International Commission
for Mountain Emergency Medicine
ICAR MEDCOM

ICAR MEDCOM 2013 MINUTES, BOL,CROATIA

Thursday, October 17, 2013

Welcome
President Fidel Elsensohn welcomed the members of the Commission.

Attending: see appendix

Apologies: Nicole Gantner-Vogt, Kazue Oshiro, Herbert Forster, Günther Sumann, Theohearis Sinifakoulis, Peter Mair, Rick de Decker, Arthur Morgan, Tore Dahlberg,

Introductions. Introductions of new and old members

Minutes of the last meeting.
The minutes from the Spring meeting were approved without changes.

Internet platform
Fidel mentioned the internet platform and encouraged all members to register.
http://www.stage4.us/icar/

Financial Report and Bank Account
Our balance is € 8531,96. No change since last meeting

President's report

Fidel and Hermann were in Taiwan in November 2012 at the World Congress Mountain Medicine representing ICAR MEDCOM and promoting the World Congress of Mountain Medicine that will take place in Bolzano in May 2014.

Jose Ramon Morandeira passed away suddenly this year. He introduced mountain medicine in Spain. He was a professor at Zaragoza. He was an expert in treating frostbite. He sponsored many research expeditions. We had a moment of silence for our friend who is no longer with us.

Founding of the Bulgarian Mountain Medicine Society in Sofia.Lectures from Hermann, Peter and Fidel

Spring meeting in Bad Tölz. (see minutes)

Meetings of the Executive Board. The new proposes for proposed to the Bylaws will be presented at the Assembly of Delegates.

Next year's meeting is in South Lake Tahoe 6-10 October 2014.
The 2015 meeting will be in Ireland.

Elections of officers. All officers were elected for another term:
Fidel Elsensohn - President
John Ellerton – Vice President and President-Elect
Ken Zafren – Vice President

Report of Nepalese Mountain Rescue Project
Fidel gave a report of the Mountain Rescue training in Kathmandu in May 2013.

New papers published, submitted or in press
No papers submitted at this time.

Diploma in Mountain Medicine
John Ellerton discussed the new regulations of the ICAR MEDCOM, UIAA MEDCOM, ISMM. This will be a topic at the ISMM meeting in Bolzano in May 2015.
There are currently about 25 courses worldwide. The process of evaluating courses will need to be changed to accommodate this large number. The syllabus will need to be updated.
There was a discussion about methods to ensure that others can verify whether someone holds a diploma.
There was a discussion about assessment of courses.
Currently, certification is for life. There was a discussion about whether individuals should be required to renew their diplomas.
The final topic regarded charging the courses in order to support the administrative committee.

Papers in preparation

Modular First Aid Kit for Alpinists, Mountain Guides and Alpinist Physicians (title has been modified) Reisten O, Soteras I, Wiget
The paper will be revised and the revised version will be presented at the Spring meeting.

Analgesia in the mountains and remote areas. Ellerton J, Paal P, et al.

Evidence-based recommendations for canyoning rescue. Soteras I, Strapazzon G.

Avalanche triage form. Blancher M, Kotkman A

Alpine trauma registry. Strapazzon G.

German data collection Müller N

Thursday, October 17, 2013

Short communications

Ladislav Kotrusz: Medical Training in Slovak Mountain Rescue
The level of medical education is excellent, but the organization plans to improve the training for medical care in mountain rescue.

Giancelso Agazzi: Avalanche rescue 1909
The Laghi Gemelli (Twin Lakes) Pass avalanche of December 7, 1909 buried a group of 7 mountaineers, killing one victim. The depth of the snow that slid was 2 meters. A compact layer above slid on a poorly compacted deep layer. The group sat out a blizzard for 2 days at the hut before attempting to cross the pass. Six of the eight were on foot while 2 were on skis. One turned around due to cold feet. They were accompanied by a mountain guide at the hut. The guide refused to lead the group over the pass because of dangerous snow conditions.

The rescuers were notified by telegram the next day. The rescuers, including 2 doctors were hampered by a storm. Some of the rescuers suffered frostbite. It took two days to evacuate two of the injured victims. One victim reported complete burial with an air pocket. The body of the dead victim was found on December 26.

Volker Lischke: Medical simulation training in helicopter-assisted mountain rescue operations.
Various personnel must work together, randomly assorted. In order to improve performance, a training center was established. The goal was to promote skill level behavior which is much faster than rule-level behavior. The training facility, in Bad Tölz, Germany, includes a maneuverable helicopter simulator and a cable car on cables. Volker described the results of the initial training involving rescuers, including doctors, from all over Germany.

Alex Kottman: Avalanche Victim Resuscitation Checklist (flowchart)

Further discussion. The modified checklist was accepted.

Manuel Genswein: Survival chance optimized procedures in rescue and how to minimize injuries during evacuation.
Manuel presented an algorithm designed to conserve resources by concentrating efforts on avalanche victims with higher chance of survival. Many patients have little hope of survival. Once rescuers have identified a patient with little chance of survival, if resources are limited, only a short course of CPR is provided. If unsuccessful, rescuers then shift efforts to victims with higher survival chances, including victims who are still buried. A second flowchart prioritizes evacuation of multiple victims depending on the expected survival benefit of transport to medical care. A third flowchart, “Priorities and elementary procedures in basic level companion rescue,” presents a flowchart for companion rescue, including the need to call or go for help, prioritizing rescue attempts and resuscitation of multiple victims.

Jeff Boyd: Avalanche triage
Jeff presented a case of 17 school children buried of whom 7 were rescued by 2 mountain guides who happened to be on a slope above the valley where the avalanche ran. One of the rescued victims dug out and saved 3 other victims. Two deeply buried victims were found by organized rescuers with obstructed airways. The esophageal temperatures of the these two dead victims were both above 32°C. This led to the development of Canadian AvSAR – Rescue triage.

In a multiple casualty incident (MCI) resources are overwhelmed. Priority – modified – survival probabilities – “greatest good for the greatest number.” Modified – rather than “reverse” – triage. Jeff presented the algorithm from the paper by Bogle et al. in Wilderness and Environmental Medicine: the AvSORT algorithm. Patients with severe injuries who are not breathing would be managed expectantly.

A working group are planning to extend the avalanche check list to a triage algorithm. Hermann Brugger proposed a joint effort among several groups to develop a triage algorithm. Manuel Genswein proposed applying simulation techniques. Hermann pointed out that simulations are not a high level of evidence. There is limited data. The Swiss database may be useful. We may be able to produce a joint paper with the avalanche commission.

Joint preconference in Lake Tahoe
Fidel announced a joint conference of the Medical Commission and the Avalanche Commission to discuss mass casualty incidents. The main theme of the conference in Lake Tahoe is mass casualty incidents.

Mountain Rescue Book – Iztok Tomazin

Iztok presented his book, which will be a compendium of stories of mountain rescue doctors. It will be published in English and German and will include photos. Members of the commission are encouraged to submit chapters to Iztok.

FORTHCOMING EVENTS

2014 ICAR MedCom Spring meeting in Bozen/Bolzano, Italy in conjunction with the X. ISMM World Congress of Mountain Medicine. Our session will be on Thursday, May 29 to finish papers and to plan the preconference for Lake Tahoe. The next few days will include the mountain rescue sessions.

2014 October 5-10 ICAR General Assembly. Lake Tahoe, Nevada, USA

2015 May: dates to be determined Spring meeting Ticino, Switzerland (Oliver Reisten and Gregoire Zen-Ruffinen)

2015 ICAR General Assembly Ireland

2016 ICAR MedCom Spring meeting. Cape Town, South Africa.

CLOSING
Fidel closed the meeting.

MINUTES TAKEN BEI KEN ZAFREN

Michael Swangard Canada; Igor Zulian Croatia; Volker Lischke, Germany; Joe O'Gorman Ireland; Marko Petrovic Serbia; Kotrusz Ladislav Slovaki; Kyfouidou Sofia Greece; Krassen Demizev Bulgaria; Erik Sandstrom Sweden; Marie Nordgren Sweden; Perolof Edvinsson Sweden; Moskal Wozciech Poland; Ashish Lohani Nepal; Marija Mijuskovic Montenegro; Borislav Aleraj Croatia; Richard Price New Zealand; Alex Kottmann Switzerland; Marc Blancher France; Oliver Reisten Switzerland; Inigo Soteras Spain; Peter Miskovic Croatia; Jaroslav Edlman Czech Republic; David Hillebrandt UIAA Medcom; Mario Milani Italy; Greg Zen Ruffinen Switzerland; Fidel Elsensohn (President) Austria; Ken Zafren (Vice President) USA; John Ellerton (Vice President) England and Wales; Peter Paal Austria; Jeff Boyd Canada; Dave Watson Canada; Bruce Brink Canada; Johannes Schiffer Germany; Natalie Muller Germany; Iztok Tomazin Slovenia; Øyvind Thomassen Norway; Hermann Brugger Italy; Sven Christjar Skiaa Norway; Mario Milani Italy; Lana Donlagic Croatia;

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CONCEPTS

Triaging Multiple Victims in an Avalanche Setting: The Avalanche Survival Optimizing Rescue Triage Algorithmic Approach

Lee B. Bogle, MD; Jeff J. Boyd, MBBS, UIAGM; Kyle A. McLaughlin, CCFP (EM)

From the University of Calgary, Calgary, AB, Canada (L.B. Bogle); Mineral Springs Hospital, Banff, AB, Canada (J.J. Boyd); and the Department of Emergency Medicine, University of Calgary, Calgary, AB, Canada (K.A. McLaughlin)

As winter backcountry activity increases, so does exposure to avalanche danger. A complicated situation arises when multiple victims are caught in an avalanche and where medical and other rescue demands overwhelm resources in the field. These mass casualty incidents carry a high risk of morbidity and mortality, and there is no recommended approach to patient care specific to this setting other than basic first aid principles. The literature is limited with regard to triaging systems applicable to avalanche incidents. In conjunction with the development of an electronic avalanche rescue training module by the Canadian Avalanche Association, we have designed the Avalanche Survival Optimizing Rescue Triage algorithm to address the triaging of multiple avalanche victims to optimize survival and disposition decisions.

Key words: mass casualty incident, triage, avalanche, mountain rescue, AvSORT

Introduction

Avalanche fatalities have been increasing over time in North America, with a 10-season average of 41 deaths/year between 1998–1999 and 2007–2008.[1] This correlates with the increase in backcountry skiing, snowboarding, and snowmobiling.[2,3] Injuries are diverse and may range from asphyxia to traumatic injuries (eg, spinal fractures) and to exposure injuries (eg, hypothermia).[4] Currently, it is common for extricated avalanche victims to be treated according to standard first aid principles, such as evaluating and treating the ABCs (airway, breathing, and circulation). Additionally, an avalanche resuscitation algorithm has been developed.[5] Whereas these can help guide the management of individual patients, they are not designed as triage tools for multiple victims.

Mass casualty incident is a term that may be used in circumstances when multiple victims place an excessive demand on finite resources.[6] Mass casualties in an avalanche incident not uncommonly overwhelm first responders due to limited manpower in remote settings and the time necessary to locate, dig out, and extricate buried victims.[7–10] In such incidents, triage needs to rapidly identify those that will benefit from limited resources and may only allow simple lifesaving interventions, such as opening an airway or stopping major bleeding.[9,11] Traditional cardiopulmonary resuscitation may not be an optimal use of resources,[12] notably while other potential survivors remain buried.

The hospital disposition of extricated victims should be determined, wherever possible, with those minimally injured being sent to the nearest health care facility and those more severely injured ideally being transported to designated trauma centers.[13,14]

Avalanche rescues entail unique factors that necessitate a distinct triage system. Our goal was to develop a triage tool to guide first-response avalanche rescuers in the management of avalanche incidents when initial resources are overwhelmed by mass casualties. By following a simple algorithmic approach to victim assessment, victims may receive simple lifesaving measures and be stratified for evacuation to the most appropriate facility.

