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Field management of avalanche victims

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Abstract

The median annual mortality from snow avalanches registered in Europe and North America 1981–1998 was 146 (range 82–226); trend stable in Alpine countries ($r = -0.29$; $P = 0.24$), increasing in North America ($r = 0.68$; $P = 0.002$). Swiss data over the same period document 1886 avalanche victims, with an overall mortality rate of 52.4% in completely-buried, versus 4.2% in partially-, or non-buried, persons. Survival probability in 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. Likewise, survival probability for completely-buried victims in buildings or on roads ($n = 97$) decreases rapidly following burial initially, but as from 35 min it is significantly higher than that for victims in open areas, with a maximum difference in respective survival probability (31% versus 7%) from 130 to 190 min ($P < 0.001$). 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 $\leqslant 35$ 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 with continuous cardiopulmonary resuscitation to a specialist hospital for extracorporeal re-warming.

Keywords: Avalanche; Asphyxia; Cardiopulmonary resuscitation; Emergency medical services; Hypothermia; Triage

Resumo

A mortalidade média anual por avalanches verificada na Europa e América do Norte em 1981–1988 foi de 146 (intervalo 82–226); tendência estabilizada nos países Alpinos ($r = -0.29$; $P = 0.24$), e a aumentar na América do Norte ($r = 0.68$; $P = 0.002$). Os dados da suiça n mesmo período documentam 1886 vítimas de avalanche, com uma mortalidade global de 52.4% em vítimas completamente soterradas versus 4.2% em parcialmente ou não soterradas. A probabilidade de sobrevida em vítimas completamente soterradas em áreas abertas ($n = 638$) desce de 91% 18 minutos após o soterramento para 34% aos 35 minutos, mantendo-se constante até uma nova descida aos 90 minutos. Da mesma forma, a probabilidade de sobrevida para vítimas de soterramento completo em edifícios ou estradas ($n = 97$) diminui rapidamente no início mas a partir dos 35 minutos é significativamente maior que para as vítimas de soterramento em áreas abertas, com uma diferença máxima nas probabilidades

✠ This paper is dedicated in memory of Frank Tschirky, who died suddenly aged 45 from a heart attack whilst trekking in Nepal on April 25th 2001, shortly before publication of this study. His untimely death represents a great loss of the field of avalanche research.

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de sobrevida respectivamente (315 versus 7%) dos 130 aos 190 min ($P < 0.001$). São apresentadas recomendações normalizadas para a abordagem no local das vítimas de avalanches. A estratégia de socorristas confrontados com a tríade: hipóxia, hipercápnia e hipotermia é principalmente orientada pelo tempo de permanência sob a neve e temperatura central da vítima, desde que não existam lesões fatais evidentes. Com um tempo de soterragem ≤ 35 minutos a sobrevida depende da prevenção da asfixia através da libertação rápida e permeabilização da via aérea e ressuscitação cardiorespiratória para vítimas inconscientes sem ventilação espontânea. Com tempos > 35 minutos, o combate á hipotermia assume importância primordial. Assim, a libertação cuidadosa, monitorização do ECG e temperatura central e isolamento do corpo são mandatórios; as vítimas não reactivas devem ser intubadas e as vítimas sem pulso e temperatura central < 32 °C (89.6 °F) (sendo pré-requisito a existência de uma bolsa de ar e via aérea livre) devem ser transportadas com ressuscitação cardiorespiratória contínua para um hospital especializado com aquecimento extra-corporal.

Palavras chave: Avalanche; Asfixia; Ressuscitação cardiorespiratória; Serviços de emergência médica; Hipotermia; Triagem

1. Introduction

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) [1]. Fig. 1 shows no significant change over this period in avalanche mortality in the European Alpine countries (Austria, France, Germany, Italy and Switzerland), in contrast to the significant increase noted for the data from Canada and the USA [2]. Avalanche accidents are mostly sports-related, triggered by skiers, snowboarders and, especially in the USA, snowmobilers in open, i.e. non-controlled, areas. Avalanches triggered spontaneously by specific topographic or meteorological circumstances are rare, but inflict a high death toll on victims buried in buildings or on roads engulfed by the snow masses. Thus, major elemental avalanche catastrophes claimed 284 lives in south east Asia Minor in 1992 [3], 197 in two disasters in 1995 (Kashmir [4] and Iceland [5]) and, most recently, 38 in Austria in 1999 [6].

