8 Treatment of Casualties in Hostile Environments

Emergency Medicine in Mountain Sports

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8.1 Introduction

Rescue operations in mountains and remote areas are different from usual scenarios in urban areas. Topographical conditions, tactical considerations, medical equipment, and environmental conditions make mountain rescue operations a great challenge for the entire team.

In most European countries depending on the weather and visibility conditions, helicopters are activated in case of accidents or illness in the mountains. They are regularly equipped to cover all expectable technical and medical operations, and rescue personnel is trained according to international standards [1, 2] (Fig. 8.1).

Terrestrial rescue teams usually work in poor weather conditions and at night or when the airbound intervention teams need technical assistance. During rescue operations medical rescue personnel is frequently facing a hostile environment with cold, wet, windy, and low visibility conditions. In addition, the patient's condition can already deteriorate by delayed arrival time.

These circumstances complicate the initial assessment and diagnosis and limit medical treatment and outcome. Terrestrial rescue operations require extended activation time, high physical exertion, and environmental hazards during access to the site of the accident and prolonged evacuation time (Fig. 8.2).

Medical and technical management must be adapted to the conditions in order not to increase risk to the patient and the rescue team and to improve outcome. Monitoring may be restricted or not possible because devices are not always available and sometimes the weather conditions (freezing monitors), darkness, or certain injuries of the patient, for example, hypothermia, set limits for a continuous monitoring. All injured and sick persons in the mountains are considered hypothermic until the contrary is proved [3]. Further drop of body temperature should be avoided and assessment and treatment should avoid unnecessary undressing and provide proper insulation as soon as possible [4]. Physicians working in the mountains or mountainous environment must be comfortable in exposed situations, conscious of their own and the patient's safety, and being able to work under extreme conditions. Technical mountain knowledge and experience as well as theoretical and practical skill of climbing in steep terrain in summer and winter conditions are mandatory. Training for doctors must basically include the same technical skills like self-belaying and other rescue maneuvers, transport and management of avalanche victims, canyoning rescues, and other specific emergencies like regular training for all rescuers. Physicians as part of a helicopter crew frequently

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Fig. 8.1 Long-line operation

may be supported by a single (air) rescuer. Thus they must be trained in performing long-line or winch operations without the support of a team. In case of bad weather conditions, the physician must be able to move safely and descend by himself when necessary [5, 6] (Fig. 8.3).

Overall he should consider and accept that medical treatment may be limited and injuries usually survived in urban areas may lead to death in this setting. Despite intensive training, alpine emergency physicians constantly face the situation that mountain rescue personnel does not show the same high level of medical education as in urban emergency medical system, where usually professional staff provides emergency medical assistance [7]. In an urban setting different tasks are performed by professional health-care providers. In mountain rescue operations, emergency physicians must perform usually delegated measures by themselves. Nevertheless, they should not lose track of the overall situation and adapt medical care to the specific situation of the mission. Unnecessary and excessive medical measure ("stay and play") may delay the entire rescue operation unnecessarily and expose the patient and all team members to additional

Fig. 8.2 Terrestrial transport at night

Fig. 8.3 Long-line evacuation of patient

danger. In rescue operations risk assessment and management is one of the main tasks of the team leader. However, the emergency physician must adjust his actions to the situation and include the objective risk into his considerations. Emergency physician working in the mountains must adapt medical measures to existing human and technical resources. Optimized therapy should have priority over maximized treatment causing delay. Rapid evacuation may be an effective form of treatment. Every therapy, once begun, must be carried out until the patient is handed over to the following team. Adequate supply of medical or technical equipment, drugs, and oxygen is either not possible in reasonable time or might delay the entire rescue operation. Often the entire recovery cannot be brought later to the scene without delaying. In addition changing environmental factors and/or the patient's condition may force the emergency physician to employ alternative medical strategies or evacuation procedures in cooperation with the team leader. In extreme weather situations, it may be appropriate to stay with a medically stable patient in a safe place (hut or bivouac), until the situation allows terrestrial or air-bound evacuation. In mountain rescue the emergency physician is frequently not the first on the scene either because no doctor was available from the beginning or the first message about the severity of the injury or illness was not correct. In this situation the key question arises: can the patient be treated by first responders sufficiently and transported to the doctor? Or must the emergency physician ascend to the location of the accident? Assessment of symptoms and signs of injury severity can be performed by trained rescuers who act as first responders, and initial steps of treatment can be prioritized by radio or mobile phone. Evacuation time may be shortened, hazards reduced, and medical treatment will start earlier. Increasing numbers of mountaineers seek recreation in mountain regions where the existing rescue resources are far less and the problems much greater than in the situations as described above. Commonly rescuers reach the scene of the accident hours or days later, apart from the fact whether there are any technical and medical options for professional mountain rescue. Expedition medicine in high altitudes or in very remote mountainous areas is beyond the scope of this disquisition.

8.2 Assessment of Victims in the Mountains

In any emergency situation in the mountains, rescuers must first ensure their own safety. Then they must evaluate whether the person is in a safe position and protect him from further injury. Objective risks such as rockfall, avalanches, lightnings, etc., must be kept to a minimum. In dangerous situations it is justified to evacuate the person before assessment and treatment.

Blunt traumas caused by falls are most common in accidents in the mountains. They might affect all parts of the body and result often in combined or multiple trauma with hypovolemic shock and traumatic brain injury. The mechanism of injury gives information about the expected injury pattern and severity. High-impact mechanisms (falls from more than 3 m height) are likely to cause multiple trauma and internal injuries. The mechanism of injury of falls in the mountains is markedly different from falls in urban areas. Falls in mountainous terrain may include periods of free fall interrupted by periods of sliding and falling. The landing surface in the mountains is generally not horizontal in comparison to usually flat surface in urban falls. Impact forces may be reduced substantially by steep slopes or snow. Several impacts and different body positions may occur during the fall. Injuries may be caused by deceleration (resulting from tissue displacement following the sudden arrest of motion during impact) or direct impact-associated injuries [8]. Assessment should follow standardized algorithms and all findings should be recorded. Hypothermia is a severe risk and leads to poor outcome in severe trauma and must not be overlooked [9]. The patient should be monitored continuously, depending on the skills of rescuers and the availability of equipment. In extreme cold situations, monitoring systems may fail due to rapid loss of battery capacity and freezing displays. Every new team, which assumes care of a patient, must perform their own reassessment and must transfer information from earlier teams to following teams until the patient arrives at the hospital.