Concept development

The existing mass casualty triage systems Simple Triage and Rapid Treatment (START), Care-Flight, and

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Triage Sieve were evaluated for applicability to avalanche rescue.[8,15–17] A literature search was performed using PubMed, EMBASE, and Google Scholar using the search term "avalanche." Broad Internet searches using Google and hand-searching augmented the literature search. This project was undertaken in conjunction with the development of an electronic avalanche rescue training module by the Canadian Avalanche Association.[10,18]

Triage literally means "to sort."[19] A mass casualty incident is typified by rescuers and resources being overwhelmed, and the general principle of a mass casualty triage system is to prioritize victims to promote the greatest survival benefit for the greatest number.[6] The prompt identification of severely injured persons that may benefit from simple interventions, given the limited resources, is particularly essential. Several triage systems exist for mass casualty incidents. START, Care-Flight, and Triage Sieve use an algorithmic approach to stratify patients based on readily observed characteristics such as the ability to walk, respiration status, the ability of a victim to obey a command, and capillary refill. Based on these factors, patients are assigned to immediate, urgent, delayed, or unsalvageable categories. When the individual criteria of these triage systems were analyzed in a retrospective study, it was found that a reduction in the motor component of the Glasgow Coma Score (GCS) below 6 or a systolic blood pressure less than 80 mm Hg were the most sensitive predictors of severe injury.[11] An inability to obey a simple command reflects a motor component of the GCS score of less than 6.[20] The absence of a radial pulse is considered indicative of a systolic blood pressure of less than 80 mm Hg[20] and has been proposed as an alternative for slowed capillary refill in mass casualty incidents.[17] Whereas these triage systems are useful in the general prehospital setting, they are not designed for the specific and austere environment of avalanche rescue.

Overtriage for hospital disposition is the situation where patients with relatively minor injuries are assigned to higher-level trauma centers incorrectly, and a rate of up to 50% is acceptable in a mass casualty setting to prevent missing any serious injuries.[13] Undertriage is the situation where those who are seriously injured are not appropriately triaged to the severity of their injuries and are thus sent to the nearest hospital instead of a trauma center. Undertriage rates of up to 5% are acceptable.[13]

An avalanche resuscitation algorithm, derived from original research and adopted by consensus among expert rescue physicians of the Medical Commission of the International Commission for Alpine Rescue (ICAR MedCom), has been developed[5,21] (Figure 1). However, it is designed for organized rescue teams, which, in Europe, usually include specialist physicians with advanced life support (ALS) equipment and that respond rapidly due to the widespread cellular phone coverage and short helicopter flight times.[22] This rapid and skilled response, although ideal, rarely applies to first responders in North America who may have very limited equipment, may lack ALS training, and may be overwhelmed by mass casualties. The ICAR MedCom algorithm focuses on the management of individual victims and is not a triage tool.

In developing our proposed mass casualty algorithm, several factors were taken into account. The algorithm would need to promptly identify survivable and nonsurvivable injuries under the resource-strained circumstances, then divide the potential survivors into those requiring immediate, urgent, or delayed treatment when resources allow.

The avalanche literature describes asphyxia as the cause of death in the majority of fatalities as well as a spectrum of lethal and nonlethal mechanical trauma that may range in incidence from 5% to 32%[4,23–25] (Table). Asphyxia is due to avalanche debris obstructing the airway, from mechanical chest compression, and rebreathing expired air resulting in hypercapnia and hypoxia.[26,27] The presence of an "air pocket, defined as any space surrounding the mouth and the nose, no matter how small, with a patent airway," is necessary for prolonged survival from burial.[5,28] Rescue diggers should always search for this air pocket. In victims buried for longer than 35 minutes, the absence of an air pocket foretells death.[29]

The AvSORT algorithm

Taking into account the above factors, we propose the following Avalanche Survival Optimizing Rescue Triage (AvSORT) algorithm for mass casualties when resources are overwhelmed (Figure 2). We have retained general management concepts from existent mass casualty triage systems but have incorporated key elements specific to avalanche rescue. The inclusion of a step to determine "obvious fatal trauma" is deemed necessary due to the mechanical injury that can occur during an avalanche. Though it relies on the judgment of the first responder as to what is obviously fatal, it could allow rescuers to reallocate precious time to victims who could be saved. After 35 minutes of burial, the presence of an air pocket is a critical determinant of survival, and its absence would designate a victim as expectant. When burial time is less than 35 minutes or the time is unknown and the airway is obstructed by impacted material such as snow or by

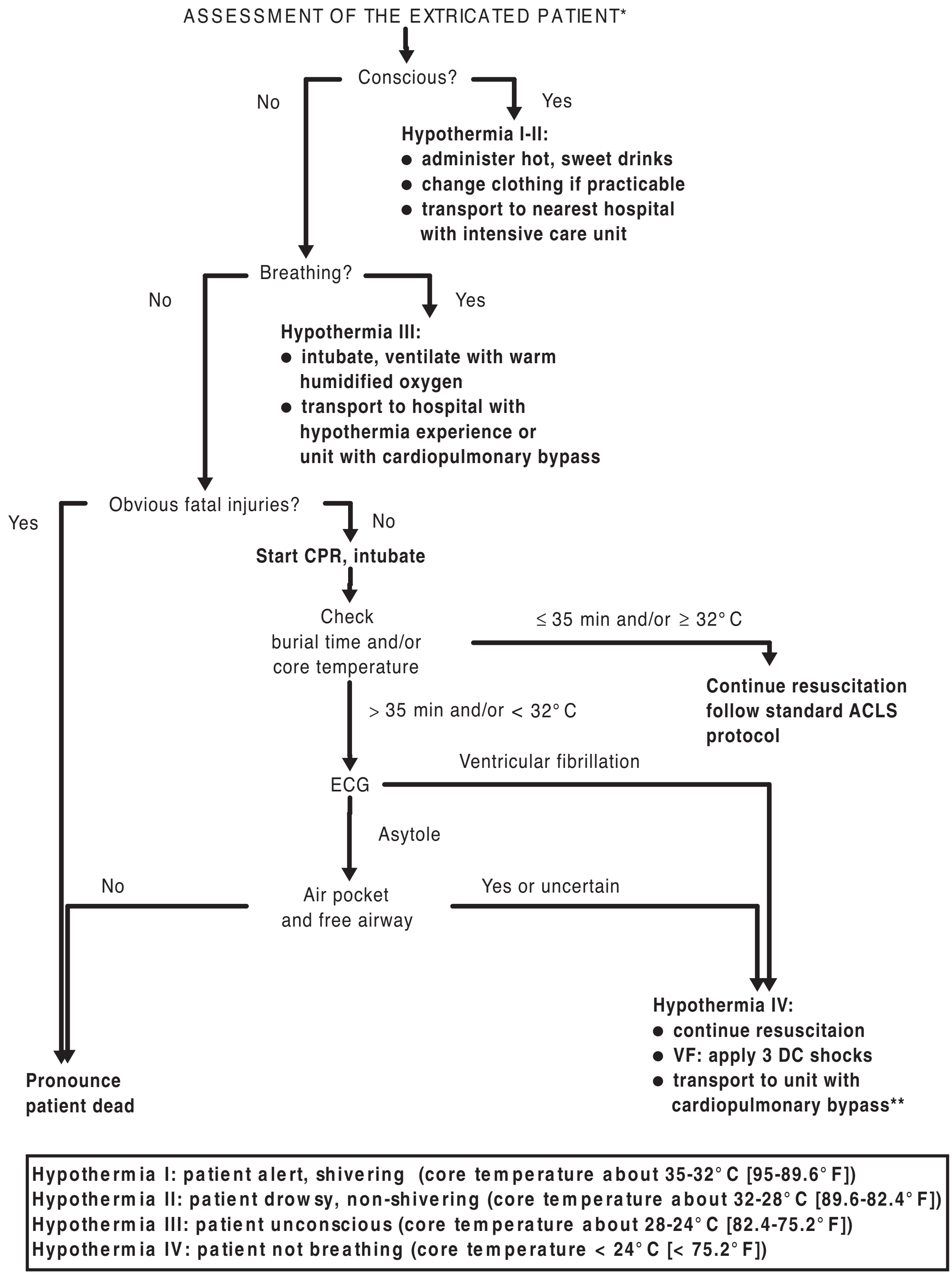

Figure 1. Algorithm for on-site management of avalanche victims. Staging of hypothermia according to Swiss Society of Mountain Medicine guidelines. *Transport to nearest hospital for serum potassium measurement if hospitalization in a specialist unit with cardiopulmonary bypass facilities is not logistically possible. Source: Reprinted from Ref. 18 with permission.

occluding posture, then the airway should be cleared, repositioned, and opened before the breathing is reassessed.

The ability to obey simple commands, the presence of a radial pulse, and heart rate are also incorporated as triage factors, as in other mass casualty triage algo-

Table. Pattern and severity of injury in 105 avalanche victims[a]

Type of injury	*Occurrence (n)*[b]
Asphyxia - fatal	33
Cervical spine fracture with dislocation - fatal	2
Hypothermia - fatal	1
Extremity trauma	20
Chest trauma	18
Spine fracture	7
Cerebral trauma	2
Abdominal trauma	1
Pelvic fracture	1
Minor or no injury	21

[a] Source: Reprinted with permission.[4]
[b] The occurrence of these injuries distributed among the 105 victims in this study.

rithms.[12,15,16] Capillary refill will be unreliable with cold exposure, and was avoided.[30] If there is doubt at any decision step, such as total burial time or obvious fatal injury, the decision must be made in a conservative manner to proceed with additional evaluation of the victim. The AvSORT algorithm is designed to assign many patients to the "immediate" hospital disposition category in order to overtriage victims by the appropriate 50%.[13] Patients in the immediate category should receive priority first aid and transport out of the field and should demand more initial attention than those in the urgent category, who subsequently receive priority for treatment and transport over delayed category patients. Patients in the expectant category should only be reassessed after all other victims are attended. When manpower is increased, then further treatment of expectant victims may be considered. Formal pronouncement of death and notification of legal authorities should be performed according to procedures established in the particular jurisdiction.

Very importantly, the proposed triage algorithm does not depend on medical equipment and is designed to be simple to use in a stressful situation. It might be printed as a quick reference card to be placed in first responders rescue kits.

The 2008–2009 season was marred by an above-average avalanche fatality rate in North America with 54 deaths.[1] Twenty-three of the 40 fatal incidents involved multiple individuals being caught, injured, and/or buried. The number of individuals caught in these fatal avalanches ranged from 1 to 11 individuals. Research has shown that in 26% of avalanche incidents where complete burials occurred, there were 4 or more complete burials in the party.[7]

The best chance for survival is for companion rescue, either by members of the same party or nearby parties, as the initial survival rate of 92% at 15 minutes of burial time plummets to only 30% at 35 minutes.[29] Recovery times include location of the victim, best with an avalanche transceiver, in addition to shoveling heavy consolidated avalanche debris down to the victim and subsequent extrication from the burial hole. Deeper burials are associated with longer and more difficult extraction. Victims buried deeper than 200 cm have a probability of survival of only 10% compared with 80% for those buried less than 50 cm.[24]

The inevitable delay for organized rescue, provided by a trained rescue team that is off-site, is believed responsible for the limited increase in survival despite improvements in rescue and medical care.[29]

The AvSORT algorithm is designed to improve avalanche victims' outcomes in a mass casualty incident by offering only the simple lifesaving interventions of opening airways and stopping external bleeding to already severely hypoxic or injured victims but allowing first responders to recover other victims who may have better chances of survival. Rescuers will also have started to triage for evacuation to appropriate facilities when transport becomes available. Using simple criteria will reduce confusion and allow direction in the potentially chaotic circumstance of a large avalanche rescue, especially with respect to the final destination of seriously injured victims. The importance of appropriate evacuation decisions is demonstrated by the finding that direct transport of more severely injured patients to an accredited trauma center has been shown to reduce morbidity and mortality.[14,31] In some circumstances, due to transportation limitations, individuals may be transported to the nearest health care facility for stabilization and initial treatment until further transport can be arranged.