Switzerland is the only country in which all avalanche accidents are comprehensively documented with scrupulous precision. Retrospective analysis of these recorded data enabled accurate calculation of avalanche survival chances [7], and formulation of guidelines for mountain rescue doctors undertaking on-site triage of asystolic victims [8]. In this further study a protocol is proposed for the field management of rescued persons.

2. Pathophysiological considerations

2.1. Avalanche mortality

'Complete burial' is defined as coverage of the victim's head and chest by snow, otherwise the term 'partial burial' applies [9]. Altogether, 1886 avalanche

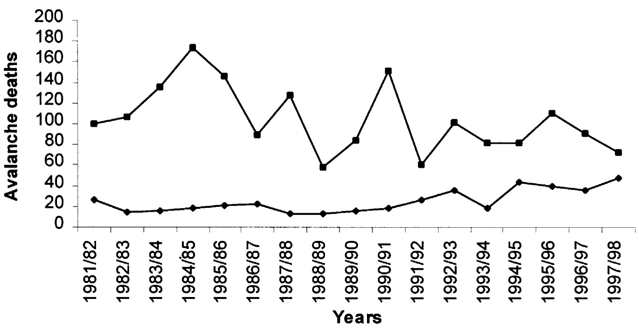

Fig. 1. Annual figures of avalanche deaths in Austria, France, Germany, Italy and Switzerland (■), as well as in Canada and the USA (◆) 1981–1998 [1] (n total = 2197). No trend is observed in the Alpine countries ($r = -0.29$, $P = 0.24$; Spearman's correlation coefficient). By contrast, the curve for North America shows an increase in avalanche deaths ($r = 0.68$, $P = 0.002$; Spearman's correlation coefficient).

Table 1
Analysis of the comprehensive data on victims extricated alive or dead in all avalanche accidents in Switzerland 1981–1998 [9] according to site (A), and extent (B), of burial

	Total number of victims		Site of burial (A)				Extent of burial (B)			
			Open areas		Buildings, roads		Completely buried		Partially or not buried	
Alive on extrication	1453	77.0%	1053	73.4%	400	88.5%	350	47.6%	1103	95.8%
Dead on extrication	433	23.0%	381	26.6%	52	11.5%	385	52.4%	48	4.2%
Respective totals	1886	100%	1434	100%	452	100%	735	100%	1151	100%

Within (A) and (B), we compared frequencies using Pearson's Chi-Square, whereby all P values are <0.001.

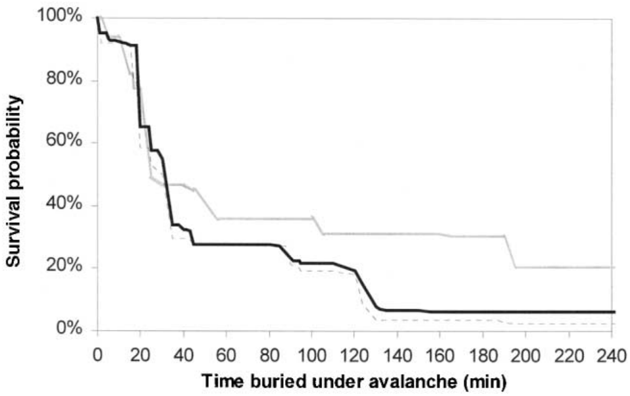

Fig. 2. Survival probability for completely-buried avalanche victims in Switzerland 1981–1998 ($n=735$) in relation to time (min) buried under the snow, contrasting victims buried in open areas (black curve, $n=638$) with those buried in buildings or on roads (grey curve, $n=97$). Median extrication times were 37 min (open areas) and 56 min (buildings, roads) ($P=0.17$, Mann–Whitney U-Test). In open areas only 16.6% of all survivors are extricated after the cut-off point of 35 min, as compared with 32.7% in buildings and on roads ($P=0.008$; Pearson's Chi-Square). The respective findings for the cut-off point of 130 min are 1.7% (open areas) and 16.3% (buildings, roads) ($P<0.001$; Pearson's Chi-Square). 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. [7].

