RESUSCITATION OF THE AVALANCHE VICTIM: AN EVIDENCE-BASED GUIDELINE

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ABSTRACT: Background. Earlier avalanche resuscitation recommendations, published in 1996 and 2001, were principally extrapolated from biostatistical survival analysis. The first systematic review of clinical evidence, examining 4 critical prognostic factors, was published in 2010 and underpinned the avalanche resuscitation recommendations in the 2010 American Heart Association and European Resuscitation Council BLS and ALS Guidelines. Although current adoption of these recommendations approximates 75% there are substantial failures, notably in initiation or withholding CPR and triage to extracorporeal rewarming (heart-lung bypass).

Additionally, recent research in avalanche trauma, survival analysis and hypothermia management has shifted emphasis. Methods. The International Commission for Mountain Emergency Medicine of the ICAR MEDCOM performed a structured review of 27 specific and 10 general questions, using a worksheet developed by the scientific committee prior to the review. The findings were then debated at 2 full meetings and consensus recommendations were developed in October 2011. Results. Keyword- and hand-searching found 3530 citations of which 96 articles were scrutinized in detail for content, study design and methodological quality. Thirty seven recommendations were developed and classified for benefit. Conclusion. Field recommendations range from simple evidence-based victim-handling measures to integrating critical factors in crucial decisions that include prehospital termination of resuscitation. Advanced airway use as well as AED and core temperature monitoring are more relevant with improved training of avalanche professionals. Trauma management includes the use of tourniquets as well as decompression of pneumothorax. Triage of multiple victims on-site, and those severely hypothermic to appropriate centres, is enabled using the integrated avalanche resuscitation algorithm.

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1. BACKGROUND

Prior to survival analysis of Swiss avalanche burial victims 20 years ago (Brugger et al. 1992; Falk et al. 1994) we had little idea of the pathophysiology of avalanche injury. This biostatistical analysis produced a sigmoidal-shaped survival curve with distinct phases (Figure 1).

![Figure 1: Survival function of totally buried avalanche victims (n = 422). Extracted from Falk et al 1994.](image)

The initial “survival phase” ended with 92% survival after the first 15 minutes with mortality mainly from trauma. The subsequent “asphyxia” phase demonstrated major mortality from asphyxia as survival plummeted to 30% at 35 minutes. Thereafter, those that had been able to continue breathing survived until the onset of death from hypothermia at 90 minutes.

The survival in western Canada was only 77% at the end of the first 10 minutes, due mainly to death from trauma, then plummeted to only 9% at 35 minutes due to earlier and more rapid asphyxia related to the denser snow. Notably long-term survival was very poor, only 9% at 90 minutes vs 23% for Swiss victims, from limited skills on-scene and longer transport times.

Deducing that victims unable to breathe had succumbed to asphyxia at the end of 35 minutes, while those with an open airway and an air space could survive until death from hypothermia at 90 minutes, the investigators proposed a resuscitation guideline and algorithm that underwent expert review by the International Commission for Mountain Emergency Medicine (ICAR MEDCOM) (Brugger et al. 2002; Brugger et al. 1996; Brugger et al. 2001). This algorithm served rescue clinicians well although it was somewhat “busy” (Figure 3).

![Figure 3: Algorithm for on-site management of avalanche victims. Extracted from Brugger et al 2001.](image)

The first systematic review of clinical evidence for these recommendations confirmed that duration of burial, airway patency, core temperature and serum potassium levels were reliable predictors of...
survival (Boyd et al. 2010) and, after expert review by the International Liaison Committee for Resuscitation (ILCOR), were included in the 2010 BLS and ALS Resuscitation Guidelines for North America and Europe (Soar et al. 2010; Vanden Hoek et al. 2010).