Mass casualty avalanche incidents not uncommonly overwhelm first responders that are limited to a few individuals and that have to manage a large number of victims forcing rescuers to focus on victim recovery efforts with limited initial resuscitation opportunities.[7,8,27] As there may be no way of knowing the injury status of buried individuals, rescuers must assume that some may be buried with minor injuries but are in danger of death from asphyxiation and need prompt extraction. Thus, it would be for the greater benefit of the whole to extract potential survivors that risk asphyxia while buried rather than engage in protracted resuscitation on probable nonsurvivors. This assumption is based on the critical element of time of burial reflected in the well-established survival curve.[29] Rescuers may be forced to make tactical triage decisions, incorporating such factors as relative burial depths, measured by transceiver signal strengths as well as probing, that may override initial extensive resuscitative measures. Additionally, rescuers need to ensure their own safety, and the risk of being buried in subsequent avalanches may preclude comprehensive resuscitation.[32,33]

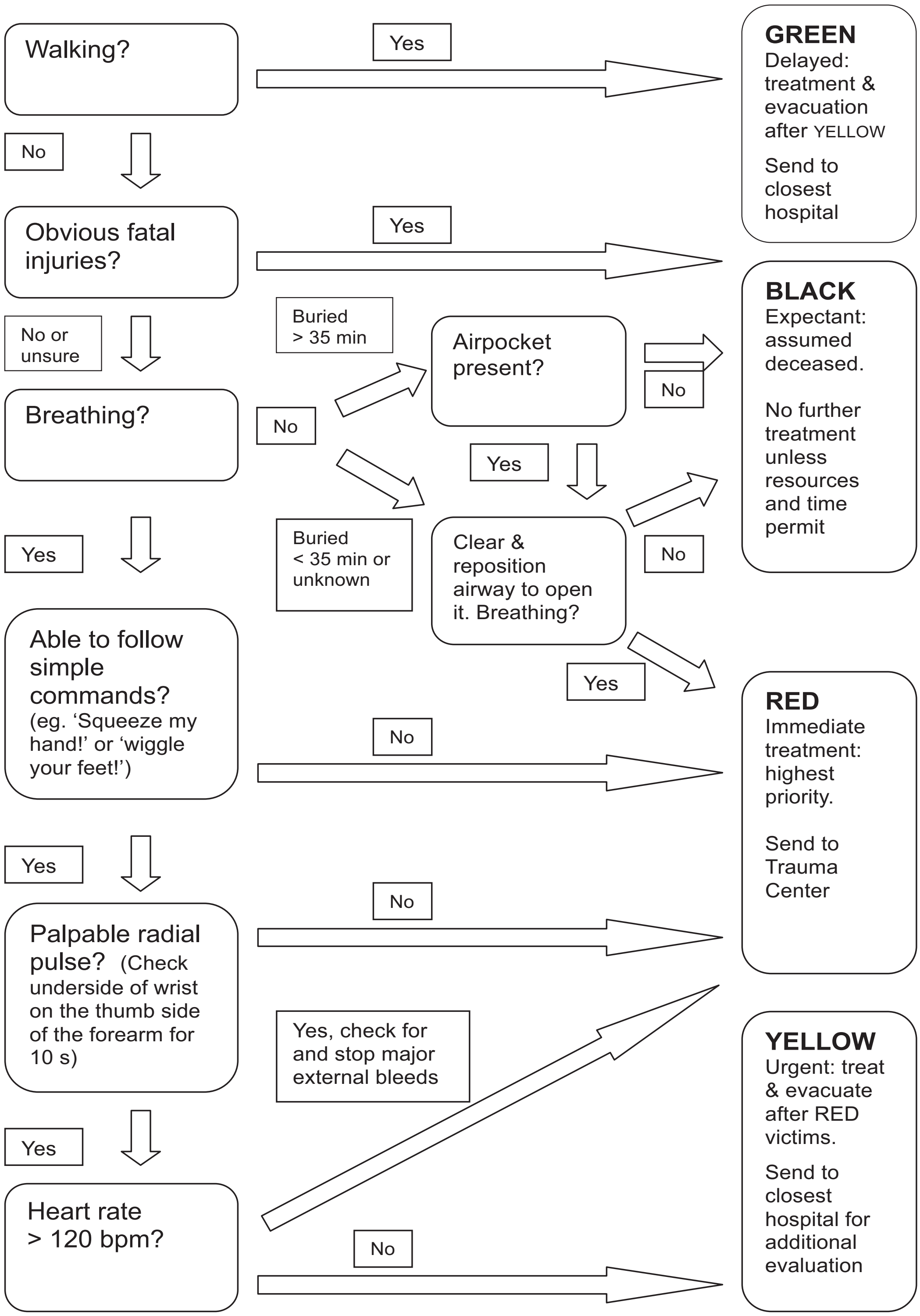

Figure 2. The Avalanche Survival Optimizing Rescue Triage (AvSORT) algorithm for the management of multiple burials in an avalanche to be used as an initial triage tool when needs exceed resources. Further treatment within the scope of rescuer ability with standard first aid principles may be warranted upon extraction and evaluation of all victims.

Limitations

While our algorithm is designed for the initial management of mass casualty avalanche incidents when manpower is overwhelmed, it is not designed for situations where resources allow for standard resuscitation and treatment of all extracted individuals, such as in the ICAR MedCom ALS algorithm. Each avalanche incident is unique in the mix of numbers of buried, types of injuries, and abilities of first responders as well as dynamic changes in any layered response, therefore no one static system will handle all evolving situations appropriately. We propose the AvSORT algorithm to help guide rescuers to triage victims efficiently thereby optimizing survival. We anticipate the AvSORT algorithm will be used in conjunction with appropriate avalanche training, equipment, and common sense to adequately manage avalanche risk and safely execute a rescue.

Our proposed AvSORT algorithm is based on established concepts in avalanche and mass casualty triage medicine but has not been subjected to formal case-based study for this specific incident type. Further prospective research into the performance of this algorithm is needed to validate its efficacy in the field.

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Brief Report

LUCAS compared to manual cardiopulmonary resuscitation is more effective during helicopter rescue—a prospective, randomized, cross-over manikin study☆

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Abstract

Objective: High-quality chest-compressions are of paramount importance for survival and good neurological outcome after cardiac arrest. However, even healthcare professionals have difficulty performing effective chest-compressions, and quality may be further reduced during transport. We compared a mechanical chest-compression device (Lund University Cardiac Assist System [LUCAS]; Jolife, Lund, Sweden) and manual chest-compressions in a simulated cardiopulmonary resuscitation scenario during helicopter rescue.

Methods: Twenty-five advanced life support–certified paramedics were enrolled for this prospective, randomized, crossover study. A modified Resusci Anne manikin was employed. Thirty minutes of training was allotted to both LUCAS and manual cardiopulmonary resuscitation (CPR). Thereafter, every candidate performed the same scenario twice, once with LUCAS and once with manual CPR. The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions.

Results: LUCAS compared to manual chest-compressions were more frequently correct (99% vs 59%, $P < .001$) and were more often performed correctly regarding depth (99% vs 79%, $P < .001$), pressure point (100% vs 79%, $P < .001$) and pressure release (100% vs 97%, $P = .001$). Hands-off time was shorter in the LUCAS than in the manual group (46 vs 130 seconds, $P < .001$). Time until first defibrillation was longer in the LUCAS group (112 vs 49 seconds, $P < .001$).

Conclusions: During this simulated cardiac arrest scenario in helicopter rescue LUCAS compared to manual chest-compressions increased CPR quality and reduced hands-off time, but prolonged the time interval to the first defibrillation. Further clinical trials are warranted to confirm potential benefits of LUCAS CPR in helicopter rescue.

☆ Conflict of interest statement: None of the authors has a conflict of interest.

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1. Introduction

1.1. Background

After cardiac arrest, high-quality chest-compressions are of paramount importance for survival and good neurological outcome. Unfortunately, even healthcare professionals have difficulty performing effective cardiopulmonary resuscitation (CPR). Chest-compressions often are too shallow; hands-off time is too long [1], and CPR performance deteriorates over time [2]. During helicopter transport, chest-compression effectiveness may be further reduced due to movements of the vehicle, confined space and prevailing safety regulations [3]. Such limiting factors could be the cause of low survival rates reported in helicopter transported cardiac arrest patients [4].

1.2. Importance

Mechanical chest-compression devices deliver uninterrupted chest-compressions of a predefined depth and rate. Thus, chest-compression devices may play an important role in maintaining good quality CPR in specific circumstances where CPR is difficult to perform, for example, helicopter transport, or when CPR has to be performed over a long period, for example, during hypothermic cardiac arrest [5,6]. However, data supporting this assumption are limited [7]. We hypothesized that the Lund University Cardiac Assist System (LUCAS; Jolife, Lund, Sweden) could improve chest-compression quality during helicopter transport compared to manual CPR. LUCAS is an electrically powered piston device providing 4 to 5 cm deep chest-compressions and active decompressions back to the neutral position with a frequency of 100 min^{-1} and a duty cycle of 50%.

1.3. Goal of this investigation

The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions with LUCAS compared to manual CPR [8,9]. Secondary outcome measures were compression depth, pressure point, complete pressure release, and compression rate as well as hands-off time and time until first defibrillation.

2. Methods

2.1. Study design and setting

The ethics committee of the Ludwig Maximilian University Munich, Germany, waived the requirement for a committee approval of this manikin study and authorized commencement of the study. This prospective, randomized, cross-over, manikin study was conducted at the simulation centre of the Bavarian Mountain Rescue Service in Bad Toelz, Germany, in February 2011 (www.bergwacht-bayern.de).

2.2. Participants

Twenty-five healthy advanced life support (ALS)–certified paramedics with no previous experience using LUCAS were enrolled (Supplemental Figure 1). All candidates signed informed consent and participated voluntarily. Before starting the test, the candidates were instructed by ALS-certified instructors on LUCAS and conventional manual CPR according to the American Heart Association (AHA) 2010 guidelines [10] for 30 minutes, respectively. Each candidate performed the identical scenario in a randomized order (www.randomizer.org), once with LUCAS and once with manual chest-compressions.

2.3. Intervention

Immediately after the training, a standardized simulated cardiac arrest scenario was presented to the candidates: "You are part of a helicopter crew called to a hypothermic cardiac arrest patient. Neither pulse nor breathing is detectable and bystander CPR is being performed. Core body temperature is 28°C (82.4°F). Please take care of this patient."

A modified Resusci Anne manikin (Laerdal, Stavanger, Norway) was employed. For better CPR error, analysis the scenario was divided into three parts: *before, during, and after helicopter flight*. The *before flight* part started with a short emergency assessment performed by an emergency physician (BP). In the manual group the candidates performed manual chest-compressions in rotation with the physician every 2 minutes. In the LUCAS group candidates performed manual chest-compressions until LUCAS placement. At this point mechanical chest-compressions commenced until termination of the test. Candidates were not corrected during placement or conduction of LUCAS or manual chest-compressions. After applying the defibrillation pads on the manikin the electrocardiogram showed ventricular fibrillation. Three defibrillations at intervals of 2 minutes were given without reversing ventricular fibrillation. The manikin was intubated, ventilated with a bag-valve device (Ambu, Bad Nauheim, Germany), and after the third defibrillation, fastened on a stretcher and transported to the helicopter to conclude the *before flight* part (~6 minutes).

The *during flight* part consisted of a simulated eight minute flight (average transport time of medical helicopters in the Eastern European Alps). The manikin was loaded into the helicopter (BK117dummy, MBB, Ottobrunn, Germany) and connected to an Oxylog ventilator (Dräger, Lübeck, Germany). In the manual group, the candidates continued chest-compressions while kneeling beside the manikin`s chest and the physician was positioned behind the head. After landing, the manikin was loaded on a trolley.

In the *after flight* part, CPR continued on the manikin, which was placed on a trolley for the simulated two minute transport to the trauma department. Manual chest-compressions were delivered in a straddling position [11].

2.4. Outcome measures

The primary outcome measure was the percentage of correct chest-compressions relative to total chest-compressions. The percentage, and not the absolute number, of correct chest-compressions was used to rule out the influence of too high or low compression rates. Secondary outcome measures were depth, pressure point, complete pressure release and rate of chest-compressions, hands-off time, and time to first defibrillation.

