trauma nurses must be trained in reducing hemorrhages to prevent complications and buy time to allow evacuation.

Our casualty had a cardio-pulmonary arrest (CPA) en route to the hospital. Cardiopulmonary resuscitation (CPR) was instituted immediately, as per the AHA BLS protocol, and the casualty could be revived in less than 2 minutes. The casualty had a second cardiac arrest on arrival to the hospital, and again immediate CPR was initiated, and the casualty was quickly revived. Effective and good quality CPR is the essential tool of management that affects casualty outcomes in cardiac arrest (more in medical causes). In compression-only CPR (COCPR), continuous chest compressions to ventilation ratio of 30:2 are recommended by the American Heart Association (AHA). CO-CPR should be continued till the medical help arrives or the casualty reaches the hospital. In our casualty, the cause of cardiac arrest was a hypovolemic shock [15].

For a casualty with hemorrhagic shock, surgical intervention to control bleed has to be taken as soon as possible. Since a cardiac arrest is a major co-morbidity, administering and maintaining safe anesthesia to a casualty like ours who has had a recent cardiac arrest can be very complicated. Good optimization and efficient hemodynamic monitoring are the cornerstones to safe anesthesia.

In a casualty with trauma, patient-specific concerns like hemodynamic instability, myocardial damage or dysfunction, and electrolyte imbalances should be balanced against surgery specific concerns like blood loss and fluid shifts. Tachycardia, hypotension, severe anemia, hypocarbia, fluid overload, hypoxemia, hypothermia, and shivering can all adversely affect myocardial oxygen demand and supply balance. Since our casualty had significant blood loss and had already sustained two episodes of cardiac arrest, the intra-op risks for emergency surgery were magnified.

Apart from standard hemodynamic monitors, intra-op monitoring in such patients should be invasive monitoring, central venous catheter, temperature monitors, the bispectral index (BIS), trans-esophageal echocardiography (TEE) and bladder catheter. In our center, we did not have BIS and TEE; hence it was not used. All other monitors were applied.

Intra-operative ECGs can help detect intra-op myocardial ischemia, pericarditis, pericardial effusion, and pulmonary embolism. Intra-arterial catheters help display a continuous arterial BP, monitor respirophasic variation in the waveform, and intermittent ABG sampling. Central venous catheters are used for infusion of vasopressors, fluid, blood, measurement of $ScvO_2$ and CVP. TEE helps in monitoring cardiac status, especially in unstable patients, intra-op. Urinary output is monitored using a bladder catheter, and UO > 0.5 mL/kg per hour should be targeted [16]. There is a significant correlation between the Glasgow coma scale (GCS) and BIS [17].

Management of patients with trauma in trauma operation theatres and ICUs with BIS monitoring was associated with better outcomes. BIS is a processed electroencephalogram (EEG) parameter with extensive validation and demonstrated clinical utility. BIS monitoring is used as a guide for adjusting the dosage of sedative agents and can help minimize agitation, failure of extubation, and length of stay in ICU [18].

After cardiac arrest, most patients are already intubated and sedated before they reach the operation theatre. Such patients may not need induction agents. Nevertheless, for conscious casualties, like ours, induction should be smooth with minimal hemodynamic fluctuation. The goal of anesthesia should be to attenuate hemodynamic responses without compromising blood flow to the myocardium and brain. Adequate pain relief (using opioids, NSAIDs), sedation, and unconsciousness are necessary throughout the surgery. After a recent cardiac arrest, patients can have insistent myocardial ischemia/dysfunction that can cause hypotension, which happened in our case also.

Fluid management of post-cardiac arrest patients should be done carefully. Aggressive crystalloid boluses (250–500 mL/bolus) are usually administered during hypovolemia-induced cardiac arrests. Hence, during the post-arrest period, it is imperative to avoid overresuscitation and maintain euvolemia, either by fluids/blood, to avoid stress on the cardiac function. In total, we transfused 6.25 L of RL and three packs (350 mL each) of fresh whole blood in our casualty. In a center with a blood bank, targeted blood transfusion is the ratio of 1:1:1 for RBCs: Plasma: Platelet. In our casualty, we gave 10 mL of 10% calcium gluconate to replenish the potential depletion due to emodilution or due to binding with citrate in blood products.

End organ perfusion can be maintained by optimizing BP using fluids, blood, or drugs (vasopressors/inotropes) to prevent secondary injury from hypotension [19]. For the same, the mean arterial pressure (MAP) targets are thus kept > 65 mm Hg (Grade 2C) [20]. This also helps to reverse the state of acute shock following initial resuscitation in patients with shock and CPA. If ROSC is achieved late or the patient has a neurological insult due to the cardiac arrest, then targeted MAP > 80–100 mm Hg to compensate for the upward shift of the limits of cerebral autoregulation [21].