Although current adoption of these recommendations approximates 75% there are substantial failures, notably in initiation or withholding CPR and triage to extracorporeal circulation (ECC) rewarming (heart-lung bypass) (Brugger 2011). Additionally, recent research in avalanche trauma (Boyd et al. 2009; Hohlrieder et al. 2007), survival analysis (Haegeli et al. 2011) and hypothermia management (Brown et al. 2012) has shifted emphasis.

2. METHODS

A structured review of the components of the 2001 algorithm was performed using an ILCOR worksheet format after establishing subject matter, objectives and inclusion/exclusion criteria a priori at a Topic meeting of the ICAR MEDCOM. This format examined each of 27 components using individual PICO (population, intervention, comparator, outcome) questions as well as 10 general questions. Findings were presented by the working group to 2 specific meetings of the ICAR MEDCOM for expert debate, and consensus recommendations were developed in October 2011.

3. RESULTS

Keyword- and hand-searching found 3530 citations of which 96 articles were scrutinized in detail for content, study design and methodological quality. Thirty seven recommendations were developed, classified for benefit and a simplified algorithm was developed.

4. GUIDELINE

4.1 Safety and welfare

The safety and welfare of rescuers and all others remain paramount.

4.2 Companion and organized rescue

Prompt extrication with initiation of BLS resuscitation remains the priority for companions. Organized rescue is best mobilized early, ideally by helicopter, with rescue emergency physicians or paramedics equipped with critical medical and safety kit, plus dogs with handlers.

4.3 Airway patency and air pocket

Rescuers are to dig from the side and note whether the airway is patent +/- an air pocket present.

4.4. General measures

To mitigate against the common rescue collapse from cardiac arrhythmias hypothermic victims are best managed with minimal truncal and limb movements, without rough motion and kept in a horizontal position.

Dry insulation includes insulation from the snow surface as well as from continued conductive, convective and radiant heat loss. Assemblies include blankets, padded rescue bags and outer windproof and waterproof reflective foils. Wet clothing may be replaced with dry layers if efficient although adding thick insulation over wet clothing is equally effective and usually more practical (Henriksson et al. 2012).

Field rewarming is principally prevention of further heat loss, with chemical heat packs although more sophisticated rewarming with specific equipment may be indicated if evacuation is prolonged. Heated humidified inspiratory air or oxygen requires field-usable equipment and does not greatly reduce heat loss but may be indicated in prolonged transports.

Oxygen is indicated for any degree of asphyxia and will reduce the risk of arrhythmias in hypothermia (Danzl 2012). Pulse oximetry may be unreliable with cold extremities and device malfunction from the cold, bright light and high altitude (Luks et al. 2011).

4.5 Monitoring

Victims of significant involvement are best monitored throughout evacuation and ideally from the moment they are exposed. This includes electrocardiographic (ECG) monitoring with an AED or monitor-defibrillator. Core temperature is most reliably measured in the lower oesophagus in victims that have an endotracheal tube in place. A medical thermistor probe is preferable although inexpensive probes from indoor/outdoor thermometers can be sufficiently accurate (Pasquier et al. 2012). Epitympanic probes are accurate if used appropriately (Walpoth et al. 1994). Rectal temperatures provide a reasonable initial temperature (Danzl 2012) although require undressing the victim and lag during rewarming. Other temperatures are likely unreliable. Clinical staging is unreliable if asphyxia impairs mentation.
4.6 Airway management and ventilation

An unresponsive victim without an advanced airway is best transported in the recovery position with the cervical spine stabilized as well as possible. Airway interventions have low risk of inducing arrhythmias and include oro-pharyngeal airways as well as advanced airways such as endotracheal intubation or supraglottic airways. Advanced airways protect against aspiration of vomitus and allow better access and spinal stabilization with the victim supine.

Ventilation is indicated when breathing is inadequate and always with chest compressions in CPR.

4.7 Trauma management

Pneumothorax is managed with needle thoracostomy (large-bore needle through the chest wall) or open thoracostomy (hole through the chest wall), ideally in a victim that is ventilated with an advanced airway.