The LUCAS default setting for chest-compressions depth was 38 to 51 mm in alignment with the 2005 AHA guidelines [12]. Because the candidates were already trained according to 2010 guidelines, we considered all compressions with a depth of 40 to 60 mm as correct to combine the LUCAS default setting with the 2010 AHA guidelines [10]. The pressure point was counted as correct when performed in the lower half of the sternum and pressure release was correct when complete release between chest-compressions was recorded by the Laerdal Skill Reporting System (Laerdal, Stavanger, Norway). Correct pressure rate was defined as 100 to 120 chest-compressions per minute. Data were analyzed with Microsoft Excel (Microsoft, Redmond, WA) and SPSS (Version 18; IBM, Armonk, NY).

2.5. Statistical analysis

In a pilot LUCAS vs manual CPR study, the mean of correct chest-compressions was 80% vs 60% and SD was 15%. Based on these data and considering $\alpha = .01$ and $\beta = 90\%$, 15 participants were necessary to allow for significant results. To allow for possible dropouts 25 participants were included in this study. The outcome measure values are presented as mean ± SD and 95% confidence interval (95% CI). The Kolmogorov-Smirnov test was used to test for normality. Student *t* test was used for paired samples with normal distribution, and Wilcoxon test for samples with non-normal distribution. All reported *P* values were 2 sided, and a type I error level of 5% was considered. The statistical power varies between 90% and 99% depending on the group comparisons.

3. Results

Two candidates were excluded from the analysis because of incomplete data recording during the scenario due to wire dislocation between the manikin and the data-recording laptop. The remaining 23 candidates (6 female) had a mean age of 29 ± 11 years, mean height of 178 ± 10 cm, and mean weight of 75 ± 14 kg.

3.1. Primary outcome

LUCAS compared to manual chest-compressions were more frequently correct, both *before* (97% vs 61%, $P < .001$), *during* (100% vs 41%, $P < .001$) and *after flight* (100% vs 76%, $P < .001$), as well as in the overall scenario (99 vs 59%, $P < .001$; Table 1 and Fig. 1A).

3.2. Secondary outcome

LUCAS compared to manual chest-compressions were more often performed correctly regarding depth (99% vs 79%, $P < .001$), pressure point (100 vs. 79%, $P < .001$) and pressure release (100% vs. 97%, $P = .001$; Table 1 and Fig. 1B-D). In the LUCAS compared to the manual group, mean compression rate was less (100 vs.113min^{-1}, $P < .001$), hands-off time was shorter (46 vs 130 seconds, $P < .001$), and time to first defibrillation was longer (112 vs 49 seconds, $P < .001$). The mean compression depth did not differ between groups (49 vs 47 mm, $P < .309$; Table 2).

The *before flight* part in the LUCAS compared with the manual group lasted on average 393 (95% CI 383-403) vs 350 seconds (95% CI 336-364), the *during flight* part 491 (95% CI 484-499) vs 488 seconds (95% CI 482-493), the *after flight* part 169 (95% CI 165-172) vs 170 seconds (95% CI 166-175), and the overall scenario 1053 (95% CI 1039-1067) vs 1008 seconds (95% CI 990-1025).

4. Discussion

In this study of simulated CPR during helicopter rescue, LUCAS chest-compressions were more often correct than manual chest-compressions. Also, total hands-off-time was shorter in the LUCAS group, whereas time to first defibrillation was longer.

While LUCAS delivered uninterrupted high-quality chest-compressions, the quality of manual chest-compressions was consistently inferior throughout the scenario (Table 1). This was most pronounced during the helicopter flight with only 41% of correct manual chest-compressions (Fig. 1A), most likely because of the confined space and the unfavorable position of the candidates in the helicopter. This contrasts with a prior manikin study, reporting that manual chest-compressions were equally effective during helicopter flight as on the ground with ~77% correct chest-compressions by assessing chest-compressions depth and pressure point [3]. Similarly, another manikin study found a comparable chest-compressions depth during helicopter flight when compared to CPR at the scene. However, the median chest-compressions depth was only 33 mm during flight and 37 mm at the scene [13]. These two studies are

Table 1 Absolute numbers of chest compression variables in both groups presented as mean value±standard deviation and 95% CI. Before denotes performance *before flight*; during, *during flight*; after, *after flight*; and overall, *the overall scenario*

	LUCAS group	95% CI	Manual group	95% CI
Total chest compressions				
Before	588 ± 38	572-605	508 ± 58	483-533
During	814 ± 29	801-826	909 ± 44	890-928
After	279 ± 16	272-286	242 ± 20	234-251
Overall	1681 ± 53	1658-1704	1659 ± 94	1618-1700
Correct chest compressions				
Before	567 ± 34	553-582	309 ± 136	250-367
During	814 ± 29	801-826	369 ± 233	268-470
After	279 ± 16	272-286	186 ± 74	154-218
Overall	1660 ± 45	1640-1679	864 ± 381	699-1028
Correct depth of chest compressions				
Before	579 ±37	563-595	389 ± 124	335-442
During	814 ± 29	801-826	705 ± 224	608-802
After	279 ± 16	272-286	203 ± 68	173-233
Overall	1671 ± 52	1649-1694	1296 ± 380	1132-1460
Correct pressure point of chest compressions				
Before	583 ± 36	567-599	426 ± 88	389-464
During	814 ± 29	801-826	539 ± 200	453-625
After	279 ±16	272-286	228 ± 49	207-249
Overall	1675 ± 50	1654-1697	1194 ± 260	1081-1306
Correct pressure release of chest compressions				
Before	581 ± 38	565-597	476 ± 90	437-515
During	814 ± 29	801-826	894 ± 75	862-927
After	279 ± 16	272-286	238 ± 23	228-248
Overall	1673 ± 50	1652-1695	1608 ± 166	1536-1680

lacking a mechanical CPR group. Our study clearly shows that LUCAS can improve CPR during a transport scenario. However, a recent manikin study showed that LUCAS chest-compressions are less efficient than manual chest-compressions [14]. According to this study, 57% of the participants did not apply the mandatory stabilization strap of LUCAS, which resulted in sliding of LUCAS on the chest during CPR. Contrary to our study, the participants did not train with LUCAS directly before the study. This may be the reason for the poor CPR quality with LUCAS and emphasizes the imperative of regular training to apply LUCAS efficiently.

The hands-off time in our study was remarkably short in both study groups. In the manual group it accounted for only 13% of the total scenario time. In real life hands-off times of up to ~50% have been reported as a result of multiple tasks during CPR [1,15]. In the LUCAS group the hands-off time accounted for only 4% of the total scenario time and was only registered before initiation of mechanical CPR and during rhythm analysis.

Chest-compression quality and shorter hands-off time directly influence survival during CPR [9]. This is particularly important for hypothermic cardiac arrest patients, as prolonged CPR may be required before return of spontaneous circulation [5,16]. Despite prolonged CPR outcome may be good and improved by high-quality CPR as provided by a mechanical chest-compression device. Therefore, recently published expert-based guidelines of the University Hospital Berne, Switzerland, recommend the initiation of mechanical chest-compressions for all hypothermic cardiac arrest patients immediately after helicopter landing until return of spontaneous circulation [17].

Time to the first defibrillation was prolonged in the LUCAS group due to time required for installation of the device before the first rhythm analysis. The time delay until first defibrillation may negatively affect clinical outcome [18]. However, a recently published cluster-randomized trial found no difference in survival or neurological outcome whether an early or delayed (ie, 2 minutes) defibrillation was performed [19]. Moreover, longer periods to check for pulse and respirations as well as a maximum of three defibrillations are recommended below a core body temperature of 30°C. Therefore, a short delay until first defibrillation in hypothermic cardiac arrest seems to be of lesser importance to normothermic cardiac arrest, provided that the time until first defibrillation is bridged with high-quality manual CPR.

5. Limitations

Firstly, CPR was simulated on a manikin and transport and flight were performed in a simulator. Thus, this setting

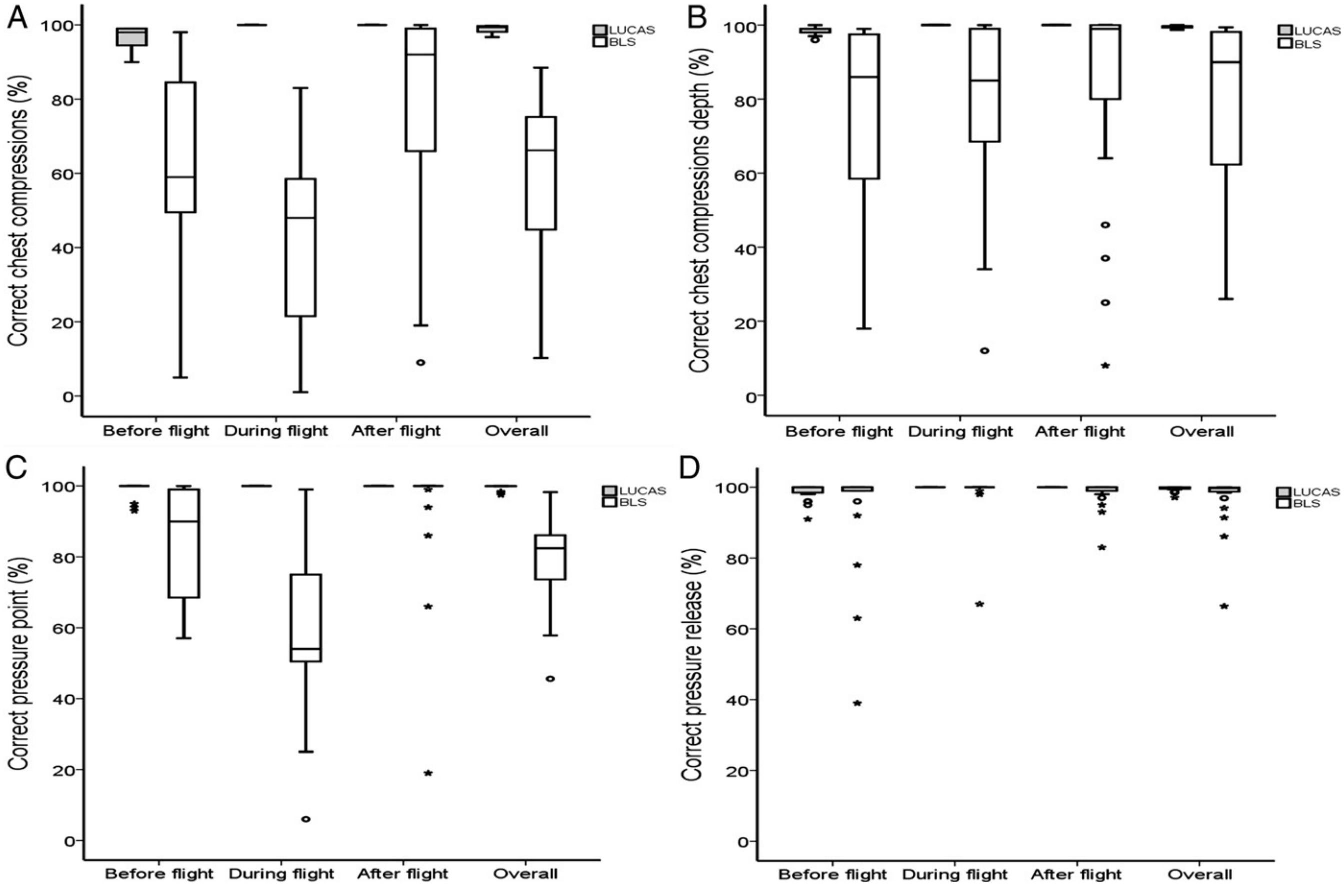

Fig. 1 Graphs display chest compression variables for the LUCAS and the manual group before, during and after flight and for the overall scenario. Outliers and extreme values are shown as circles (○) or as asterisks (*), respectively. A, Correct chest compressions (%). B, Correct chest compression depth (%). C, Correct chest compression pressure point (%). D, Correct chest compression pressure (%).

does not necessarily reflect a real CPR scenario. Secondly, improvements in CPR depicted by this study may not result in improved patient outcomes. Although there have been studies demonstrating that mechanical chest-compressions may improve clinical parameters such as blood pressure [20], coronary perfusion pressure [21], cortical cerebral blood flow [22], and end-tidal CO_2 [23], no high-quality study has been published yet which shows improved outcome in humans [24,25]. Thirdly, it was not possible to blind the candidates to the intent of the study. But they were blinded to the adequacy of chest-compressions.