Invasive monitoring using intra-arterial catheters is necessary during surgical interventions for a sampling of ABG and to titrate vasopressors/inotropes. Nor-epinephrine is the drug of choice in hypotension present in post-cardiac arrest patients (Grade 2C) [22]. In our casualty, hypotension was treated with an infusion of nor-epinephrine titrated to MAP (maximum dose given was 0.2 mcg/kg/min i.v. infusion). Vasopressin infusion is added if there is persistent asoplegia with low systemic vascular resistance (Grade 2C) [23]. Inotropic agents like Milrinone may be indicated in patients with significant left/right ventricular failure. Global myocardial insult usually improves by 8 hours and left ventricular function returns to baseline in about 72 hours post-arrest [24, 25].

Arrhythmias are common after a cardiac arrest. Hence it is advisable to have transcutaneous pacing/defibrillator pads on the patient prior to induction, should a need arise for cardioversion, defibrillation, or transcutaneous pacing. All antiarrhythmic drugs should also be available for acute administration.

In post-cardiac arrest patients, strategies for mechanical ventilation should balance the need to reverse hypoxemia and acidosis while negating the effects of hyperventilation and hyperoxia (PaO_2 > 300 mm Hg) [26, 27]. Our casualty had a pH 7.33, pO_2 88 mm Hg, pCO_2 52 mm Hg, bicarbonate (HCO_3) 21 mmol/L, base deficit (BD) -2 mEq/L and lactate: 2.4 mmol/L on arrival at the operation theatre (OT). Most patients entering the OT after a cardiac arrest usually come from the ICU, and in such cases, it is recommended to continue the same settings intra-op, as were before, as part of the lung-protective ventilation strategy. Our casualty was intubated in the OT. However, the goals of ventilation were the same. The goal of this strategy is to minimize lung injury and prevent hemodynamic compromise. Tidal volumes should be of 6 to 8 mL/kg predicted body weight. It is imperative to prevent hyperinflation or high PEEP, increasing intrathoracic pressure and decreased MAP [28]. The usual targets are maintaining a peripheral SpO_2 at 94% and PaO_2 at 100 mm Hg, using adjustments in a fraction of inspired O_2 (FiO_2). $PaCO_2$ is ideally maintained at 40–45 mm Hg and $ETCO_2$ at 35–40 mm Hg by adjusting the respiratory rate. This permissible hypercapnia can prevent hypocapnia-induced cerebral vasoconstriction [29].

Intra-operative normothermia should be maintained throughout the surgery, and hyperthermia should be avoided. Fever is presumed to aggravate secondary brain injury and is associated with worse neurological outcomes [30].

Events of hyper/hypoglycemia should be carefully avoided by keeping the serum glucose maintained (140–180 mg/dL) throughout the surgery. Hyperglycemia is associated with poor outcomes in post-cardiac arrest patients as it is assumed to aggravate secondary brain injury by increased tissue acidosis. Our casualty's blood sugars were within normal limits [31, 32].

The first three days of post-cardiac arrest are crucial, and myocardial dysfunction peaks during this time to even cause cardiogenic shock. A trans-oesophageal echo (TEE) can show global hypokinesis, and a sample from the CVC can show low central mixed venous oxygen saturation ($ScvO_2$). $SCVO_2$ > 70% is a good target for resuscitation [33]. Our casualty was closely monitored for the same. However, he did not develop any cardiac complications.

CONCLUSION

Our case report suggests that in a battle casualty, if a casualty is appropriately evacuated, optimized pre-op, and carefully managed intra-op, they can withstand prolonged surgery under general anesthesia, even after just attaining ROSC. Effective and timely initiation of CPR in all cases of cardiac arrest should be overemphasized. Taking the risk to attempt a complex and specialized surgery can save the limb and also buy time if it is based on the guidelines of resuscitation and goals of anesthesia. Military medicine is based on quick reaction, innovation, and teamwork. However, meticulous health care planning for emergencies and contingencies with regular replenishments in the war zone is inevitable.

WBB can save the lives of hemorrhaging casualties when no blood banks are available close by. This case was an excellent test of knowledge, skill, materials, process, military evacuation drills, and personnel.

Conflict of interest

All authors declare no conflict of interest.