8.3 Hypothermia

Hypothermia is commonly assessed by clinical findings [10] (Table 8.1).

Patients should be considered to be hypothermic if they have been exposed to the cold and if they have a cold trunk and a body core temperature <35 °C (95 °F). Hypothermia can be diagnosed clinically by assessment of vital signs using the Swiss staging system. Temperature measurement in intubated patients in the preclinical setting should be measured by insertion of a probe in the lower third of the esophagus. Thermistor probes inserted in the ear canal for epitympanic measurement require a free ear canal without snow or cerumen. Infrared cutaneous, aural, and oral measurements are often inaccurate. It is of great importance to assess every

Table 8.1 Staging of hypothermia [10]

Swiss staging of hypothermia		
HT I	Clear consciousness with shivering	35–32 (°C)
HT II	Impaired consciousness without shivering	32–28
HT III	Unconsciousness	28–24
HT IV	Apparent death	24–15
HT V	Death due to irreversible hypothermia	<15 (9?)

hypothermic patient without vital signs, whether cardiac arrest occurred prior to hypothermia (postmortem cooling) or cardiac arrest is caused by hypothermia. At low temperatures the brain tolerates cardiocirculatory arrest much longer without permanent damage than in normal core temperature. Prehospital treatment of hypothermia should focus on careful handling, basic life support (BLS) or advanced life support (ALS), and external rewarming. Detecting a pulse or breathing in a patient with deep hypothermia may be difficult and should be performed over 1 minute. Every sign of life, like breathing movements, should prompt a watchful waiting and careful transport. In the absence of vital signs, cardiopulmonary resuscitation (CPR) should be started. Full body insulation with chemical heat packs provides a substantial amount of heat to prevent further heat loss. Conscious, shivering patients can be treated in the field. Patients with impaired consciousness but stable circulation require active external rewarming (blankets, forced air heating, or chemical or electrical heat packs) at the closest hospital. Patients with cardiac instability or cardiac arrest should be transported, favorable with helicopter, to a center with the ability of extra-corporal rewarming either with ECMO or cardiopulmonary bypass [3, 10, 11].

8.4 Lightning

In a continuing thunderstorm, evacuation of a victim might be postponed if there is a high risk for rescuers. If rescuers decide to perform a rescue operation, the victim should be moved as fast as possible to an area of lower risk. A person hit by a direct lightning strike in the open is dead in many cases. However, the most common cause of death is cardiorespiratory arrest produced by ventricular fibrillation or asystole caused by current splash either from an object nearby (e.g., tree), a contact with an object hit by a lightning (e.g., fixtures of a via ferrata), or a ground current. Blunt trauma may be caused by a shock wave and consecutive falls by loosing balance during climbing. Respiratory arrest may be prolonged (due to paralysis of the medullary respiratory center) and lead to secondary cardiac arrest from hypoxia. Spontaneous return of cardiac activity is the rule in this case if the patient's ventilation is maintained and severe hypoxia does not occur. In case of more than one victim hit by a lightning, the normal triage rules for trauma patients do not apply to non-breathing victims. In triage situations with trauma casualties, victims with vital signs are given priority for emergency treatment rather than patients in cardiorespiratory arrest. The rule in lightning strikes is to "resuscitate the apparently dead first" [12].

8.5 Trauma Management in Mountain Rescue Operations

Traumatic injuries are most common in mountain accidents. Approximately 10 % suffer from major trauma with traumatic brain injury (TBI) often in combination with injuries of the trunk, vertebral spine, pelvis, and extremities [8, 13]. Emergency physicians must consider the mechanism of injury to correctly assess pattern and severity of injuries, provide sufficient analgesia, stabilize circulation by control of external bleeding and adapted fluid resuscitation, and organize safe evacuation under constant surveillance and monitoring of the patient. Early pain treatment is not only for the comfort of the patient but allows repositioning of fractures and dislocations, reduces secondary damage to soft tissues, reduces bleeding, and is the first step of circulatory stabilization. Environmental conditions as well as psychological factors, comorbidities and time affect pain. Using a pain score, such as verbal numerical rating, can be helpful. Insufficient treatment of pain not only reduces outcome but also increases the development of post-traumatic stress disorder. Pervading culture and knowledge of health-care providers determine the provision of prehospital analgesia [14]. No analgesic drug will accomplish all expected effects in every situation. Non-pharmacological methods such as splinting and positioning should be taken in consideration especially by nonmedical personnel without the possibility of pharmacological pain treatment [15] (Fig. 8.4).

The number of drugs carried should be reduced to a minimum and tailored to the expected injuries and skills of the health-care provider. All persons administering analgesics should receive appropriate detailed training. Health-care providers should be familiar with the effects of all administered drugs and should be able to manage adverse effects. Sufficient pain relief might be constrained by national laws in countries where health-care professionals do not routinely attend the site of accident and nonprofessionals are not allowed to administer drugs [16]. An intravenous access should be established rapidly, and depending on pain assessment, a potent painkiller should be administered. If intravenous administration is not possible, other parenteral routes such as intraosseous and intramuscular routes may be utilized. Intranasal and buccal administration of opioids, ketamine, and sedative drugs is recommended in situations where no i.v. line can be established [17, 18]. Loco-regional anesthesia offers another way of excellent analgesia. It also may permit patient contribution during difficult and long evacuation or in high-altitude rescue [19, 20]. A combination of analgesic drugs is frequently used but a higher rate of side effects must be expected. Severe adverse effects such as respiratory depression, nausea, and vomiting can become hazardous during evacuation, especially in austere environment. Rescue population becomes older and comorbidities more common. Therefore,

Fig. 8.4 Rescue of injured patient in steep rock

analgesia should be individualized to each casualty, and preexisting drug use must be taken into consideration. Hypothermia alters the pharmacokinetics and pharmacodynamics of fentanyl, morphine, ketamine, and midazolam; especially the side effects of ketamine to an irritable hypothermic heart may be harmful [21]. Opioids remain the gold standard for pain management in acute trauma. Hypotension caused by significant blood loss may be limited by reduced initial dose given over a longer period of time [22] (Fig. 8.5).

