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Field management of Avalanche victims: the ICAR MEDCOM guidelines 2002

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Summary

The median annual mortality from snow avalanches registered in the 17 ICAR countries 1981 – 1998 was 146 (range 82 – 226). Swiss data document a mortality rate of 52.4% in completely-buried, versus 4.2% in partially-, or non-buried, persons (n = 1886). Survival probability of completely-buried victims in open areas (n = 638) plummets from 91% 18 min after burial to 34% at 35 min, then remains fairly constant until a second drop after 90 min. Standardised guidelines are introduced for the field management of avalanche victims. Strategy by rescuers confronted with the triad hypoxia, hypercapnia and hypothermia is primarily governed by the length of snow burial and victim's core temperature, in the absence of obviously fatal injuries. With a burial time ≤ 35 min survival depends on preventing asphyxia by rapid extrication and immediate airway management; cardiopulmonary resuscitation for unconscious victims without spontaneous respiration. With a burial time > 35 min combating hypothermia becomes of paramount importance. Thus, gentle extrication, ECG and core temperature monitoring and body insulation are mandatory; unresponsive victims should be intubated and pulseless victims with core temperature < 32°C [89.6°F] (prerequisites being an air pocket and free airways) transported under continuous cardiopulmonary resuscitation to a specialist hospital for extracorporeal re-warming.

Pathophysiological considerations

The number of persons killed annually by snow avalanches world-wide is not known precisely. However, in the 17 countries represented by the International Commission for Alpine Rescue (ICAR) in Europe and North America, deaths from avalanche incidents have been accurately recorded over the past two decades; the median annual mortality registered between 1981 and 1998 was 146 (range 82 – 226) (Valla, 1998). Avalanche accidents are mostly sports-related, triggered by skiers, snowboarders and, especially in the USA, snowmobilers in open, i.e. non-controlled, areas.

"Complete burial" is defined as coverage of the victim's head and chest by snow, if not the complete body, otherwise the term "partial burial" applies (Winterbericht, 1981-1998). Altogether 1886 avalanche victims were registered in Switzerland 1981 – 1998. An analysis shows an overall mortality rate of 23.0%; 735 of these persons (39.0%) were completely buried, whereby 52.4% were dead on extrication, as compared with only 4.2% in 1151 partially-, or non-buried, victims (Brugger et al., 2001).

The avalanche survival probability for completely-buried victims in open areas on the basis of Swiss data for 1981 – 1998 (n = 735) in relation to duration of burial, has been calculated by a computer-assisted, non-parametric method in Fig 1. The data show a precipitous drop in calculated survival probability from 91% at 18 min after burial to 34% at 35 min (acute asphyxiation of victims without an air pocket), a flattening of the curve between 35 and 90 min ("latent phase" for victims with an air pocket), followed by a second drop to only 7% at 130 min (death of victims with a "closed" air pocket from slow asphyxia and hypothermia). This analysis confirms the previously-proposed survival probability curve (Falk et al., 1994).