6. Conclusions

During this simulated cardiac arrest scenario in helicopter rescue LUCAS compared to manual chest-compressions increased CPR quality and reduced hands-off time but prolonged the time interval to the first defibrillation. Further clinical trials are warranted to confirm potential benefits of LUCAS-CPR in helicopter rescue.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ajem.2012.07.018.

Table 2 Secondary outcome measure variables of both groups presented as mean value±standard deviation and 95% CI

	LUCAS Group	95% CI	Manual Group	95% CI
Hands-off time (s)	46 ± 5	43-48	130 ± 15	123-136
Time to first defibrillation (s)	112 ± 12	107-118	49 ± 6	47-52
Mean compression rate ($1/min^{-1}$)	100 ± 0,5	100-100	113 ± 6	110-116
Mean compression depth (mm)	49 ± 2	48-50	47 ± 6	45-50

Acknowledgments

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Avalanche Triage: Are Two Birds in the Bush Better Than One in the Hand?

To the Editor:

In a previous issue of *Wilderness and Environmental Medicine*, Bogle, Boyd, and McLaughlin discuss a proposed triage algorithm for use in avalanche incidents in which the number of victims exceeds the capacity of the rescuers to give optimum treatment to each victim.[1] They claim that this algorithm, which they call "AvSORT," will help rescuers "rapidly identify those that will benefit from limited resources."

While a triage algorithm for multiple casualty avalanche incidents might be useful, the proposed algorithm has potential problems. The main difficulty is the assumption that someone who is still buried might have a better chance of suvival than someone who is extricated without obviously lethal injuries. This assumption is contrary to the common wisdom that a bird in the hand is worth two in the bush.

The authors quote statistics showing that there have been many fatalities in avalanches with multiple victims, but they have not analyzed past avalanche incidents to see what effects their proposed algorithm might have had if it had been applied in actual incidents. Instead they have modified existing trauma triage algorithms in a data vacuum. While they claim that the AvSORT avalanche would produce desirable percentages of overtriage and undertriage, they present no evidence in support of this assertion. They also present no evidence that their algorithm would result in an increased number of survivors.

The authors are not specific about the conditions under which their proposed algorithm should be used. What is the definition of a "mass casualty incident"? For example, does this term apply in the case of 2 avalanche victims and 2 uninjured rescuers? The algorithm also does not define how first responders should determine when they are "overwhelmed," nor does it give criteria for determining if the area is "remote." Is an area remote if the response time for rescue is 2 hours? Arrested hypothermic patients have been successfully rewarmed after 4 hours of cardiopulmonary resuscitation (CPR), even in Europe.[2]

It is important that the proposed algorithm not be used as a reason to deviate from established resuscitation guidelines except under the most extenuating circumstances. Apneic, severely hypothermic avalanche victims have been successfully resuscitated.[2] It is critical to recognize that victims buried for more than 35 minutes who have a patent airway have a chance of survival. The guiding principle should be not to give up! It would be tragic if a rescuer did not try to resuscitate such a patient due to feeling "overwhelmed." The proposed algorithm should be modified so that victims buried longer than 35 minutes who have a patent airway but are not breathing not be triaged to the "expectant" category. They should receive CPR and be transferred to a hospital capable of performing cardiopulmonary bypass.

Because the authors are advocating a triage guideline, they have not specified all the specifics of treatment in the various triage categories. For this, rescuers will need to follow another algorithm, such as the International Commission for Mountain Emergency Medicine (ICAR MEDCOM) avalanche resuscitation guidelines.[3] The authors present these guidelines but state that they "rarely" apply to first responders in North America. It is true that the ICAR MEDCOM guidelines cannot be fully applied without the use of cardiac monitoring, but they are predominantly based on clinical criteria that do not require special equipment. The authors note that if the number of rescuers is adequate to search for buried victims as well as treat extricated victims, standard treatment guidelines apply. In this case, there is no need for a triage algorithm.

Although the proposed algorithm makes use of the duration of burial to determine treatment, it does not use duration as a prognostic factor for buried victims. Avalanche survival probability of buried victims is 91% at 18 minutes but drops precipitously to 34% after 35 minutes as victims without an air pocket die from asphyxiation.[4] Survival then decreases gradually to a mere 7% at 130 minutes as victims with a "closed" air pocket succumb to slow asphyxia and hypothermia. It makes less sense to divert resources from treating extricated victims with a chance of survival to searching for buried victims after about 2 hours than it does at 35 minutes. Unfortunately, the reality of avalanche incidents, even in Europe, is that increased rescue capabilities have not increased survival. This is because the best chance for an avalanche victim to survive is to be extricated rapidly by other members of the party who were not buried.

Another problem with the proposed algorithm is the designation of destination hospital. While the European Alps are dotted with hospitals only a 15-minute helicopter flight from almost any point and referral centers capable of intensive care within 30 minutes, the situation in North America is that even the closest hospital may be an hour or more away by helicopter and "trauma centers" are often beyond the range of helicopter transport at all. In the case of apneic hypothermic patients, the most appropriate destination hospital may not be a trauma center but should be a center capable of performing cardiopulmonary bypass.

A recent case report[5] illustrates the major potential pitfall of the proposed triage algorithm. In this case report, 2 skiers were completely buried in an avalanche in the Italian Alps. Uninjured companions activated an emergency response by cell phone. Amazingly, the first victim was breathing when extricated from a depth of 3 m (9.8 ft) after 100 minutes. However, he was unconscious and severely hypothermic with an epitympanic core temperature of 22°C (71.6°F). The second skier was found a few minutes later in asystole without an air pocket. He was declared dead by the emergency physicians on site, according to the ICAR avalanche guidelines.

The first patient was intubated and transported to the nearest hospital by helicopter. During transport he went into ventricular fibrillation. He continued to be ventilated, but chest compressions were not administered for 15 minutes. Initial attempts at defibrillation at the destination hospital were unsuccessful because of hypothermia. He was subsequently transferred to a referral hospital where he could be placed on cardiopulmonary bypass. He was successfully resuscitated and rewarmed. He eventually made a complete neurologic recovery.

Had there been few rescuers rather than the many who actually responded and had the AvSORT algorithm been applied, the first victim would have been triaged to the "immediate treatment" category and transferred to a trauma center. However, if ventricular fibrillation had started before he was placed in the helicopter and the second victim had not yet been found, the first victim would have been triaged or retriaged into the category of "expectant" management and would have received no further treatment. The result would have been a fatal outcome rather than the complete recovery he actually experienced.

Until the authors of the AvSORT algorithm can produce convincing data to show that their proposed triage method would increase survival in multi-casualty avalanche incidents, rescuers should resuscitate potentially live victims who have already been found and not divert necessary medical resources to further searching.

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In Reply to Avalanche Triage

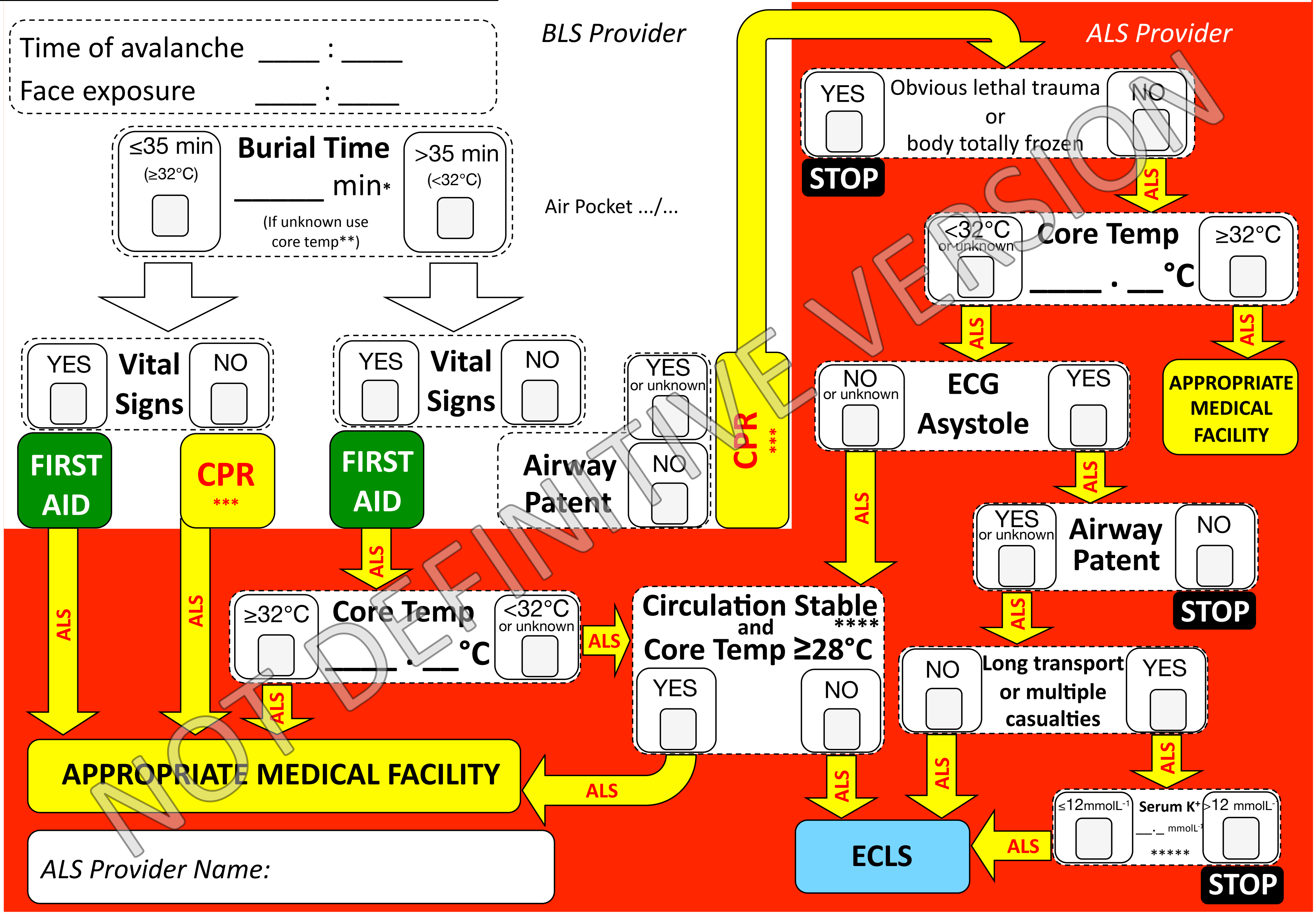
To the Editor:
In reply to the letter by Dr Ken Zafren, we take this opportunity to resolve any confusion with the use of the Avalanche Survival Optimizing Rescue Triage (AvSORT) algorithm.[1]

On February 1, 2003 in backcountry Canada, 2 mountain guides watch with horror as an avalanche engulfs and buries a school group of 17 participants below them.[2-4] They immediately realize their priority for rescue is to uncover as many victims as possible prior to the onset of asphyxia. They "cannot save everybody"[4] but must focus on "the greatest good for the greatest number."[5-11] They decide, as 2 rescuers, they will only dig enough to allow resumption of breathing, to clear airways, and to hand responsive victims their own shovels for self-extrication before moving on. They recognize that to stop and attempt cardiopulmonary resuscitation (CPR) on any one asphyxiated victim will seriously compromise the survival of other victims still buried. The first victim, recovered in the first 5 minutes, is the school teacher who calls on his satellite phone for outside organized rescue. As the avalanche debris sets up "like concrete,"[4] victims who are not buried too deep are uncovered while deep burials are passed over due to the pressure of time. One victim goes on, after fully extricating himself, to locate and uncover 3 of his classmates, resulting in their survival. The first rescue helicopter lands after 55 minutes and of the 17 buried victims 10 survive. The rational action of the 2 mountain guides is credited with the survival of the majority of these victims in this mass casualty avalanche incident.[3,4] The development of our proposed AvSORT algorithm is a result of this and other similar incidents that we cite in the text of our article. This algorithm is designed for the "initial management of mass casualty avalanche incidents when manpower is overwhelmed."[1] We must re-emphasize this.