Injuries with severe bleeding, traumatic brain injury (TBI), and multiple trauma require an individualized strategy for each patient. Traumatic shock during terrestrial mountain rescue operation, especially in uncontrolled bleeding and/or TBI, has a poor outcome. Aggressive fluid management in all cases failed to improve survival in

Technique/agent		Adult starting dose (dose in children)	Adult subsequent dosis	Comments contraindications
Opiods[1]				
Morphine				
	IV	5–10 mg* (100 mcg/kg) max 10 mg	5 mg	Avoid if renal failure
	IM	10–20 mg (200 mcg/kg) Max 10 mg)	10 mg	As above
	IO	5–10 mg* (100 mcg/kg) max 10 mg	5 mg	As above
Fentanyl				
	IV	50–100 mg* (1–3 mcg/kgmax 100 mcg)	25 mcg	Avoid if on monoamine oxidase inhibitors (MAOI)drugs
	IN	180 mcg* (1.5 mcg/kg)	60 mcg x2 (15 mcg x2)	As above
	Buccal	OTFC 800 mcg* (10–15 mcg/kg)		As above
Tramadol				
	IV	50–100 mg (700 mcg/kg) Over 2-3min	50 mg every 20 min max 600 mg/day	Avoid if on monoamine oxidase inhibitors (MAOI)drugs
NSAID				
Ketoralac				
	IV	15–30 mg (0.5 mg /kg, max 15 mg)	None	Avoid if risk of GI beeding and if current or past cardio- vascular disease
Others				
Paracetamol		>50 kg: - 1g; < 50 kg: - 15 mg/kg over 15 min		
Ketamin (for analgesia) halve if S-Ketamine is used				
	IV	10–20 mg* (100 mcg/kg)	5–20 mg	Larger dose for procedural sedation, Midazolam may be co-administered
	IM	1 mg/kg*	-	
	IN	0.5 mg/kg*	0.5 mg	
Inhalational				
Penthrox® Methoxyfluran				
	Inhaled	Self- administration 3 mL via inhaler	3 mL (max 6mL/day; 15 mL/week)	Avoid in renal impairment
50 % Nitrous oxide/50 % Oxygen				
	Inhaled	Self- administered		Avoid after SCUBA diving and when tension pneumothorax suspected. Maintain cylinder at 10 °C (50 °F)

* Consider halving in the elderly, frail and hemodynamically compromised
[1] Diamorphine, where available, is an alternative with the advantage that intranasal administration can be used
OTFC = oral transmucosal fentanyl citrate
Data from: Thomas (2008); Rickard (2007); Moy and Le Clerc (2011); Ellerton (2013); Royal Pharmaceutical Society of Great Britain and British Medical Association (2013); Finn and Harris (2010); Borland et al (2007); BOC Healthcare (2011)

Fig. 8.5 Recommended pharmacological agents for treating moderate or severe pain in mountain rescue [21] most studies [25–27]. Two decisive key conditions must be recognized in suspected major or multiple trauma: severe uncontrolled hemorrhage or presence of traumatic brain injury. Accurate diagnosing could be difficult as symptoms could be masked in the prehospital setting. Rapid deterioration or only transient responding circulatory parameters under initial fluid resuscitation could be caused by pressure-depending hemorrhage. Increasing impaired consciousness may be caused by traumatic brain injury but also by arterial hypotension, hypoxemia, cardiac dysfunction, and hypothermia. Mechanism of injury (e.g., high-velocity trauma) and/or external signs of head injury, anisocoria, and a Glasgow Coma Scale (GCS) below 9 are strong indicators for TBI (Fig. 8.6).

Terrestrial mountain rescue operations in patients with multiple trauma and shock are often characterized by prolonged evacuation time and hostile environment. Reduced diagnostic and monitoring facilities, limited oxygen fluids, and drugs make any medical intervention difficult. Different strategies of prehospital fluid resuscitation are practiced in different regions worldwide, and none of these concepts support them beyond any scientific doubt. Systolic arterial blood pressure (SABP) ≤90 mmHg in trauma may decrease outcome. But in uncontrolled severe hemorrhage (e.g., liver, spleen, and kidney lacerations or ruptured vessels), aggressive fluid resuscitation may increase bleeding and does not show any increase in outcome [27]. Withholding fluid ("delayed resuscitation") or limiting fluids with aimed blood pressure to just maintain consciousness and/or palpable central pulse (indicating an SABP above 60 mmHg) ("permissive hypotension") may be a better option for patients in traumatic shock even in prolonged evacuation [28].

In these cases rapid evacuation and transport in combination with sufficient analgesia are the key to improve outcome, and medical interventions should follow the principle: "Load and Go." Rapid transport may be considered as one form of treatment [29].

If traumatic brain injury or a spinal lesion is suspected, the main goal for prehospital treatment is SABP higher than 110 mmHg in order to ensure adequate perfusion of the central nervous system (Fig. 8.7). Rapid elevation of blood pressure can be achieved by administration of hypertonic solutions followed by isotonic fluids. Catecholamine may be advantageous. After establishing intravenous or intraosseous access airway protection by endotracheal intubation or laryngeal tubes, high flow of oxygen (if available) should follow. Sufficient analgesia is mandatory as it may reduce sympathetic stimulation