victims were registered in Switzerland 1981–1998 [9]. An analysis (Table 1) shows an overall mortality rate of 23.0%; 735 of these persons (39.0%) were completely buried, with 52.4% dead on extrication, compared with only 4.2% in 1151 partially-, or non-buried, victims. Avalanches struck in open areas in 1434 (76.0%), whilst the remaining 452 (24.0%) persons were trapped by snow masses in buildings or on roads. The latter group contained a higher proportion of partially-, or non-buried, persons (78.5%; 355[1] out of 452) than the former group (55.5%; 796[1] out of 1434) $P<0.001$; Pearson's Chi-Square. This accounts for the significantly lower mortality rate (11.5%) in persons buried in buildings or on roads, compared with mountain skiers and snowboarders in open areas (26.6%).

2.2. Survival probability and asphyxia

The avalanche survival probability for completely-buried victims in relation to duration of burial, calculated by a new computer-assisted, non-parametric method on the basis of Swiss data for 1981–1991 ($n=422$) [7], has now been recalculated and updated in Fig. 2 to cover the extended period 1981–1998 ($n=735$). Moreover, the present study compares the survival function for victims completely buried in buildings and on roads ($n=97$) with that for completely-buried skiers and snowboarders in open areas ($n=638$). The augmented data for persons buried in open areas (black curve) show a precipitous drop in calculated survival probability from 91% at 18 min 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), confirming the previously-proposed survival probability curve [7]. The survival probability for victims trapped in buildings and vehicles (grey curve) initially falls rapidly too, but from 35 min it is significantly higher than that for skiers and snowboarders in open areas. Thus, the survival probability in the former group remains above 30% until 190 min, dropping to 21% thereafter. The better outcome is due to the fact that these victims are more frequently surrounded by a large cavity, or one open to the exterior ('open' air pocket), than their counterparts buried in open areas [9]. The longest recorded survival time for a person completely buried in an open area is 44 h (Italy 1972) [10], compared with the record of 13 days in a building (Austria 1951) [11].

2.3. Air pocket physiology

The inflection point of the survival probability curve at 35 min (Fig. 2) indicates that victims completely buried under an avalanche cannot survive beyond 35 min without an air pocket [7]. According to the standard definition, an air pocket is any space surrounding the mouth and nose, no matter how small, with a patent airway. 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 [8]. Air pockets are usually only a few centimetres wide in the case of buried skiers [9]. 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 victims with an air pocket is largely unresearched as yet, particularly regarding how long an air pocket of a certain volume can support life. Calculations [12] and experimental studies in snow [13] on hypoxia and hypercapnia in a closed space have shown that in a model air pocket measuring 0.5 cubic metres the alveolar pO_2 sinks to 5.6 kPa (42 mmHg), a level initiating loss of consciousness in vivo, after 88 min. Very recently, two studies have measured the respiratory variables in volunteers breathing into an artificial air pocket in snow. Grissom et al. [14] observed the following significant changes in seven volunteers who were completely buried in snow and provided with an air pocket mea-

[1] Data not given in the table.

suring 500 cubic centimetres. O_2-saturation (SpO_2) decreased from a mean value of 96% (range 90–99%) to 84% (range 79–92%) and end expiratory pCO_2 ($ETCO_2$) increased from a mean value of 4.3 kPa (32 mmHg) (range 3.6–5.1 kPa (27–38 mmHg)) to 7.2 kPa (54 mmHg) (range 5.9–8.4 kPa (44–63 mmHg)), necessitating termination of the experiment after a mean burial time of 10 min (range 5–14 min). As a preliminary to an ongoing study by our group, pilot experiments were carried out on 12 volunteers breathing from outside into an air pocket of 1000 or 2000 cubic centimetres in volume. A significant decrease in SpO_2 and increase in $ETCO_2$ were found. The decrease in SpO_2 was significantly greater in the subjects with the smaller air pocket. Three of the 12 subjects were able to complete the planned 30-min protocol; they developed a respiratory steady state and breathed into the air space without difficulty [15]. 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 h after burial [9]. Hence, assumptions regarding the pathophysiology must be considered theoretical as yet.