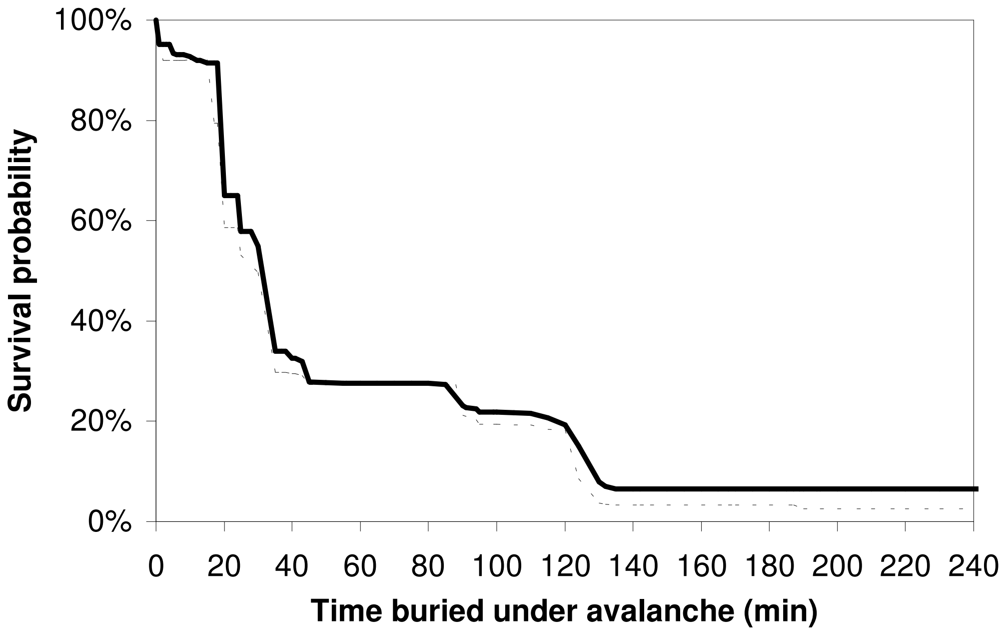

Figure 1: Survival probability for completely-buried avalanche victims in open areas in Switzerland 1981 – 1998 (n = 735) in relation to time (min). The dotted curve represents the survival function for completely-buried avalanche victims in open areas (n = 422) based on the Swiss data for 1981 – 1991, calculated by Falk et al., 1994. Reprinted from Brugger et al. (2001) Resuscitation 51:7-15 with permission from Elsevier Science.

The inflection point of the survival probability curve at 35 min (Fig 1) indicates that victims completely buried under an avalanche cannot survive beyond 35 min without an air pocket (Falk et al., 1994). According to standard definition, an air pocket is any space surrounding mouth and nose, no matter how small, with the proviso of free air passages. The definition "no air pocket" is only permissible if the extricated victim's mouth and nose are found to be hermetically sealed off by snow or debris (Brugger et al., 1996). Air pockets are usually only a few centimetres wide in the case of buried skiers (Winterbericht, 1981-1998). Although these can easily be overlooked in the stress of the rescue procedure, well-trained rescuers are usually able to identify even small air pockets, which are often iced up on the inner surface.
It must be noted that the underlying pathophysiology in the case of persons with an air pocket is largely unresearched as yet, in particular regarding how long an air pocket of a certain volume can support life. Sumann will report at this Conference on recent pilot experiments carried out by our group on 12 volunteers breathing from outside into an air pocket of 1000 or 2000 cubic centimetres in volume. Notwithstanding these experimental observations, recorded data following complete burial under an avalanche reveal that many victims with only a small air pocket have, in fact, been extricated alive up to at least 2 hours after burial (Winterbericht, 1981-1998).

Accidental hypothermia plays a less important role in avalanche disasters than is generally assumed and should not be equated with accidental hypothermia of other aetiology, such as environmental exposure. In particular, the therapeutic principle "no one is dead until warm and dead" (Danzl et al., 1989) has only limited applicability to avalanche victims, in contrast to the successful re-warming, with full neurological recovery, achieved in severely hypothermic patients following accidental environmental exposure (Walpoth et al., 1997).
The lowest recorded core temperature (13.7°C [56.7°F]) from which a person with accidental hypothermia has been successfully resuscitated was reported recently in a 29 year-old woman trapped in icy water in Norway (Gilbert et al., 2000). In avalanche accidents the equivalent nadir is 19°C (66.2°F) (Althaus et al., 1982). Since the first reports in 1967 of successful extracorporeal blood-warming (Kugelberg et al., 1967; Davies et al., 1967), this procedure has become established as the gold standard in the treatment of patients with accidental hypothermia and circulatory arrest. Heparin-coated machines enable cardiopulmonary bypass therapy to be used even in traumatised patients (von Segesser et al., 1991).
The risk of injury largely depends on the prevailing type of snow, as well as the terrain in the path of the avalanche. Thus, wet-snow avalanches descending over rocky and/or forested slopes are independent factors associated with a heightened risk of injury. A review of 136 autopsy reports on avalanche victims in various countries reported mechanical trauma as the cause of death in 13% of cases (Stalsberg et al., 1989).

General therapeutic principles

Risks to avalanche victims and their rescuers during the rescue operation are not always calculable. Hence, in all decisions the goal of rapid rescue of the victim(s) must be balanced against the risks to the rescue team. The possibility of a second avalanche, the snow conditions, as well as all relevant topographic and meteorological factors must be evaluated. Furthermore, time factors must be taken into consideration. "Thinking ahead" should be the guiding principle of the rescue procedure.

Rescue Time Goals

Recalculation of the survival probability in relation to duration of burial with the augmented Swiss data (Fig 1) confirms the rescue time goals proposed by Falk et al., 1994 for extrication of completely-buried avalanche victims in open areas. Over 90% of victims could be extricated alive if the first deadline of 15 min after descent of the snow masses were achieved by uninjured companions. 90 min should be the operational target for professional rescue teams to salvage the lives of any remaining victims with a closed air pocket and free airways.