REFERENCES

1. Cross J, Ficke J, Hsu J, et al. Battlefield Orthopaedic Injuries Cause the Majority of Long-term Disabilities. American Academy of Orthopaedic Surgeon. 2011; 19: S1–S7, doi: 10.5435/00124635-201102001-00002.
2. Sasidharan S. Battlefront medicine – scoop and scoot or stay and play? Revista Chilena de Anestesia. 2021; 50(4): 558–560, doi: 10.25237/revchilanestv50-04-03.
3. Nolan JP, Berg RA, Andersen LW, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Template for In-Hospital Cardiac Arrest: A Consensus Report From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia). Circulation. 2019; 140(18): e746–e757, doi: 10.1161/CIR.0000000000000710, indexed in Pubmed: 31522544.
4. Mateen FJ, Josephs KA, Trenerry MR, et al. Long-term cognitive outcomes following out-of-hospital cardiac arrest: a population-based study. Neurology. 2021; 77(15): 1438–1445, doi: 10.1212/WNL.0b013e318232ab33..
5. Sasidharan S, Lahareesh BL, Dhillon H. Lessons from a battle-front: When and where to "scoop and scoot"? MRIMS Journal of Health Sciences. 2021; 9(2): 77, doi: 10.4103/mjhs.mjhs_6_21.
6. Kragh JF, Litrell ML, Jones JA, et al. Battle casualty survival with emergency tourniquet use to stop limb bleeding. J Emerg Med. 2011; 41(6): 590–597, doi: 10.1016/j.jemermed.2009.07.022.