Fig. 8.6 Terrestrial rescue at night

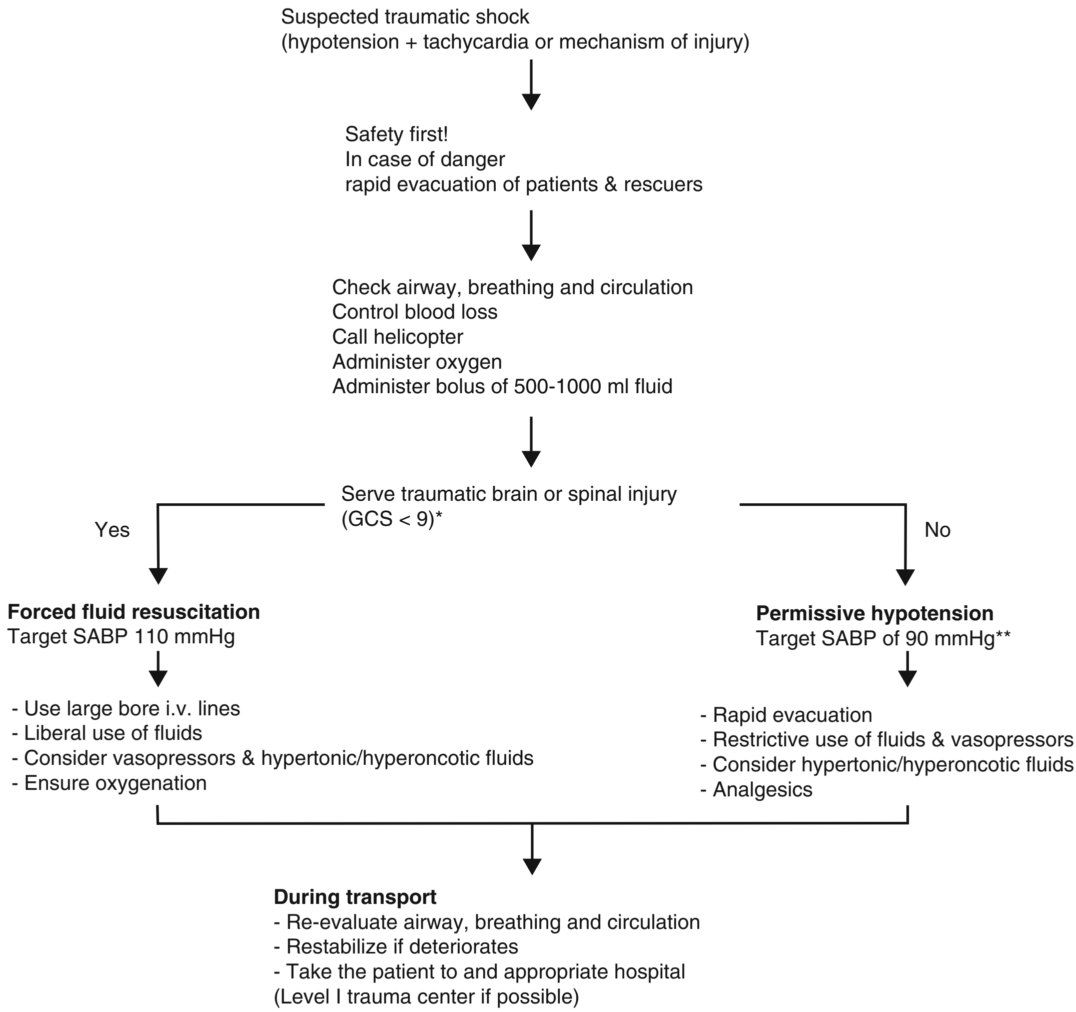

Fig. 8.7 Fluid management in traumatic shock. A protocol for the prehospital management of patients in traumatic shock with or without brain or spinal injury in mountainous terrain and remote areas. Impairment of consciousness does not necessarily indicate severe TBI in a shock patient; hypoxia, tension pneumothorax, cardiac dysfunction, and hypothermia should be excluded. If uncontrolled hemorrhage is suspected, lower values maintaining consciousness and/or palpable central pulses may be reasonable. *GCS* Glasgow Coma Scale, *SABP* systolic arterial blood pressure [23, 24]

and hasten evacuation. During transport frequent reassessment of reestablishment of breathing (e.g., deflating a tension pneumothorax) and circulation must take place, and an alternative strategy of fluid resuscitation may be considered. Besides fluid administration control of blood loss by wound management, repositioning, and splinting and prevention of hypothermia is essential [30, 31]. Hypothermic patients in traumatic shock and cerebrospinal injury are prone to hypothermia due to destabilized thermoregulation. Hypothermia increases bleeding by reduced platelet function and consecutive critical coagulopathy below 34 °C with reduced outcome [9, 32].

All patients should be transported to an appropriate trauma center without delay if possible with helicopters [33]. Multiple trauma in combination with TBI in the mountains or remote areas shows poor outcome when compared to urban areas, and urban traumatic shock protocols may not apply in all situations.

8.5.1 Prehospital Treatment of Avalanche Victims

Approximately 150 people die on avalanches per year in Europe and North America [34]. In less developed countries, fatalities are presumed to be many times higher. If a person is caught by an avalanche, four factors are decisive for survival: grade of burial, duration of burial, presence of an air pocket and a free airway, and severity of trauma. The overall mortality is 23 % but in completely buried victims (head below snow) it is 52 % and only 4 % if the head is not covered. In completely buried victims, survival drops from 80 % after the first 20 min to 30 % at 35 min. Initial mortality is mainly caused by trauma, whereas the steep decline between 20 and 35 min is due to asphyxia. After this period, survival is decreasing slower depending on trauma and the possibility to breathe under the snow. Limiting factors in this period are hypoxia, hypercapnia, and hypothermia [35]. Decline of survival seems to be affected by snow density resulting in lower survival rate in Canada compared to Swiss findings representing the situation in the Alps [36] (Figs. 8.8 and 8.9).

Avalanche survival is strongly time dependent. Therefore, immediate search and excavation performed by companions may be lifesaving. As soon as the head is free, assessment of airway and breathing and if necessary cardiopulmonary resuscitation (CPR) must be started and maintained until return of spontaneous circulation (ROSC) or a professional rescue team takes over. The victim's body must be protected from the cold by insulation with all available materials such as rescue blanket, jackets, hat, gloves, and bivouac bag [35].