Dependence of Emergency Management on Duration of Burial

With a burial time of up to 35 min, rapidity of extrication is the decisive factor in preventing irreversible obstructive asphyxia. Hence, if the patient is extricated in a critical condition within this period, the cause can be attributed with certainty to obstructive asphyxia (obstruction of the airways, mechanical compression of the thorax, or aspiration) or trauma, but not to hypothermia. With a burial time exceeding 35 min, open airways and the existence of an air pocket are decisive factors governing survival, as well as therapeutic strategy and triage decisions. Hence, great care must be taken by rescuers during extrication of the person to avoid destruction of a possible air pocket. Despite the inherent pressures, gentleness should take precedence over speed in the rescue procedure (Brugger et al., 2001).

On-site Staging of Hypothermia

Hypothermia is generally graded according to Danzl's classification of severity (Danzl et al., 1998), which is based on a precise measurement of the core temperature. However, interim clinical staging according to criteria implemented by the Swiss Society of Mountain Medicine (Durrer, 1991) has the advantage that it can be established by non-medical members of the rescue team at the avalanche site, since it is not based on measurement of the core temperature (Fig. 2). However, since there may be great individual variation in the observed clinical features, it is imperative that the core temperature is accurately measured as soon as possible by a medical attendant.

ECG and Core Temperature Monitoring

Monitoring of the ECG and core temperature is commenced immediately after extrication of the victim. Cardiac monitoring is of prime importance in alerting the medical team to induced arrhythmias or ventricular fibrillation during the rescue process. Pulse oximetry is considered unreliable in hypothermia. The core temperature should be taken on site and monitored continuously during transport. The attendant's choice of oesophageal or epitympanic measurement (Walpoth et al., 1994) of the core temperature usually depends on personal experience. However, oesophageal measurement is the gold standard, since the epitympanic method gives false low values under certain circumstances, namely 1) very cold outside temperatures, 2) blockage of the patient's external ear passages by snow or water and 3) circulatory arrest – i.e. in the absence of carotid flow (Locher et al., 1997). Epitympanic measurement may be useful in patients showing spontaneous breathing, but is categorically ruled out as a basis for pronouncing death on site.

Insulation

The aim of field management is not active re-warming of the extricated avalanche victim at this stage, but prevention of any further drop in core temperature. Thus, shielding the patient from the wind and removal of wet garments are undertaken if possible, but rough movements should be avoided in the process. Passive rewarming can be achieved by the use of blankets, aluminium foils and bivouac bags. For active external rewarming 2 – 3 chemically-heated packs should be applied to truncal areas only (neck, armpits, or groin). The conscious patient (Swiss stages I - II) should be given hot, sweet, non-alcoholic drinks, if able to swallow.

Infusion of Warmed Fluids and Administration of ACLS - Protocol Drugs

Numerous authors recommend the infusion of warmed fluids (42 - 44°C [108 - 111°F]) in hypothermic patients to counteract the increased vessel permeability and diuresis in response to cold (Hanania et al., 1999; Jolly et al., 1992), although no therapeutic benefit has yet been proven. Establishing an intravenous line in hypothermia can be very difficult and time consuming due to the centralised circulation of the patient. The advantages of an intravenous line have to be balanced against the risk of further cooling out, especially if the transport time to hospital is short. If intravenous access is established, then infusion of 0.9% NaCl and/or 5% glucose is recommended. Lactate should be avoided since it is poorly metabolised in hypothermia. The administration of ACLS drugs, including epinephrine and vasopressin, is still controversial in hypothermia (Krismer et al., 2000).

Inhalation of Warmed Oxygen

Administration of humidified, warmed oxygen (42 - 46°C [108 - 115°F]) by means of a mask or endotracheal tube in order to prevent temperature afterdrop is the only practicable field procedure recommended for active internal re-warming of the rescued victim. It is, moreover, a causal therapeutic measure to combat asphyxia. This technique is appropriate for field implementation since it is non-invasive and, indeed, simple in application (Weinberg, 1998).

Individual steps of field management

Highest priority must be given to ensuring reversal of hypoxia and hypothermia after extrication of avalanche victims. Often several buried persons are dug out of the snow masses simultaneously and, thus, adherence to specific triage criteria is important in the assessment of treatment priorities and mandatory in on-site pronouncement of death (Brugger et al., 1996).

During extrication of the victim from the snow masses, unnecessary movement of the trunk and large joints (shoulder, hip and knee) must be avoided, in order to prevent the development of cardiac arrhythmias triggered by the flow of cold, peripheral blood to the heart and/or the irritable myocardial state.