By comparison Dr Zafren cites an incident in which 3 helicopters with 15 rescuers, 2 emergency physicians, and 2 dog handlers are on scene for 2 buried victims, 1 of whom survives.[12] This would never be considered a

Patient ID

AVALANCHE VICTIM RESUSCITATION CHECKLIST



Air Pocket

☐Yes, ___ x ___ x ___ (cm)
☐No
☐Unknown

Rescue Service:

Base:

Phone:

Abbreviations:
Pat ID = Patient Identity
CPR = Cardiopulmonary Resuscitation
ALS = Advanced Life Support
ECLS= Extracorporeal Life Support (Cardiopulmonary Bypass/Extracorporeal Membrane Oxygenation)

* Time between burial and uncovering the face.
**If duration of burial is unknown, core temperature may substitute using oesophageal or epitympanic (thermistor-based sensor) temperature.
*** CPR can be withheld if unacceptable level of risk for the rescuer, total body frozen or obvious lethal trauma (decapitation, truncal transsection).
**** Patients who present with cardiac instability (ventricular arrhythmias, systolic blood pressure <90mmHg) or core temperature <28°C should be transported towards hospital with ECLS rewarming possibility.
***** if K^+ at hospital admission exceeds 12mmolL^{-1} consider stopping resuscitation (after exluding crush injuries and consideration of the use of depolarizing paralytics); in an adult with K^+= 8-12 mmolL^{-1} and other factors consistent with non-survival, termination of resuscitation should be considered.

Neurologic Recovery From Profound Accidental Hypothermia After 5 Hours of Cardiopulmonary Resuscitation

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Objective: To describe the successful neurologic recovery from profound accidental hypothermia with cardiac arrest despite the longest reported duration of cardiopulmonary resuscitation.

Design: Case report.

Setting: Mountain.

Patient: A 57-year-old woman experienced profound accidental hypothermia (16.9°C) in a mountainous region of Grenoble. She was unconscious and had extreme bradycardia (6 beats/min) at presentation. A cardiac arrest occurred at the mobilization that was not responsive to electrical shocks or epinephrine.

Intervention: Cardiopulmonary resuscitation was continued for 307 minutes after rescue until venoarterial extracorporeal membrane oxygenation blood flow had been established at the emergency department.

Measurements and Main Results: At a 3-month follow-up, the patient showed good physical and mental recovery.

Conclusion: With no evidence of trauma or asphyxia, profound accidental hypothermia with cardiac arrest represents a specific condition for which successful neurologic recovery is feasible despite prolonged cardiopulmonary resuscitation. (*Crit Care Med* 2013; 42:00–00)

Key Words: accidental hypothermia; cardiac arrest; extracorporeal rewarming; mountain

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Long-term survival rates of up to 60% with minimal neurologic impairment after profound accidental hypothermia with cardiac arrest have been reported in young healthy adults (1, 2). This is essentially due to improved prehospital life support and effective rewarming techniques in hospital (3). We report the case of a severe hypothermic victim who received cardiopulmonary resuscitation (CPR) for 5 hours until full extracorporeal blood flow was established. The patient showed good physical and mental recovery at a 3-month follow-up. Written informed consent was obtained from our patient.

CASE PRESENTATION

A 57-year-old woman (59 kg, 1.65 m) and her friend were found lost during a snowstorm on December 16, 2011, in the French Alps at 2,000 m altitude. An emergency call was made at 4.43 PM. Because of continuing snowfall, access to the victims was very difficult and only five members of the rescue team arrived on site at 8.35 PM. The first victim was conscious. She was transferred to the nearest hospital and discharged a few hours later with no medical injury. The second victim fell unconscious around 25 minutes before the arrival of the recovery team according to the first victim. Carotid pulse rate was 6 beats/min, and she had no perceptible breathing movements. A cardiac arrest occurred when the victim was mobilized and CPR began immediately (8.40 PM). An automated external defibrillator was put on the victim's chest, and a ventricular fibrillation rhythm was identified at first. Despite three electrical shocks successively delivered, the subsequent cardiac rhythm was asystole. Epinephrine at an intraosseous dose of 1 mg had no clinical response. Full-body insulation was provided but body temperature was not measured. Although the decision was made to immediately evacuate under CPR, it was impossible to both move and resuscitate in these adverse environmental conditions and deep snow. Manual ventilation was technically impossible as well. An alternating sequence with 1 minute of manual 100-chest compressions and 1-minute walking to reach the road was therefore undertaken for 25 minutes, with a distance of 1.1 km and a 122-m difference in height. Once on the road (10.30 PM), advanced life support was provided including endotracheal intubation and mechanical ventilation with 100% oxygen, along with the continuation of manual chest compressions. Initial end-tidal Co_2 ranged between 12 and 19 mm Hg. The victim was then transported by road ambulance for admission to the emergency department of the regional level I trauma center at 1.10 AM. A mechanical chest-compression device (Lucas, Jolife AB, Physio-Control, Lund, Sweden) was in use only during the last hour of the transportation.

On arrival, the rectal temperature was 16.9°C according to a properly calibrated, low-temperature reading thermometer. The patient was thus classified as hypothermia stage IV according to the Swiss staging system (4) (**Table 1**). No sign of trauma was found using extended-focused assessment with sonography for trauma (CX 50, Philips Healthcare, Eindhoven, The Netherlands) or with anterior-posterior radiographs of the chest and the pelvis. On arrival, the level of serum potassium was 5.8 mmol/L, and other biological variables from venous samples were pH, 7.25; Pao_2, 48 mm Hg; $Paco_2$, 38 mm Hg; serum sodium, 140 mmol/L; lactate, 5.7 mmol/L; creatine kinase, 4,576 IU/L; and activated partial thromboplastin ratio, 1.5. Based on these findings, an extracorporeal heating system using surgically exposed femoral access sites and venoarterial extracorporeal membrane oxygenation (ECMO) was considered. CPR was continued until full extracorporeal blood flow was established at 1.47 AM, that is, 307 minutes after rescue. Arterial blood gases were Pao_2 (69 mm Hg), $Paco_2$ (26 mm Hg), and pH (7.35). A spontaneous cardiac activity with sinus rhythm was detected at 3.08 AM when body temperature had risen to 33.8°C. The patient was then transferred to an ICU and kept in mild hypothermia (35°C) for the next 24 hours.

In the ICU, ECMO operated at a blood flow of 4 L/min with 0.4 inhaled oxygen fraction and 1.2 mg/hr norepinephrine to maintain mean arterial blood pressure at 70–80 mm Hg. Under volume-controlled mechanical ventilation, initial biological measurements were arterial Pao_2 (74 mm Hg) and $Paco_2$ (33 mm Hg), arterial pH (7.21), and serum lactate (2.31 mmol/L). Extracorporeal life support was required for 3 days due to severe cardiac dysfunction. During the 55 days of her ICU stay, acute kidney failure developed in the patient due to massive rhabdomyolysis, which was treated by hemodiafiltration. Three weeks after the insult, she had a severe epistaxis in relation with arterial hypertension, which was treated by transcatheter arterial embolization of internal maxillary arteries and a pulmonary embolism treated by heparin infusion. A first neurologic assessment of the patient after cessation of IV sedation on day 14 showed mental alertness with full motor responses to command of all extremities. The findings from electroencephalography were normal. At day 42, brain MRI revealed the integrity of brain parenchyma and no evidence of brain anoxo-ischemic lesions (**Fig. 1**). The patient was transferred from the ICU to a neurologic rehabilitation unit with no organ failure, and she left hospital 1 month later. Mild cognitive impairment with an impairment of short-term memory and an alteration in executive functions such as planning and flexibility was attested 3 months after the insult by a mini-mental state score of 24 of 30 (normal cognition if ≥ 25 of 30) and a bedside score of 11 of 18 according to the frontal assessment battery (5, 6).

TABLE 1. Staging of Accidental Hypothermia (4)

Stage	Clinical Symptoms	Core Temperature (°C)
HT I	Conscious with shivering	35–32
HT II	Impaired consciousness with no shivering	32–28
HT III	Unconsciousness, vital signs present	28–24
HT IV	No vital signs	< 24

HT = hypothermia.

DISCUSSION

Survival with no or minor neurologic impairment after profound accidental hypothermia and cardiac arrest is possible even when a number of hours of CPR is required before the initiation of extracorporeal rewarming, such as can occur in nonasphyxiated victims of mountain accidents (7–12). According to a recent review (3), our case with a CPR duration of 5 hours in accidental hypothermia should represent the longest reported duration of CPR leading to good neurologic recovery.

The key issue in the resuscitation of hypothermic cardiac arrest is deciding whether the victim is eligible for initial CPR until extracorporeal rewarming. Patients with nonasphyxiated profound accidental hypothermia are known to have better prognosis than drowned patients with secondary hypothermia (13). As such, guidelines for avalanche resuscitation and termination of CPR in mountain rescue have been recently published (14, 15). In the absence of causes of death such as trauma or asphyxia, patients with accidental hypothermia showing no vital signs should be considered for CPR. On the other hand, asystole on electrocardiogram, normothermic cardiac arrest, and unwitnessed loss of vital signs are all criteria to terminate CPR (15). Our case presented with none of these latter criteria. Furthermore, the presence of an extreme bradycardia at presentation, even transient, might be considered as a vital sign in a patient with profound accidental hypothermia. In cases of hypothermic cardiac arrest, the prehospital duration of CPR cannot be considered in the decision about whether or not to undertake extracorporeal rewarming.

In our case, a nonconventional CPR sequence for 25 minutes was imposed due to the geographical situation and adverse

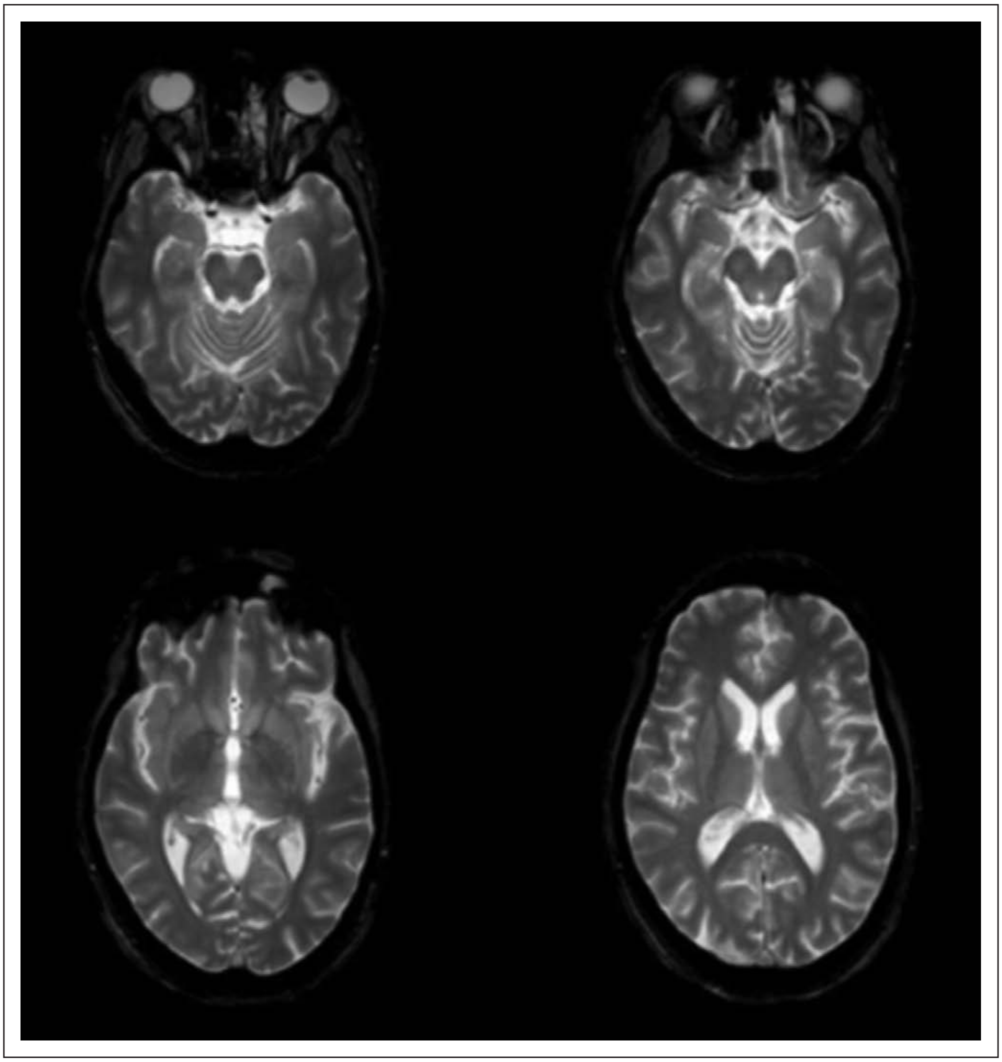

Figure 1. T2-weighted MRI sequence showing integrity of brain parenchyma and basal ganglia.