Organized rescue in Europe is mainly based on helicopter rescue. In good weather conditions, a fully equipped and staffed rescue helicopter should be activated without delay [1] (Fig. 8.10).

An avalanche rescue team might incur critical risk, and therefore the expected benefit to the victim must be weighed against the risk to the rescue team. Several accidents with numerous fatalities among rescue teams the last few years strongly indicate accurate risk assessment. All rescuers working on-site of the avalanche must be equipped with avalanche transceivers, probes,

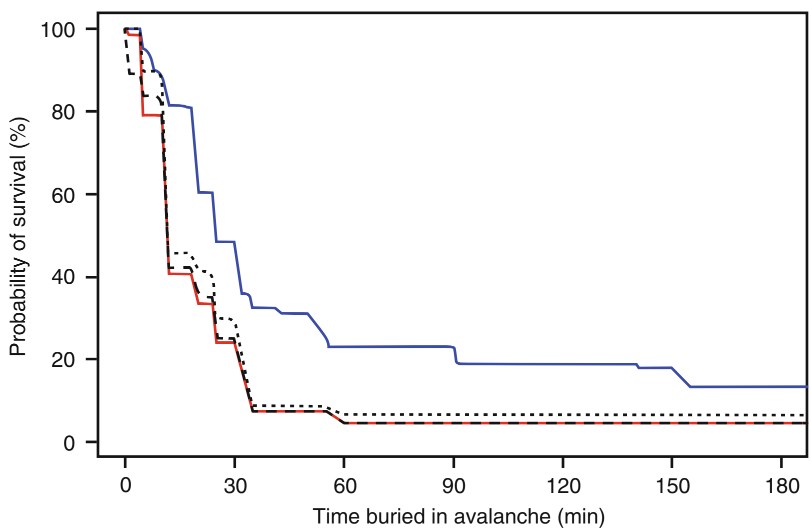

Fig. 8.8 Avalanche Survival Curve. Comparison of survival curves: Swiss survival curve (*blue*; $n=946$) and Canadian survival curve (*red*; $n=301$). The black dotted survival curve is based on the Canadian dataset without trauma fatalities ($n=255$). The *black dashed* survival curve is calculated with the Canadian dataset where the extraction times for severe trauma fatalities was replaced with an estimated time of death of 1 minute after burial ($n=301$) (From: Haegeli et al. [36])

Fig. 8.9 Evacuation of injured person

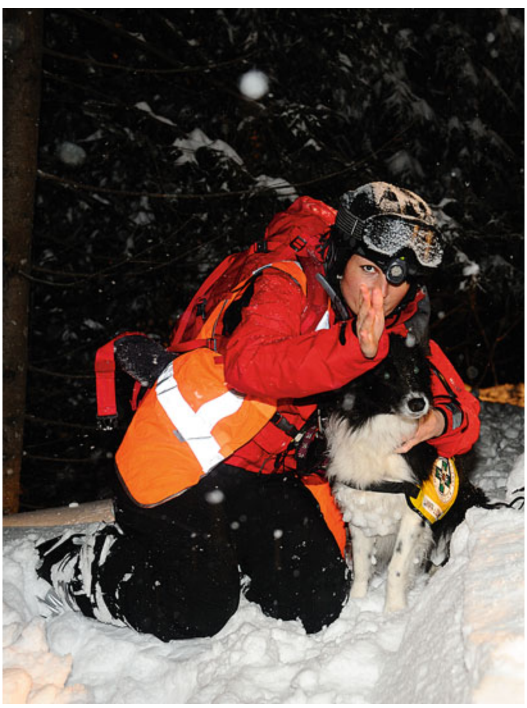

Fig. 8.10 Preparing rescue dog for search mission

shovels, and ideally with avalanche airbags. Optimal searching strategy, rapid locating of victims with transceivers, and effective shoveling are mandatory to reduce burial time. Located victims should receive immediate assessment and adapted treatment according to clinical findings. ECG monitoring and core temperature measurement should already start when the head and trunk is free. Extricated patients must be protected from hypothermia by full body insulation including chemical heat packs, aluminum foils, and thermo rescue bags. Further treatment is depending on the cardiorespiratory situation and body core temperature.

In patients found in cardiac arrest with clear signs of lethal trauma or if the chest or abdomen is not compressible or if transport with continuous CPR presents a high risk to the rescuers, resuscitation is not indicated [37].

If duration of burial exceeds 60 minutes, a patent airway is the key for survival and prevention of further heat loss and treatment of hypothermia is essential. Consciousness varies widely among hypothermic patients. Therefore, early measurement of core temperature should be performed immediately either by thermistor-based probes in the ear canal. In intubated patients esophageal probes are the gold standard. All patients should receive cardiac monitoring prior to transport to detect arrhythmias provoked by movement of the body during extrication. In hypothermic patients pulse oximetry is not reliable. Establishing an i.v. line may be difficult and time consuming in hypothermic patients, and aggressive fluid resuscitation is contraindicated in deep hypothermia. ALS drugs should only be administered only in normothermic avalanche victims. In victims with core temperature below 30 °C, effectiveness of advanced life support drugs has not been shown due to decreased metabolism. Vasopressors may cause arrhythmias and frostbites. Hypothermic patients in ventricular fibrillation should receive three attempts of defibrillation if it does not delay or interrupt transport [3].