7. Bogdan Y, Helfet D. Use of Tourniquets in Limb Trauma Surgery. Orthopedic Clinics of North America. 2018; 49(2): 157–165, doi: 10.1016/j.ocl.2017.11.004.
8. Malo C, Bernardin B, Nemeth J, et al. Prolonged prehospital tourniquet placement associated with severe complications: a case report. CJEM. 2015; 17(4): 443–446, doi: 10.1017/cem.2014.44, indexed in Pubmed: 26134057.
9. Drolet B, Okhah Z, Phillips B, et al. Evidence for Safe Tourniquet Use in 500 Consecutive Upper Extremity Procedures. HAND. 2014; 9(4): 494–498, doi: 10.1007/s11552-014-9667-1.
10. Lakstein D, Blumenfeld A, Lin G, et al. Tourniquets for hemorrhage control on the battlefield: a 4-year accumulated experience. J Trauma. 2003; 54(5 Suppl).
11. Berséus O, Hervig T, Seghatchian J. Military walking blood bank and the civilian blood service. Transfus Apher Sci. 2012; 46(3): 341–342, doi: 10.1016/j.transci.2012.03.026, indexed in Pubmed: 22475543.
12. Sessler D. Perioperative thermoregulation and heat balance. The Lancet. 2016; 387(10038): 2655–2664, doi: 10.1016/s0140-6736(15)00981-2.
13. Hrezo R, Clark J. The walking blood bank: An alternative blood supply in military mass casualties. Disaster Manag Response. 2003; 1(1): 19–22, doi: 10.1016/s1540-2487(03)70005-4.
14. Rutlen DL, Wackers FJ, Zaret BL. Radionuclide assessment of peripheral intravascular capacity: a technique to measure intravascular volume changes in the capacitance circulation in man. Circulation. 1981; 64(1): 146–152, doi: 10.1161/01.cir.64.1.146, indexed in Pubmed: 6786793.
15. Olasveengen TM, Mancini ME, Perkins GD, et al. Adult Basic Life Support Collaborators. Adult Basic Life Support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2020; 142(16_suppl_1): S41–S91, doi: 10.1161/CIR.0000000000000892, indexed in Pubmed: 33084391.
16. Egal M, Erler NS, de Geus HRH, et al. Targeting Oliguria Reversal in Goal-Directed Hemodynamic Management Does Not Reduce Renal Dysfunction in Perioperative and Critically Ill Patients: A Systematic Review and Meta-Analysis. Anesth Analg. 2016; 122(1): 173–185, doi: 10.1213/ANE.0000000000001027, indexed in Pubmed: 26505575.
17. Senapathi TG, Wiryana M, Aribawa IG, et al. Bispectral index value correlates with Glasgow Coma Scale in traumatic brain injury patients. Open Access Emerg Med. 2017; 9: 43–46, doi: 10.2147/OAEM.S130643, indexed in Pubmed: 28435334.
18. Mahmood S, Parchani A, El-Menyar A, et al. Utility of bispectral index in the management of multiple trauma patients. Surg Neurol Int. 2014; 5: 141, doi: 10.4103/2152-7806.141890, indexed in Pubmed: 25317356.
19. Paellis T, Sanfilippo F, Ristagno G. The optimal hemodynamics management of post-cardiac arrest shock. Best Pract Res Clin Anaesthesiol. 2015; 29(4): 485–495, doi: 10.1016/j.bpa.2015.10.002.
20. Rochwerg B, Hylands M, Møller MH, et al. CCCS-SSAI WikiRecs clinical practice guideline: vasopressor blood pressure targets in critically ill adults with hypotension and vasopressor use in early traumatic shock. Intensive Care Med. 2017; 43(7): 1062–1064, doi: 10.1007/s00134-016-4539-5, indexed in Pubmed: 28497273.
21. Beylin ME, Perman SM, Abella BS, et al. Higher mean arterial pressure with or without vasoactive agents is associated with increased survival and better neurological outcomes in comatose survivors of cardiac arrest. Intensive Care Med. 2013; 39(11): 1981–1988, doi: 10.1007/s00134-013-3075-9, indexed in Pubmed: 23995983.
22. Mackenzie SJ, Kapadia F, Nimmo GR, et al. Adrenaline in treatment of septic shock: effects on haemodynamics and oxygen transport. Intensive Care Med. 1991; 17(1): 36–39, doi: 10.1007/BF01708407, indexed in Pubmed: 2037723.
23. Ukor IF, Walley KR. Vasopressin in Vasodilatory Shock. Crit Care Clin. 2019; 35(2): 247–261, doi: 10.1016/j.ccc.2018.11.004, indexed in Pubmed: 30784607.
24. Erley C. Epinephrine Versus Norepinephrine for Cardiogenic Shock After Acute Myocardial Infarction. The Journal of Emergency Medicine. 2018; 55(5): 736, doi: 10.1016/j.jemermed.2018.09.031.
25. De Backer D, Biston P, Devriendt J, et al. Comparison of dopamine and norepinephrine in the treatment of shock. N Engl J Med . 2010; 362(9): 779–789, doi: 10.1056/NEJMoa0907118..
26. Vincent JL, Taccone FS, He X. Harmful Effects of Hyperoxia in Postcardiac Arrest, Sepsis, Traumatic Brain Injury, or Stroke: The Importance of Individualized Oxygen Therapy in Critically Ill Patients. Can Respir J. 2017; 2017: 2834956, doi: 10.1155/2017/2834956, indexed in Pubmed: 28246487.
27. Roberts BW, Kilgannon BA, Hunter BR. Association Between Early Hyperoxia Exposure After Resuscitation From Cardiac Arrest and Neurological Disability: Prospective Multicenter Protocol-Directed Cohort Study. Circulation. 2018; 137(20): 2114–2124, doi: 10.1161/CIRCULATIONAHA.117.032054..
28. Herff H, Paal P, Goedecke Av, et al. Influence of ventilation strategies on survival in severe controlled hemorrhagic shock. Critical Care Medicine. 2008; 36(9): 2613–2620, doi: 10.1097/ccm.0b013e31818477f0.
29. Aufderheide T, Lurie K. Death by hyperventilation: A common and life-threatening problem during cardiopulmonary resuscitation. Critical Care Medicine. 2004; 32(Supplement): S345–S351, doi: 10.1097/01.ccm.0000134335.46859.09.
30. Hensley NB, Hogue CW. Anesthesia for emergency surgery after cardiac arrest or traumatic. Anesthesia for emergency surgery after cardiac arrest or traumatic 2016; 6–11. .
31. Luethi N, Cioccari L, Eastwood G, et al. Hospital acquired complications in intensive care unit patients with diabetes: A before and after study of a conventional versus liberal glucose control protocol. Acta Anaesthesiologica Scandinavica. 2019; 63(6): 761–768, doi: 10.1111/aas.13354.
32. Finfer S, Chittock DR, Su SYS, et al. NICE-SUGAR Study Investigators. Intensive versus conventional glucose control in critically ill patients. N Engl J Med. 2009; 360(13): 1283–1297, doi: 10.1056/NEJMoa0810625, indexed in Pubmed: 19318384.
33. Shin TG, Jo IkJ, Hwang SY, et al. Comprehensive Interpretation of Central Venous Oxygen Saturation and Blood Lactate Levels During Resuscitation of Patients With Severe Sepsis and Septic Shock in the Emergency Department. Shock. 2016; 45(1): 4–9, doi: 10.1097/SHK.0000000000000466, indexed in Pubmed: 26674449.