2.4. Circulatory instability

The fall in body temperature acts as protective factor in the prevention of hypoxic damage [16]. However, at a core temperature of 32°C (89.6°F) circulatory instability may be triggered, with the incipient danger of ventricular fibrillation [17]. This critical core temperature appears to be reached about 90 min after snow burial in open areas, concurring with the average rate of body cooling, namely 3°C/h (5.4°F/h) [18], and, moreover, with the onset of the second drop in the survival probability curve (Fig. 2).

2.5. Accidental hypothermia

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' [19] has only limited applicability to avalanche victims, in contrast to the successful rewarming, with full neurological recovery, achieved in severely hypothermic patients following accidental environmental exposure [20].

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 [21]. In avalanche accidents the equivalent nadir is 19°C (66.2°F) [22]. Since the first reports in 1967 of successful extracorporeal blood-warming [23,24], this procedure has become established as the gold standard in the treatment of patients with accidental hypothermia and circulatory arrest [17]. Heparin-coated machines enable cardiopulmonary bypass therapy to be used even in traumatised patients [25]. However, in a comparison with the results of two studies [26,27] in which ten out of a total of 15 (67%) severely hypothermic victims after accidental exposure recovered fully, the combined findings of three studies on avalanche victims [28–30] showed that only six out of altogether 51 (12%) patients were successfully re-warmed. This low recovery rate is due to the dependence of the prognosis in avalanche victims primarily on the duration of asphyxia and not on the degree of hypothermia. Open airways, adequate ventilation and an air pocket are critical determinants of survival. In their absence, buried persons succumb to asphyxia before hypothermia develops. If extracorporeal re-warming is reserved for the correct indications in avalanche victims it may prove a more successful tool.

2.6. Injuries

The risk of injury largely depends on the prevailing type of snow, and 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 trauma as the cause of death in 13% of cases [31].

3. 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, and the 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.

3.1. Rescue time goals

Recalculation of the survival probability in relation to the duration of burial with the augmented Swiss data (Fig. 2) confirms the rescue time goals proposed by Falk et al. [7] for extrication of completely-buried avalanche victims in open areas. Over 90% of victims could be extricated alive if rescued within 15 min after descent of the snow masses by uninjured companions. Ninety minutes should be the operational target for professional rescue teams to salvage the lives of any remaining victims with a closed air pocket and clear airways. The first deadline of 15 min applies similarly to victims buried in buildings or on roads (Fig. 2), but since the survival probability declines at a slower rate as from 35 min than that for buried skiers and snowboarders, no time goal can be recommended for organised rescue teams. However, their chances of extricating victims alive from buildings or vehicles are undoubtedly higher over a protracted time than in the case of persons buried in open areas.

3.2. Dependence of emergency management on duration of burial

The precedence accorded to individual emergency management procedures depends on the duration of burial (Fig. 3). With a burial time of up to 35 min, rapidity of extrication is the decisive factor in preventing irreversible obstructive asphyxia. 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.