8.5.2 Resuscitation of Completely Buried Avalanche Victims [38–42]

- *Patient alert and shivering, burial time <60 minutes*
- Prevention of hypothermia by changing wet clothes if appropriate. Patient is allowed to drink nonalcoholic warm drinks and walk and should be transported to the nearest hospital for observation.
- *Patient in cardiac arrest, burial time <60 minutes*
- Traumatic brain injury or asphyxia should be presumed and standard ALS should be performed. If possible the patient should be transported to the nearest hospital.
- *Patient somnolent or comatose but breathing, burial time >60 minutes*
- Prehospital treatment focuses on adequate oxygenation, careful handling and avoiding movements of the patient, and full body insulation including chemical heat packs on the trunk to prevent further cooling. In this situation speed is not the main task. Gentle handling and a horizontal position may avoid afterdrop and rescue collapse due to arrhythmias. If the airway is not secured, the patient should be placed in recovery position. Endotracheal intubation or supraglottic airway devices protect the airway in unconscious or unresponsive patients. Prolonged assessment and treatment should be avoided to prevent further heat loss, and the patient should be transported, favorable with helicopter, to a hospital with intensive care unit experienced in treatment or severe hypothermia (Fig. 8.11).
- *Patient in cardiac arrest, obstructed airway, and burial time >60 minutes*
- Resuscitation may be started but may be terminated if not successful.
- *Patient not breathing (cardiac arrest), patent airway, and burial time >60 minutes*

Fig. 8.11 Long-line evacuation of patient in winter conditions

- Precise detecting vital signs may be difficult. If the airway is patent, all patients should be directly transported to a hospital capable of extracorporeal rewarming either with cardiopulmonary bypass or extracorporeal membrane oxygenation (ECMO). CPR should follow standard algorithms. Defibrillations are usually not successful in severe hypothermia, but three attempts may be tried if transport is not delayed. Unsuccessful defibrillation must not lead to termination of CPR as there are many case reports with full recovery after prolonged CPR followed by rewarming. Mechanical chest-compression devices increase the effectiveness of prolonged CPR not only terrestrial but also during helicopter transport. If transport to a hospital with extracorporeal rewarming is not possible, the patient may be brought to the next hospital and serum potassium may be used as additional prognostic marker. Serum potassium level <8 mmol/L presents a good chance for ROSC. Higher values may be considered as reason for termination of CPR. The main principle of avalanche rescue should be: "No hypothermic avalanche victim with a patent airway is dead until warm and dead" (Figs. 8.12 and 8.13).

8.5.3 Suspension Trauma

Suspension trauma is a usual pathophysiological reaction to the body in motionless upright position. After a short time, blood begins to pool in the lower part of the body and the patient may faint. Continuous suspension in this motionless upright position unable to fall over may cause cardiac arrest. Urgent removal and adequate medical care may prevent death. Though the exact pathophysiological mechanism is not clearly explained, different medical strategies have been reported. Keeping the patient's upper body in upright position was considered as an important measure to prevent rescue death and supported by current guidelines. However, there is no clear scientific evidence that this procedure may prevent healthy subjects from death exposed to suspension trauma. Whether death is caused by cardiac arrhythmia or acute heart failure due to volume overload is still unknown. Victims suffering from suspension trauma are generally healthy young people. In many other situations, patients with acute cardiac failure (anaphylaxis, traumatic hypovolemia, vasovagal syncope, etc.) are treated with volume replacement in supine position following ALS guidelines. Securing the airway, breathing, and circulation are the important initial steps in managing unconscious and/or traumatized patients. Assessment and treatment are generally performed in horizontal position because it may be challenging in upright position. Prehospital diagnosis of hypovolemia and reduced central venous return may be difficult; nevertheless fluid resuscitation following established guidelines should not be delayed [43, 44].

Fig. 8.12 Preparing hypothermic patient for transport

8.6 Medical Equipment in Mountain Rescue

Medical equipment in mountain rescue is usually carried in backpacks. They should be equipped according to national laws and cover typical medical emergencies in a certain region taking into account climate, geography, and medical skills of the rescue personnel. Automated external defibrillators (AEDs) should be part of this equipment when afford-