Assessment of responsiveness, breathing and pulse

The conscious patient (Swiss stages I – II) should be transported to the nearest hospital with an intensive care unit. Traumatised patients should be treated according to the International Resuscitation Guidelines 2000 and transported to a hospital with specialist expertise in the respective type of injury, if possible, otherwise to the nearest hospital with intensive care facilities. If the patient is unresponsive (Swiss stages III – IV) the rescuer should open the airways and assess breathing and pulse for 30 to 45 seconds to confirm respiratory arrest or pulseless cardiac arrest. With signs of respiratory insufficiency or arrest, resuscitation should be initiated already during the extrication procedure.

Intubation

The unconscious patient, with or without vital functions, should be tracheally intubated if possible, since the danger of iatrogenically-induced ventricular fibrillation is now considered negligible and is far outweighed by the benefits of reliable oxygenation. Unconscious patients should be transported to a hospital with the necessary expertise in the treatment of severe hypothermia and, specifically, to a unit with cardiopulmonary bypass core re-warming facilities when circulatory instability is evident.

Victims with cardiac arrest

Organised rescue teams are confronted with the fact that 85% of avalanche victims extricated by them are in cardiac arrest (Winterbericht, 1981-1998), since they only seldom reach the site of snow descent before 35 min, i.e. the inflection point of survival function (Fig 1). Cardiac arrest is due to irreversible obstructive asphyxia in most cases, but may result from severe hypothermia in victims with an air pocket and patent airways.
Formulation of an algorithm for on-site triage of avalanche victims with asystole (Brugger et al., 1996) laid the foundation for field decision-making by the emergency doctor in determining the differential diagnosis between asphyxia and hypothermia. Its implementation enables pronouncement of death in asphyxiated victims on site, ensuring that transferral for cardiopulmonary bypass core re-warming is limited to those patients with potentially reversible hypothermia.
The protocol in Fig. 2 distinguishes victims with a burial time of less than, or equal to, 35 min and/or a core temperature exceeding, or equal to, 32°C (89.6°F), when the patient is treated according to International Resuscitation Guidelines 2000, i.e. Basic Life Support or Advanced Cardiac Life Support, from those with a burial time exceeding 35 min and/or a core temperature of less than 32°C (89.6°F), when the presence or absence of an air pocket and the patency (or otherwise) of the airways dictates further procedure.
Hence, in the presence of free airways and an air pocket, or if the respective data are equivocal, the victim is assumed to have reversible hypothermia. Cardiopulmonary resuscitation (CPR) must be continued with standard rates and ratios (compression–ventilation ratio 15:2, 100 chest compressions per min) until the patient is re-warmed in a hospital with cardiopulmonary bypass facilities. If transport to a specialist unit for extracorporeal re-warming is not logistically possible, victims should initially be taken to the nearest hospital. The serum potassium level is then used as alternative triage determinant, unless invalidated by the presence of crush injuries, which are associated with rhabdomyolysis, or by prior administration of muscle relaxants (Larach, 1995). With serum potassium levels lower than, or equal to, 12 mmol/l, CPR should be continued until the patient has been transferred to a hospital with cardiopulmonary bypass facilities.

Up to three attempts at defibrillation (200 – 300 – 360 J) should be made in victims with ventricular fibrillation, in accordance with standard practice (Special Challenges in ECC, 2000). However, at core temperatures under 28°C (82.4°F) defibrillation is usually unsuccessful and then resuscitation must be maintained until the victim has been re-warmed. On the other hand, the attending emergency doctor can discontinue CPR and pronounce death by asphyxia in victims buried longer than 35 min and/or with a core temperature of less than 32°C (89.6°F) in the unequivocal absence of an air pocket or when the airways are obstructed. In conclusion, if obviously fatal injuries can be excluded, all severely hypothermic avalanche victims with an air pocket and free airways should be managed optimistically by attempted re-warming in a specialist unit with cardiopulmonary bypass facilities.