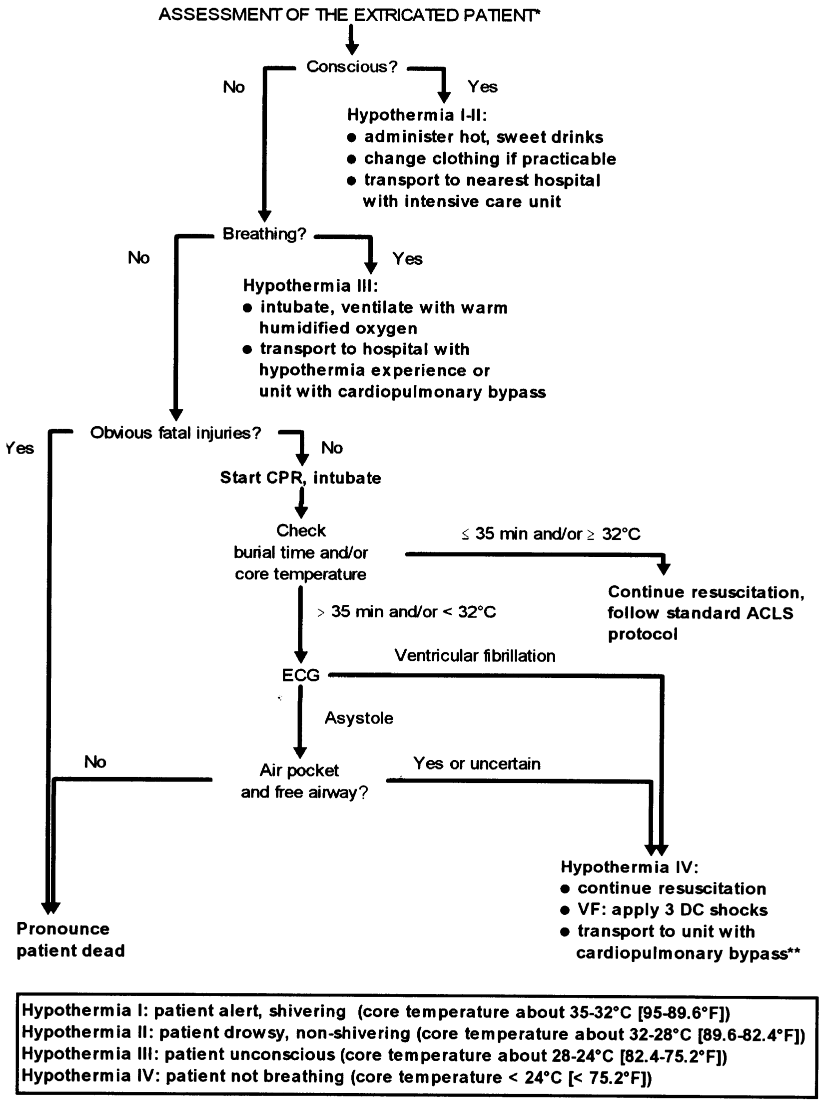

Fig. 3. Pre-hospital management of persons buried in an avalanche. *In all cases: core temperature + ECG monitoring, gentle extrication, oxygen, airway warming, insulation, hot packs on trunk; 0.9% NaCl and/or 5% glucose only if an intravenous line can be established within a few minutes; trauma treatment 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 [35].

With a burial time exceeding 35 min, open airways and the existence of an air pocket are decisive factors governing survival, as well as the therapeutic strategy and triage decisions. Hence, great care must be taken by rescuers during extrication of the person to avoid destruction of an air pocket. Subsequently, close inspection should establish the presence or absence of an air pocket. Despite the inherent pressures, gentleness should take precedence over speed in the rescue procedure [32]. Treatment of accidental hypothermia [33] is the most urgent medical emergency measure in victims with an air pocket.

3.3. On-site staging of hypothermia

Hypothermia is generally graded according to Danzl's classification of severity [34], 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 [35] 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. This grading distinguishes between alert, shivering patients (stage I: equivalent to a core temperature of about 35–32°C (95–89.6°F)), drowsy, non-shivering patients (stage II: core temperature about 32–28°C (89.6–82.4°F)), unconscious patients (stage III: core temperature about 28–24°C (82.4–75.2°F)) and patients not breathing spontaneously (stage IV: core temperature <24°C (<75.2°F)). However, since there may be great individual variation in the observed clinical features [34], it is imperative that the core temperature is accurately measured as soon as possible by a medical attendant.

3.4. 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. If the skin of the victim is extremely cold or wet it may be difficult to obtain an ECG by adhesive electrodes and then the use of needle electrodes is recommended. 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 [36] 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 [37]. Epitympanic measurement may be useful in patients showing spontaneous breathing, but is ruled out categorically as a basis for pronouncing death on site.

3.5. Insulation

The aim of field management is not immediate active re-warming of the extricated avalanche victim, 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 re-warming can be achieved by the use of blankets, aluminium foils and bivouac bags. For active external re-warming 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. Children have a higher risk of fast cooling and need special protection against further temperature loss.