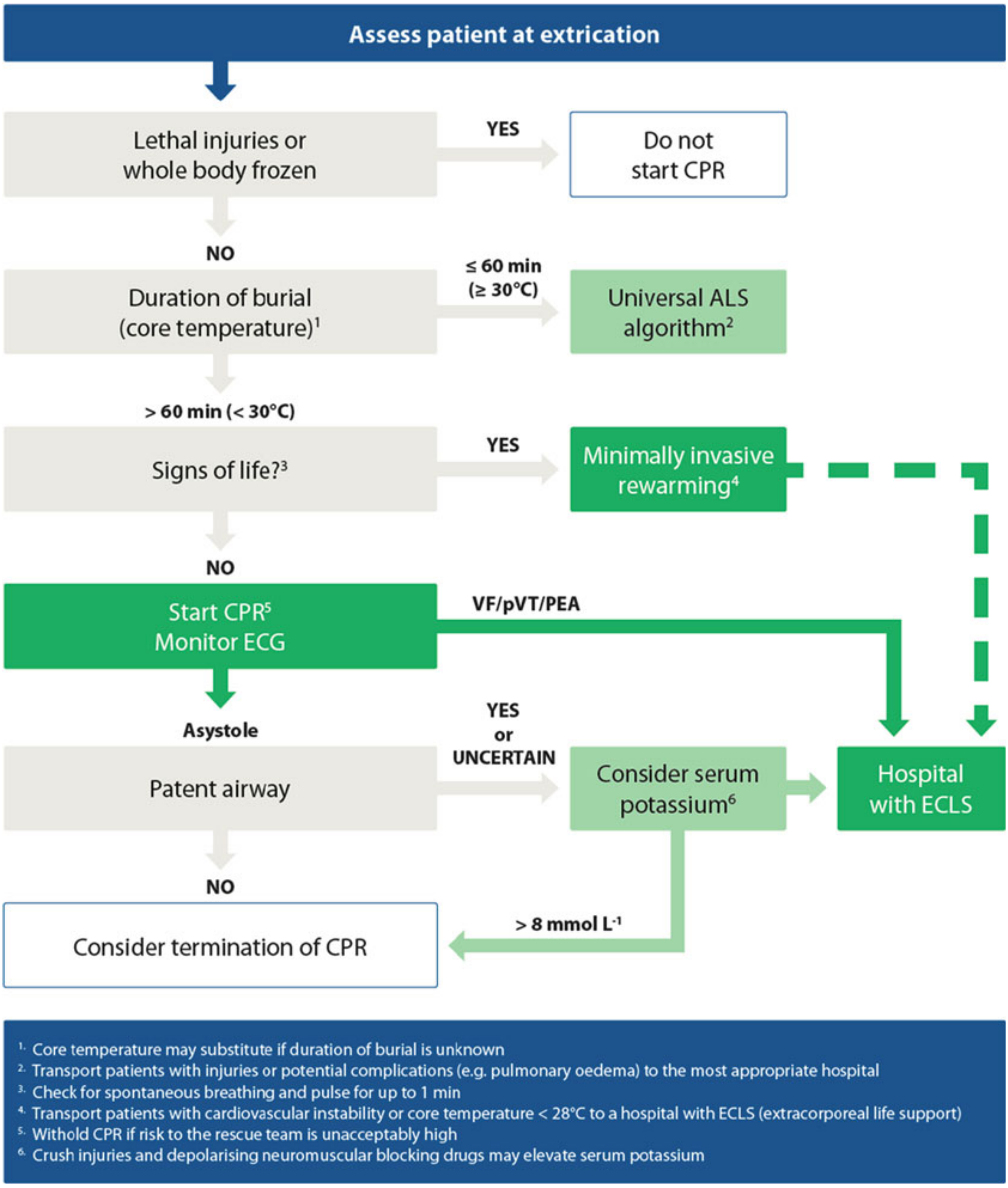

Fig. 8.13 Avalanche management algorithm [40]

able [45]. In many organizations rescue strategies follow the principle of one rapidly ascending team (first responders) with reduced technical and medical equipment and the main team providing all redundant support later. In some countries like North America, Canada, and the United Kingdom, paramedics, emergency medical technician, or certified mountain rescuers act as first responders who are able to administer a restricted range of drugs.

Table 8.2 Recommendation for mountain rescuer's medical backpack [47]

Drugs
Drugs
According to national and internal regulations, e.g., nonsteroidal anti-inflammatory drug (e.g., acetylsalicylic acid, diclofenac, ketoprofen), morphine, nitroglycerin
Medical equipment
I.v. line
Intravenous line set and infusions (e.g., 500 mL crystalloid-fluid)
Miscellaneous equipment
Adhesive tape, aluminum blanket, gloves, scissors
Monitoring
Blood pressure measurement, pulse oximetry, thermometer epitympanic
Trauma
Splinting (e.g., cervical collar, SAM splint®), wound dressing
Ventilation
Bag valve mask, manual suction device, nasopharyngeal and oropharyngeal tube, oxygen, pocket mask ®, venturi mask

Medical equipment transported to a casualty should be limited to the most essential items, because weight is premium in helicopter emergency medical services and in terrestrial rescue where it has to be carried often over a prolonged time [2].

Most mountain rescue teams have divided their medical backpacks into one for trained mountain rescuers and one for physicians tailored to the different tasks and skills. Backpacks for rescuers (first responders) should contain equipment for BLS, splinting, wound dressing, blood pressure, and hypothermia treatment. Oxygen is an important drug in prehospital care but the weight may slow down the first team. Ventilation by rescuers should be performed with mouth-to-mask ventilation [46]. Acceptance is high because handling is simple, safe, and effective. New small AEDs with monitoring function can be considered in order to complete cardiorespiratory assessment. Findings may be reported to the physician (telemetric data transmission in the future?), and advice may be given via radio (Table 8.2).

Backpacks for physicians should cover ALS, treatment of trauma, anaphylaxis, pulmonary disorders, and hypertensive urgencies. Drugs should be selected by the physician according to his experience. He should only administer drugs which he is familiar with and able to manage potential adverse effects.

In order to save weight, the rescuers' and physicians' backpacks should be complementary, and repeated training in the use and maintenance is mandatory [6]. Backpacks for rescuers usually weigh 5–8 kg and physicians' backpacks approximately 12–20 kg including all recommended items [47] (Table 8.3).

8.7 Termination of Resuscitation

Rescuers and physicians in the mountains are regularly confronted with lifeless persons either when rescuers arrive at the scene of accident prior to a physician or a physician is confronted with a lifeless person without the possibility of technical diagnosis of death (e.g., ECG). The decision to resuscitate may increase the risk for rescuers as initiation of resuscitation and extrication need to be started in dangerous terrain under extreme climate conditions. Several fatal accidents involving mountain rescuers in the line of duty during the past years demanded the establishment of guidelines in order to reduce unnecessary CPR [37]. This may not only reduce the risk for rescuers but also avoid unnecessary transport and direct limited resources to those patients who have a chance of survival [1, 6, 7, 47].

Resuscitation rules validated for resuscitation in urban areas may not be applicable for situations in the mountains. The 2012 American Heart Association guidelines recommend CPR performed by BLS providers should be continued until return of spontaneous circulation (ROSC), care is transferred to an ALS team, and rescuers are exhausted or CPR would jeopardize rescuers or others or reliable criteria for death are not met or criteria for termination of

Table 8.3 Recommendations for a physician's backpack in mountain rescue [47]

Drugs
ALS
Amiodarone, atropine, epinephrine
Analgetics
Strong opioid (e.g., fentanyl, morphine), ketamine; nonsteroidal anti-inflammatory drug (e.g., diclofenac, ketoprofen)
Sedatives
Etomidate, midazolam, propofol
Muscle paralytics
Rocuronium, suxamethonium
Cardiovascular drugs
Acetylsalicylic acid, beta-blocker, fibrinolytic, heparin, nitroglycerin, vasopressor (e.g., dopamine, norepinephrine)
Bronchodilators
Beta-agonists (inhalative and i.v.), corticosteroids (inhalative), theophylline
Other drugs
Flumazenil, furosemide, glucose 33 or 40 %, H_1- and H_2-receptor antagonists, naloxone, corticosteroids (i.v.)
Medical equipment
I.v. line
Intravenous line set and infusions (e.g., 500 mL crystalloid), hypertonic fluid
Miscellaneous equipment
Adhesive tape, aluminum blanket, gloves, indwelling urinary catheter and bag, scissors
Monitoring
Blood pressure measurement, capnography, electrocardiogram, glucometer, pulse oximetry, stethoscope, thermometer esophageal and epitympanic
Trauma
Replantation bag, splinting (e.g., cervical collar, SAM splint®), wound dressing
Ventilation
Alternative airway device (e.g., laryngeal mask), bag valve mask, manual suction device, nasopharyngeal and oropharyngeal tube, oxygen, thoracotomy set, tracheal intubation set (plastic laryngoscope scoop preferable with cold weather), venturi mask