of the patient (9°C/hr) until spontaneous defibrillation at 33°C body temperature (2). The rewarming rate after profound accidental hypothermia was reported around 5°C/hr (13). These rates of rewarming are markedly higher than therapeutic hypothermia reversal in postcardiac arrest patients (< 1°C/hr) (17). In accidental hypothermia, cardiopulmonary bypass allows high rewarming rates that theoretically might protect the heart from myocardial damages due to persistent ventricular fibrillation. Once spontaneous cardiac activity is obtained, the rewarming rate should be slowed down. Neurologic outcome was improved in patients weaning off coronary artery bypass at 33°C compared with patients actively rewarmed until 37°C (18). Collectively, these findings favor controlling the rewarming rate and keeping the patient in mild therapeutic hypothermia following the rewarming phase after accidental hypothermia (3), as was done in our case.

environmental conditions. Whether the alternating 1-minute chest compressions and 1-minute walk sequence was effective at providing vital blood flow to the brain in this case of deep hypothermia and protecting the patient's brain is conjectural. In experimental models of prolonged cardiac arrest, the interruption of circulation during the initial CPR facilitated cardiac function and neurologic recovery (16). In addition, hypothermia is believed to slow cerebral metabolism rate, which is one of the several mechanisms underlying protective effects of hypothermia (17). MRI evaluation of our patient can attest that, whatever the mechanism of protection involved in this case, there was no evidence of brain anoxo-ischemic lesions.

Our patient had normal serum potassium at admission despite a prolonged and precarious resuscitation. It is recommended to consider CPR as futile whenever the serum potassium level is higher than 12 mmol/L (3). Conversely, a low potassium level on arrival is not a guarantee of survival (1, 13). The measurement of serum potassium should be viewed as additional piece of information wherever doubt exists at initial presentation. Another point is the high rewarming rate

CONCLUSION

In conclusion, this case report shows that a good neurologic recovery can be obtained following prolonged CPR in profound accidental hypothermia. This strongly indicates that hypothermic cardiac arrest should not be considered as an irreversible condition in mountain accident victims providing no evidence of trauma or asphyxia.

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Resuscitation great

Resuscitation of avalanche victims: Evidence-based guidelines of the international commission for mountain emergency medicine (ICAR MEDCOM) Intended for physicians and other advanced life support personnel☆

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ABSTRACT

Background: In North America and Europe ~150 persons are killed by avalanches every year.
Methods: The International Commission for Mountain Emergency Medicine (ICAR MEDCOM) systematically developed evidence-based guidelines and an algorithm for the management of avalanche victims using a worksheet of 27 Population Intervention Comparator Outcome questions. Classification of recommendations and level of evidence are ranked using the American Heart Association system.
Results and conclusions: If lethal injuries are excluded and the body is not frozen, the rescue strategy is governed by the duration of snow burial and, if not available, by the victim's core-temperature. If burial time ≤35 min (or core-temperature ≥32 °C) rapid extrication and standard ALS is important. If burial time >35 min and core-temperature <32 °C, treatment of hypothermia including gentle extrication, full body insulation, ECG and core-temperature monitoring is recommended, and advanced airway management if appropriate. Unresponsive patients presenting with vital signs should be transported to a hospital capable of active external and minimally invasive rewarming such as forced air rewarming. Patients with cardiac instability or in cardiac arrest (with a patent airway) should be transported to a hospital for extracorporeal membrane oxygenation or cardiopulmonary bypass rewarming. Patients in cardiac arrest should receive uninterrupted CPR; with asystole, CPR may be terminated (or withheld) if a patient is lethally injured or completely frozen, the airway is blocked and duration of burial >35 min, serum potassium >12 mmol L^{-1}, risk to the rescuers is unacceptably high or a valid do-not-resuscitate order exists. Management should include spinal precautions and other trauma care as indicated.

1. Introduction

In North America and Europe ~150 persons are killed by avalanches every year,[1] with most triggered by skiers, snowboarders and, in the USA and Canada, by snowmobilers.[2] Avalanches inflict even higher death tolls in developing countries; for instance avalanches claimed 284 lives in South East Anatolia in 1992, >200 in Kashmir in 1995 and 135 in Kashmir in 2012. The total number of persons in avalanche terrain is unobtainable and mortality in these activity groups can only be roughly estimated. The first recommendations for on-site management and transport of avalanche victims,

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based on survival analyses,[3,4] case reports[5] and case series,[6–9] were proposed in 1996[10] and 2001.[4] The International Commission for Mountain Emergency Medicine (ICAR MEDCOM) established official consensus guidelines including an algorithm in 2002.[11] A systematic review of four prognostic factors[12] and an International Liaison Committee on Resuscitation (ILCOR) worksheet process were the basis of the recommendations for avalanche resuscitation in the 2010 Resuscitation Guidelines.[13,14] Recommendations for transport and treatment decisions of hypothermic patients including avalanche victims have been recently developed.[15] The ICAR MEDCOM sought to systematically develop evidence-based guidelines using a structured worksheet with the mandate to obtain final consensus among the ICAR MEDCOM.

2. Methods

The objectives, inclusion/exclusion criteria, working group and worksheet of 27 Population Intervention Comparator Outcome (PICO) questions (supplementary data) derived from earlier avalanche resuscitation recommendations[4] were developed by the ICAR MEDCOM at a TOPIC meeting. The electronic database of Medline was searched via PubMed with the search terms (avalanche [All Fields]) and (hypothermia [All Fields]) and the database of EMBASE via OVID with (avalanche {Including Related Terms}) and (hypothermia {Including Related Terms}). The Cochrane Database of Systematic Reviews was searched with the terms (avalanche) and (accidental hypothermia). Additional hand searching of articles, reference texts and reference lists was also performed. All articles relevant to clinical management of victims of snow avalanches and related accidental hypothermia were extracted for further review. These were evaluated for quality and relevance to the PICO questions and recommendations were developed at a SCIENCE meeting. The recommendations were further examined and consensus was reached at a MANUSCRIPT meeting in Åre, Sweden, in October 2011. Classification of recommendations and level of evidence are ranked using the American Heart Association (AHA) system (Table 1).

3. Findings and recommendations

From a total of 3530 retrieved citations, 96 articles were classified as relevant and were subjected to full review.

Survival probability

The overall survival rate of avalanche victims is 77% (1453/1886).[4] Survival depends on the grade and duration of burial and the pathological processes of asphyxia, trauma and hypothermia.

Grade of burial

Analysis of a Swiss sample showed that 39% (735/1886) of victims involved in an avalanche were completely buried, with survival in complete burials (i.e. burial of the head and chest[1]) of 47.6% (350/735) versus 95.8% (1103/1151) in partial burials.[4] Grade of burial is the strongest single factor for survival.

Duration of burial

Biostatistical survival analysis of critically buried victims[1] in Switzerland and Canada shows a progressive non-linear reduction in survival as duration of burial increases and distinct phases.[3,4,16] In Switzerland, survival probability remains above 80% until 18 min after burial ("survival phase") and plummets thereafter to 32% ("asphyxia phase"), whereas the Canadian survival curve shows an earlier and steeper decline from 77% at 10 min to 7% at 35 min, which reflects a greater mortality from trauma and an earlier onset of asphyxia due to denser snow in some regions of Canada[16,17] (Fig. 1). Supportively, hypoxia has been shown to be correlated to snow density in an experimental study.[18] Another identifiable decrease in survival occurs at 90 min due to hypothermia combined with hypoxia and hypercapnia.[4] The duration of burial is therefore an indication of pathology and should dictate treatment strategy.

3.1. Asphyxia

Asphyxia was found to be the most common cause of death in three case series that relied on autopsy, full forensic external examination and/or pre-mortem clinical findings.[16,19,20] Asphyxia may occur in combination with trauma and hypothermia.[16]

3.1.1. Expediency

Survival decreases rapidly in the "asphyxia phase", i.e. in the first 35 min.[3,4,17]

Recommendations. Companions should locate and extricate buried victims expeditiously (Class 1, LOE B).

Organized rescue should be mobilized early (Class I, LOE B).

3.1.2. Duration of burial and airway patency

A systematic review[12] confirmed that a patent airway was essential for survival for >35 min of critical burial, with four of the analyzed retrospective studies describing survival to hospital discharge in victims buried >60 min who were found with patent airways. No survivors were reported in any of the 14 case-control and case series for victims with an obstructed airway and >35 min of burial. A prospective, randomized, crossover experimental study found that when breathing into a simulated air pocket subjects achieved a steady state of survivable hypoxia for at least 20 min in 39% (11/28) of uninterrupted tests.[18] Other prospective experimental studies have indicated that redirecting gas exchange away from an air pocket, such as might occur in avalanche debris with large blocks or an opening to environmental air, improves oxygenation.[21–23]

Recommendation. If burial >35 min, airway patency should be determined upon exposure of the face (Class I, LOE A).

The ancillary presence of an air pocket should be determined by digging from the side of the victim in order to not harm the victim or destroy the air pocket (Class I, LOE C).

3.1.3. Resuscitation

Resuscitation guidelines recommend standard CPR in hypoxaemic cardiopulmonary arrest.[13,14] Ventilation should be combined with chest compressions, as compression-only CPR is inappropriate for avalanche burial.

Recommendations. Factors and decisions are integrated in a management algorithm (Fig. 2) (Class IIa, LOE C).

For victims buried <35 min found in cardiac arrest, presume asphyxia and initiate standard CPR with ventilations as soon as the head and chest are free regardless of airway patency (Class I, LOE B).

For victims buried >35 min found in non-asystolic cardiac arrest with a patent airway but who are not hypothermic (≥32 °C), presume asphyxia and initiate standard CPR with ventilations as soon as the head and chest are free (Class IIa, LOE B).

[1] In Europe the term *completely buried* refers to burial of at least the head and chest. In North America the term *completely buried* is reserved for when the individual is totally buried beneath the snow surface and *partially buried–critical* for when the individual is partially buried with at least the head under the snow surface and with breathing impaired.[57,58] The term *critical burial* will be used hereafter to identify burials that impair breathing and therefore risk asphyxia.

Table 1
Classification of recommendations and level of evidence according to the ACCF/AHA task force on practice guidelines.[a]

	Size of treatment effect			
LEVEL (Quality) of evidence (LOE)				
	CLASS I *Benefit »> Risk* Procedure/Treatment **should** be performed/administered	CLASS IIa *Benefit » Risk* **It is reasonable** to perform procedure/administer treatment	CLASS IIb *Benefit ≥ Risk* Procedure/Treatment **may be considered**	CLASS III *No Benefit or Harm* Procedure/Treatment of **no benefit or harmful**
LEVEL A	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Data derived from multiple randomized clinical trials or meta-analyses	Sufficient evidence from multiple randomized trials or meta-analyses.	Some conflicting evidence from multiple randomized trials or meta-analyses.	Greater conflicting evidence from multiple randomized trials or meta-analyses.	Sufficient evidence from multiple randomized trials or meta-analyses.
LEVEL B	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Data derived from a single randomized trial or nonrandomized studies	Evidence from single randomized trial or nonrandomized studies.	Some conflicting evidence from single randomized trial or nonrandomized studies.	Greater conflicting evidence from single randomized trial or nonrandomized studies.	Evidence from single randomized trial or nonrandomized studies.
LEVEL C	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Only consensus opinion of experts, case studies, or standard of care	Only expert opinion, case, or standard of care.	Only diverging expert opinion, case studies, or standard of care.	Only diverging expert opinion, case studies, or standard of care.	Only diverging expert opinion, case studies, or standard of care.