Severe limb bleeding is managed with tourniquets.

Other trauma modalities additionally include splinting, wound care, analgesia and antibiotics for open fractures.

Trauma victims are best transported to the medical centre that is most appropriate for their injuries, to a dedicated trauma centre if severe.

5. RESUSCITATION DECISIONS

5.1 Alert victim

These are normothermic or mildly hypothermic. After assessment add insulation with or without changing wet clothing and allow active movement that will likely be sufficient to rewarm them. They may ingest warm clear sugar-containing fluids that are not alcoholic nor strongly caffeinated so long as they are not likely to require sedation or anaesthesia in less than 2 hours and not significantly injured, especially if evacuation is delayed or prolonged. Oral fluids will maintain hydration.

If the involvement was clearly not life-threatening then a decision may be made for them to remain in the field. However, if the involvement was potentially life-threatening they are to be evacuated to the nearest emergency department for advanced assessment and observation as delayed complications may occur.

5.2 Poorly responsive victim with vital signs

These are asphyxiated +/- moderately or severely hypothermic. They are to be closely monitored, ideally with ECG monitoring as early as possible due to the risk of rescue collapse and arrhythmia. Core temperature will be very useful especially for disposition decisions.

All the general measures and airway and trauma management modalities become critical.

Transport to the nearest hospital for advanced assessment, intervention and observation is indicated. If significantly asphyxiated this would best include access to an ICU. Seriously injured victims are better transported directly to a trauma centre. Hypothermic victims need rewarming with modalities such as the forced-air warmers most commonly used in surgical programs. However, if there is evidence of cardiac instability, such as ventricular arrhythmias on the ECG, or if the core temperature is <28°C (less than 28°C) direct transport to a centre with advanced extracorporeal rewarming (ECR), such as cardiopulmonary bypass, is preferable due to the risk of cardiac arrest.

5.3 Victim with no vital signs with burial duration less than 35 minutes

These are asphyxiated and only mildly hypothermic. If lethal trauma is found resuscitation is withheld. Otherwise, prompt exposure and extrication with BLS including ventilations +/- ALS with ECG monitoring and defibrillation if indicated are to be started expediently.

If improvement results from resuscitation or any cardiac rhythm is seen on ECG or an AED prompts defibrillation then resuscitation should continue to the nearest hospital, ideally with an ICU. If no improvement is found after 20 minutes of resuscitation and only asystole (flat line) has been seen on ECG or an AED does not prompt defibrillation then resuscitation may be terminated in the field (Paal et al. 2012; Soar et al. 2010; Vanden Hoek et al. 2010).

5.4 Victim with no vital signs with burial duration more than 35 minutes

These have suffered cardiopulmonary arrest from prolonged asphyxia or hypothermia. If lethal trauma is found or the whole body is frozen resuscitation is withheld.
If they have an obstructed airway they have arrested from prolonged asphyxia which after 35 minutes has a very poor prognosis and resuscitation is withheld (Soar et al. 2010; Vanden Hoek et al. 2010).

If the airway is patent they may have arrested from prolonged asphyxia with the resultant poor prognosis; but alternatively they may have been able to breathe and the arrest may have been from significant hypothermia and the victim may therefore be salvageable. Therefore, if the core temperature is found >32°C they are principally asphyxiated and a resuscitation attempt may be initiated but terminated if no improvement is noted after 20 minutes and only asystole is seen on the ECG or an AED does not prompt defibrillation. But, if the core temperature is <32°C then arrest may be from hypothermia and resuscitation is continued and the victim is transported preferably to a centre with ECC rewarming. If the duration is not known then, understanding that a core temperature of <32°C can only occur after at least 35 minutes of cooling, a core temperature of <32°C may therefore be a surrogate for burial longer than 35 minutes (Boyd et al. 2010; Vanden Hoek et al. 2010).