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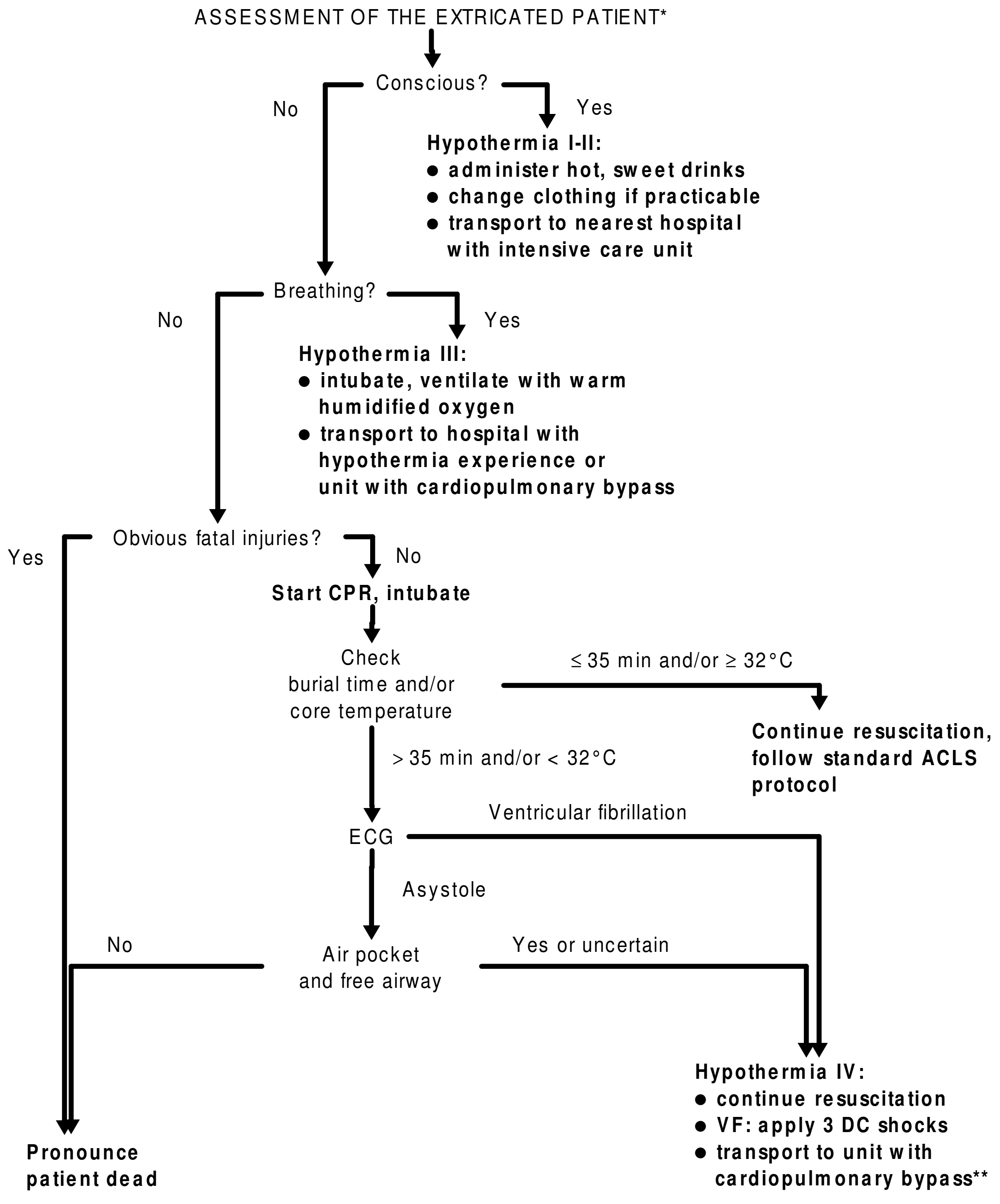
Figure 2: Pre-hospital management of persons buried in an avalanche. * In all cases: core temperature + ECG monitoring, gentle extrication, oxygen, airway warming, insulation, hot packs on trunk; 0.9% NaCl and/or 5% glucose only if an intravenous line can be established within a few minutes; trauma treatment if indicated. ** Transport to the nearest hospital for serum potassium measurement if hospitalisation in a specialist unit with cardiopulmonary bypass facilities is not logistically possible. If K^+ exceeds 12 mmol/l, stop resuscitation and pronounce death by asphyxiation; if K^+ is lower than, or equals, 12 mmol/l, continue cardiopulmonary resuscitation and transport the patient as soon as possible to a specialist hospital for extracorporeal re-warming. ACLS = advanced cardiac life support, CPR = cardiopulmonary resuscitation. Staging of hypothermia according to Swiss Society of Mountain Medicine guidelines (Durrer, 1991). Reprinted from Brugger H., Durrer B., Adler-Kastner L., Falk M., and Tschirky F. (2001) Field management of avalanche victims. Resuscitation 51:7-15 with permission from Elsevier Science.



Hypothermia I: patient alert, shivering (core temperature about 35-32°C [95-89.6°F])
Hypothermia II: patient drowsy, non-shivering (core temperature about 32-28°C [89.6-82.4°F])
Hypothermia III: patient unconscious (core temperature about 28-24°C [82.4-75.2°F])
Hypothermia IV: patient not breathing (core temperature < 24°C [< 75.2°F])