3.6. Infusion of warmed fluids and administration of ACLS – protocol drugs

Many 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 [17,34,38,39], although no therapeutic benefit has yet been proven. Establishing an intravenous line in hypothermia can be very difficult and time consuming due to peripheral venous shutdown. 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 resuscitation drugs, including epinephrine and vasopressin, is still controversial in hypothermia [40]. Their use is not recommended in severely hypothermic victims (Swiss stages III–IV), since cardioactive drugs may well not be effective and can accumulate to toxic levels. If the hypothermic patient is responsive (Swiss stages I–II), resuscitation drugs may be administered, but with longer intervals between doses than in normothermic patients.

3.7. Inhalation of warmed oxygen

Administration of humidified, warmed oxygen (42–46°C (108–115°F)) by means of a mask or tracheal tube to prevent temperature after drop is the only practicable field procedure recommended for active internal re-warming of the rescued victim. It is, moreover, a therapeutic measure to combat asphyxia. This technique is appropriate for field implementation since it is non-invasive and, indeed, simple in application [17,34,41].

4. 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 [8].

During extrication of the victim from the snow masses, unnecessary movement of the trunk and large joints (shoulder, hip and knee) must be avoided, to prevent the development of cardiac arrhythmias triggered by the flow of cold, peripheral blood to the irritable myocardium. Moreover, the patient should be transported in the horizontal position to minimise the risk of orthostatic hypotension [42].

4.1. Assessment of responsiveness, breathing and pulse

Rescuers should determine whether the person is responsive at the earliest possible moment during the extrication procedure (Fig. 3). 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 relevant 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 airway and assess breathing and pulse for 30–45 s to confirm respiratory arrest or pulseless cardiac arrest. With signs of respiratory insufficiency or arrest, resuscitation should be initiated during the extrication procedure.

4.2. Tracheal intubation

The unconscious patient, with or without vital functions, should be 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 [19]. Ventilation with 100% oxygen via bag-mask is recommended before any intubation attempt and an intravenous line may need to be established before intubation of Swiss stage III patients. Unconscious patients should be transported to a hospital with the expertise in the treatment of severe hypothermia and, specifically, to a unit with cardiopulmonary bypass core re-warming facilities when circulatory instability is evident.

4.3. Victims with cardiac arrest

Organised rescue teams are confronted with the fact that 85% of avalanche victims extricated by them are in cardiac arrest [9], since they only seldom reach the site of snow descent before 35 min, i.e. the inflection point of survival function (Fig. 2). Cardiac arrest is due to irreversible obstructive asphyxia in most cases, but may result from severe hypothermia in victims with an air pocket and a patent airway.

The formulation of an algorithm for on-site triage of avalanche victims with asystole [8] laid the foundation for decision-making in the field 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. Hence, the extracorporeal re-warmings at the University Hospital in Innsbruck (Austria) have decreased since the introduction of the triage procedure in 1993, from 5 to 6 cases annually to about one [43]. Hence, risks to rescue teams and costs have been minimised.

Two changes were endorsed after review of the algorithm in 1999 by the International Commission for Mountain Emergency Medicine: (1) The time criterion originally proposed for triage, of 45 min since burial [8], was shortened to 35 min because survival beyond this limit without an air pocket can be ruled out with certainty and (2) the alternative criterion of serum potassium level determination in hospital was revised, and the critical triage level increased from 10 mmol/l [28,29,44] to 12 mmol/l, to match Larach's recommendation for victims of accidental hypothermia [33].

The protocol in Fig. 3 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, with Basic Life Support [45] and/or Advanced Cardiac Life Support [46], 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 whether further procedures should be applied.

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) [33,47,48] must be continued with standard 2000 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. Should several asystolic avalanche victims with potentially reversible hypothermia be extricated simultaneously, then priority for transportation should be given to patients with a higher core temperature, since their prognosis is generally better. 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 [33]. 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 and 360 J) [49] should be made in victims with ventricular fibrillation, in accordance with standard practice. 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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