ALS denotes advanced life support

resuscitation are not met [48]. These rules are promising but should be applied cautiously in mountain rescue. In mountain and wilderness area, circumstances for cardiac arrest and survival may be different and unexpected survival may be possible [49]. A modified BLS termination of resuscitation guideline established in 2012 by the International Commission for Mountain Emergency Medien (ICAR MEDCOM) should limit unappropriate CPR in mountain rescue. In case of unwitnessed cardiac arrest and no spontaneous return of circulation during 20 minutes of CPR and no shock advised at any time by AED or only asystole observed by ECG and no hypothermia or other special circumstances warranting extended CPR, CPR may be terminated. In case of witnessed cardiac arrest or if one of the above criteria is absent, CPR should be continued until qualified medical personnel performing clinical assessment of the patient, situation, CPR, and transportation factors determines that further CPR is futile. Frequently reported cases of ROSC after prolonged resuscitation using mechanical chest compression devices give hope in special circumstances and emphasize

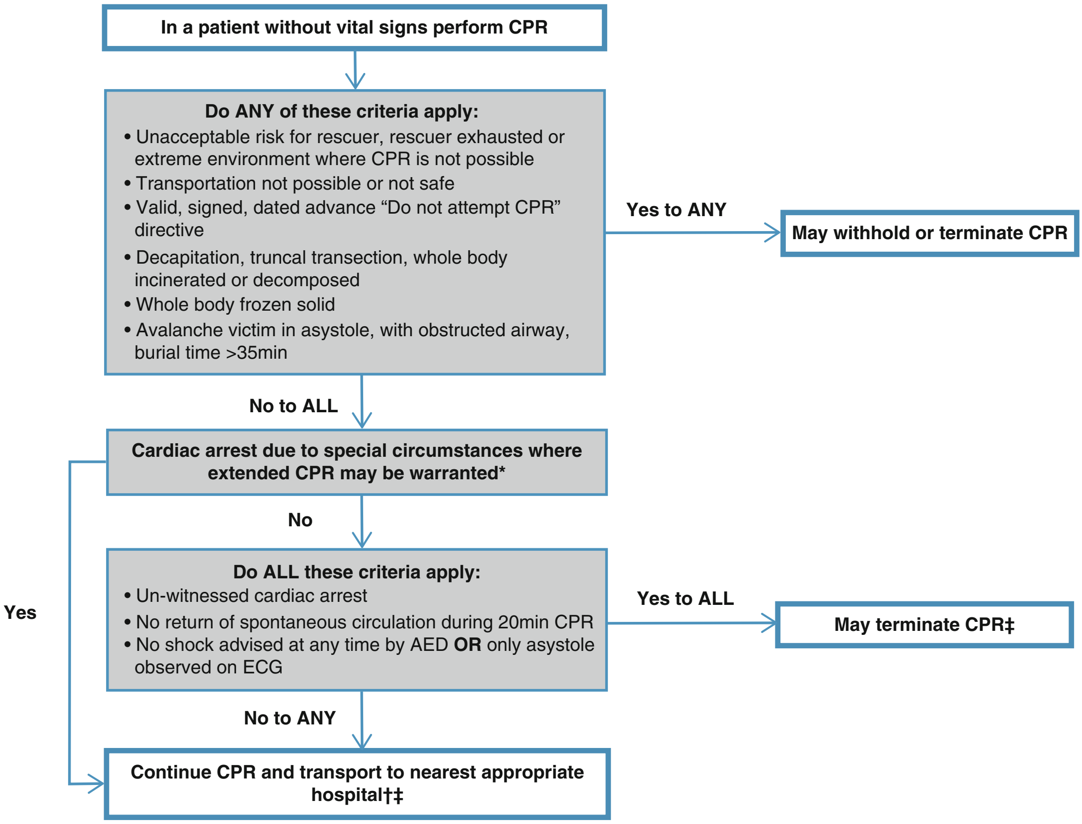

Fig. 8.14 Termination of resuscitation

the need of accurate assessment. However, prolonged CPR is not indicated when a patient is not expected to survive, consistent with the principle of medical futility or when the resources of rescuers are inadequate or excessive long transport is expected (Fig. 8.14) [48].

Conclusion

Emergency medicine in mountains and remote areas requires high physical and technical skills by rescuers and physicians. Assessment and treatment may be limited due to hostile environmental conditions and rapid deterioration of patients caused by delayed treatment and prolonged evacuation time. Hypothermia is common in mountain casualties, should not be overlooked, and accurately treated. Trauma treatment is based on sufficient pain relief and adapted fluid resuscitation. Avalanche victims have a great chance of survival if extricated within 15–20 min. Survival longer than 60 minutes in totally buried victims is dependent on a patent airway. On-site treatment and transport should focus on immediate CPR, prevention of hypothermia, and rapid transport to an appropriate hospital. Medical equipment in mountain rescue needs to be adapted to the expected scenario of injury and the skills of rescuers and physicians. In special circumstances withholding or terminating CPR may reduce the risk for rescue teams and save human and technical resources (Fig. 8.15).

Fig. 8.15 Longline operation in winter

Acknowledgment This chapter is based on recommendations and guidelines established by ICAR MEDCOM (International Commission for Mountain Emergency Medicine), a subcommission of the International Commission for Alpine Rescue (ICAR: www.alpine-rescue.org). ICAR is the worldwide platform for the exchange of experience and knowledge in mountain rescue. ICAR MEDCOM consists of over 60 members, experienced active mountain emergency physicians delegated from almost 40 organizations worldwide. All recommendations and guidelines are published in peer-reviewed medical journals. Together with the International Society for Mountain Medicine (ISMM) and the Medical Commission of the International Mountaineering and Climbing Federation (UIAA MEDCOM), ICAR MEDCOM has established curricula for the "International Diploma in Mountain Medicine" and the "International Diploma in Mountain Emergency Medicine."

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