CPR is not modified for hypothermic arrest victims although a longer check of 60 seconds for vital signs is indicated as pulses may be indistinct. Persistent breathing or movement should prompt “watchful waiting” but if no signs of life are found then CPR is best started and continued. Defibrillation is performed if prompted by AED or indicated by ECG although repetitive defibrillation (over 3 attempts) may not be successful due to the irritable heart in hypothermia. ALS medications have only been shown effective in animal studies so judicial use is appropriate (Brown et al. 2012). No intervention is to delay transport of hypothermic arrest victims. Note is made that successful rewarming has resulted in good survivals after prolonged CPR of up to 6½ hours (Brown et al. 2012).

If the duration of burial or the status of the airway is unknown or a prolonged transport to ECC rewarming is being considered then a serum potassium level (K+) at an emergency department, best in the direction of the ECC centre, may assist. If the K+ is <8mmol/L then survival is possible vs >12mmol/L which is not survivable (Boyd et al. 2010; Brown et al. 2012; Soar et al. 2010; Vanden Hoek et al. 2010). A K+ between 8 and 12mmol/L may assist in a decision made with consideration of all factors.

6. TRIAGE

Where multiple victims exceed available resources then triaging becomes necessary, especially when other victims remain buried. Victims without vital signs, especially if in asystole, are far less likely to survive and place high demands on resources. Victims exhibiting major trauma that appears likely lethal are not likely to survive. Extremely hypothermic victims, especially if their core temperature is the same as ambient temperature and is less than 10°C, are unlikely to survive. A triage algorithm for avalanche incidents that incorporates avalanche and triage concepts has been published (Bogle et al. 2010).
7. AVALANCHE RESUSCITATION ALGORITHM

Figure 4: Algorithm for prehospital and hospital management. In all cases: gentle extrication and spinal precautions. Where appropriate: core temperature + ECG monitoring, oxygen, insulation, heat packs on trunk; 0.9% NaCl and/or 5% glucose only if an intravenous or intraosseous line can be established within a few minutes; prehospital trauma care as indicated.

° Clinicians may consider withholding resuscitation at the scene if it is associated with increased risk to the rescue team and for obviously lethal injuries or where the body is completely frozen.

1 If duration of burial is unknown core temperature may be a substitute.

2 Transport victims with signs of, or concern of, respiratory (e.g. pulmonary edema) or other-system injury to the medical center most appropriate for their condition. Initiate standard BLS and ALS including CPR with ventilations and chest compressions as indicated. Resuscitation may be terminated if resuscitation is not successful after 20 minutes.

3 Hospital capable of advanced external or core rewarming. Patients who present with respiratory failure, malignant arrhythmias, systolic blood pressure less than 90 mmHg, pulseless electrical activity, should be transported towards ECC rewarming. When VF is present, perform at least one defibrillation attempt.

** If direct transport to ECC rewarming is practical, the nearest ED can be bypassed. If K+ at hospital admission exceeds 12 mmol/L, consider stopping resuscitation (after excluding crush injuries and consideration of the use of depolarizing paralytics); in an adult, levels between 8 and 12 mmol/L may, in combination with other factors consistent with non-survival, assist in the decision to terminate resuscitation.

ALS = Advanced Life Support; ED = Emergency Department; ICU = Intensive Care Unit; ECC = extracorporeal circulation.
8. CONCLUSION

Field recommendations range from simple evidence-based victim-handling measures to integrating critical factors in crucial decisions that include prehospital termination of resuscitation. Advanced airway use as well as AED and core temperature monitoring are more relevant with improved training of avalanche professionals. Trauma management includes the use of tourniquets as well as decompression of pneumothorax. Triage of multiple victims on-site, and those severely hypothermic to appropriate centres, is enabled using the integrated avalanche resuscitation algorithm.

9. CONFLICT OF INTEREST

None of the authors have any financial conflict of interest. All authors have published on mountain medicine.

REFERENCES