[a] Manual for ACC/AHA Guideline Writing Committees (Accessed 01 September 2012, at http://circ.ahajournals.org/site/manual/index.xhtml).

For victims buried >35 min found in asystolic cardiac arrest with an obstructed airway, resuscitation may be initiated but can be terminated if not successful (Class I, LOE A).

3.1.4. *Advanced airway*

Advanced airway management (e.g. endotracheal intubation and supraglottic airway devices) performed by experienced personnel enables effective ventilation, reduces the likelihood of aspiration for avalanche victims in periarrest[14] and may improve survival.[24] In prehospital settings with long transport times, endotracheal intubation is associated with improved survival.[25] However, complications are unacceptably frequent when performed by inexperienced providers.[25,26] Supraglottic devices may be more efficient and safer than endotracheal intubation or bag-mask ventilation for less experienced rescuers.

Recommendations. For unresponsive victims advanced airway management should be performed if the rescuer is competent in this skill and if airway management succeeds within a reasonable time (Class I, LOE A).

For rescuers not experienced in advanced airway management, ventilation is most effective with mouth-to-mask or bag-mask techniques (Class I, LOE A).

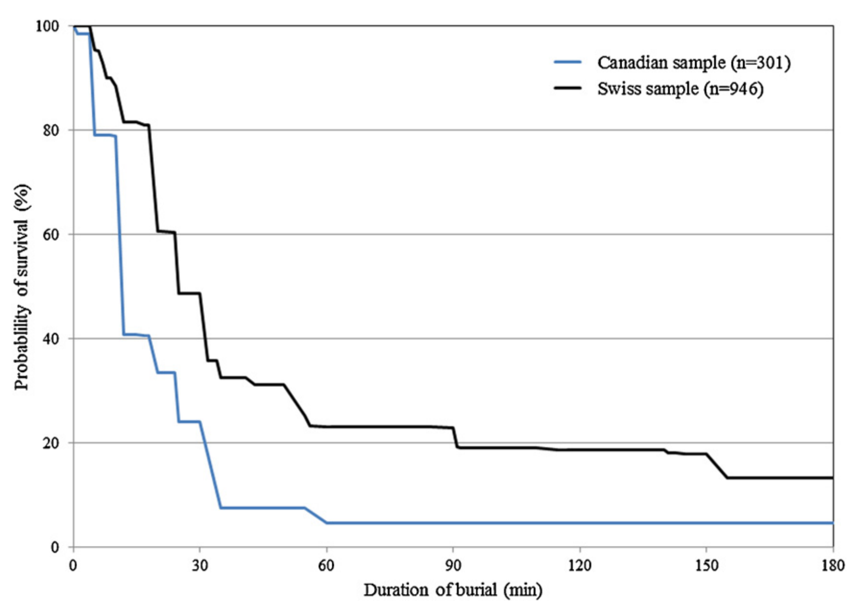

Fig. 1. Comparison of survival curves in Canada (black; $n = 301$) and Switzerland (grey; $n = 946$) from 1980 to 2005. Extracted from Haegeli et al.[16] with permission from CMAJ.

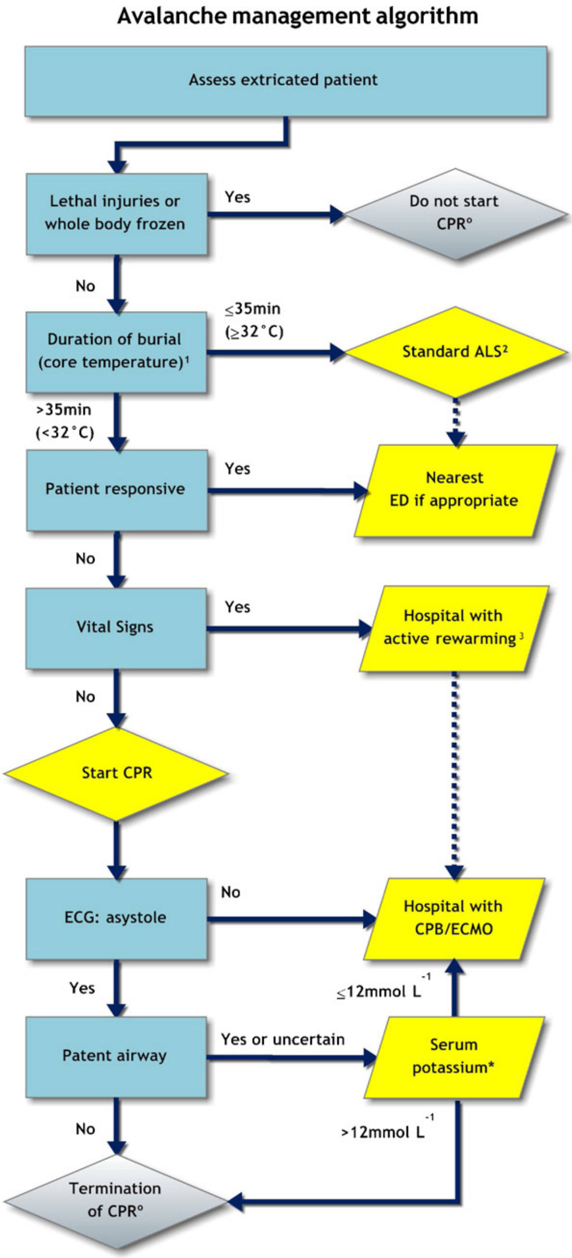

Fig. 2. Management of the buried avalanche victim. In all cases gentle extrication and spinal precautions. Where appropriate core temperature and ECG monitoring, oxygen, insulation, heat packs on trunk; 0.9% NaCl and/or 5% glucose only if an intravenous or intraosseous line can be established within a few minutes; specific trauma care as indicated. [0]Clinicians may consider withholding resuscitation at the scene if it increases risk to the rescue team or if the victim is lethally injured or completely frozen. [1]If duration of burial is unknown core temperature may substitute. [2]Initiate standard ALS including ventilations and chest compressions as indicated. Resuscitation may be terminated in normothermic patients if ALS is not successful after 20 min. Transport victims with concern of respiratory (e.g. pulmonary oedema) or other-system injury to the most appropriate medical centre. [3]Hospital capable of advanced external or core rewarming. Patients who present with cardiac instability (ventricular arrhythmias, systolic blood pressure <90 mm Hg) or core-temperature <28 °C should be transported towards ECC rewarming. Defibrillation beyond three attempts may be delayed until core-temperature >30 °C. [*]If direct transport to ECC rewarming is practical, the nearest ED can be bypassed. If K+ at hospital admission exceeds 12 mmol L^{-1}, consider stopping resuscitation (after excluding crush injuries and consideration of the use of depolarizing paralytics); in an adult with K+ 8–12 mmol L^{-1} and other factors consistent with non-survival, termination of resuscitation should be considered. ALS, Advanced Life Support; ED, Emergency Department; ICU, Intensive Care Unit; ECC, extracorporeal circulation.

For a potential survivor with a failed airway, hospital transfer should be hastened with early alert of appropriate support (Class I, LOE C).

3.1.5. *Transport*

Post-resuscitation care including therapeutic hypothermia is integral to improving survival.[25,26] Mechanical chest compression devices improve rescuer safety and reduce manual energy expenditure and may improve outcome during transport.[26] Delayed onset of pulmonary oedema has been reported in avalanche victims with vital signs after short burials.[27]

Recommendations. If resuscitation is successful or termination-of-CPR criteria are not met (see *Termination of CPR*) victims should be transported to the nearest hospital, preferably one with intensive care services (Class IIa, LOE C).

Mechanical chest compression devices and therapeutic hypothermia may be considered for prolonged transports (Class IIb, LOE B).

If victims present with signs or concern of respiratory or other system injury they should be transported to the nearest emergency department for advanced assessment and observation (Class I, LOE C).

3.2. *Trauma*

Trauma was the principal cause of death in 23.5% (48/204) of fatalities in western Canada,[16] 5.5% (2/36) in Austria[19] and 5.4% (3/56) in Utah.[20] However, in the Canadian sample major trauma, i.e. injury severity score (ISS) >15, was additionally found in 13.0% (12/92) of autopsied "asphyxia" fatalities. Chest trauma represented 45.8% (11/24) of single-system injuries; 52.1% (25/48) were found on the surface or not critically buried.[16] In the Austrian sample 8.6% (9/105) of fatality cases had an ISS score >13 although only 5.5% (2/36) were ascribed to trauma; the two trauma fatalities were fracture-dislocations of the cervical spine.[19] Similarly, in the Utah sample trauma was associated with asphyxia in 8.9% (5/56) of fatalities in addition to the 5.4% (3/56) ascribed to trauma alone; autopsies found head, abdominal and limb injuries to be common.[20] Differing rates are dependent on topographical factors (e.g. open versus forested terrain).[16]

3.2.1. *On-site management*

Current resuscitation guidelines emphasize spinal stabilization, chest decompression for tension pneumothorax, haemorrhage control, prompt evacuation to definitive care and consideration of permissive hypotension in the resuscitation of shock.[13,14] Tourniquets are life-saving in exsanguinating limb injuries.[28] In traumatic cardiac arrest survival is approximately 5.6% and prolonged CPR >16 min is associated with a poor outcome.[13] In severe head trauma outcomes are improved with early intubation and normoventilation while hypo- and hyperventilation result in poorer outcome.[29]

Recommendations. Rescuers should provide adequate spinal stabilization throughout extrication, on-scene management and transport (Class I, LOE C).

Trauma measures include splinting, insulation and analgesia (Class I, LOE C).

Clinical teams should be skilled and equipped for thoracostomy, tourniquet application, intravenous or intraosseous cannulation with controlled fluid infusion in shock or for medication administration, advanced airway management, cricothyrotomy and antibiotics for open fractures (Class IIa, LOE B).

CPR should be initiated for traumatic cardiopulmonary arrest while searching for and managing treatable causes (Class I, LOE B).

Delay of transport for on-site management should be as short as possible; direct transport to a dedicated trauma centre is preferred (Class I, LOE C).

3.3. Hypothermia

Hypothermia is commonly diagnosed clinically in avalanche victims. A systematic review of five retrospective case series found that hypothermic cardiac arrest is survivable if associated with a patent airway.[12] Hypothermia is rarely listed as the principal cause of death as post-mortem signs are limited and asphyxia and trauma are frequently concomitant.[16] At low core-temperatures the brain tolerates cardio-circulatory arrest >5 min without permanent damage.[9,30,31]

3.3.1. Cooling rate

The cooling rate during burial is variable but may be accelerated by light clothing, sweating and exhaustion. Hypercapnia and hypoxia may increase cooling rate.[23,32] This combination has been termed the “triple H syndrome,”[18] although the interactions are not elucidated. A maximum cooling rate of 9 °C h^{-1} was found during a burial of 100 min,[31] while lesser cooling rates have been reported in other case series and reports[33–35] and in experimental human[36] and animal studies.[23] At the maximum rate of 9 °C h^{-1} a minimum time of 35 min is required for the core-temperature to drop <32 °C and it is therefore concluded that the presence of a patent airway is essential for survival in any victim with a core-temperature <32 °C.[12–14]

Recommendations. (See Table 2 for the management of victims at different stages of hypothermia and Fig. 2 for the management of avalanche victims.)

For victims in cardiac arrest with a core-temperature <32 °C and a patent or unknown airway initiate resuscitation (Class I, LOE A).

For victims in asystolic cardiac arrest with a core-temperature <32 °C and an obstructed airway, presume asphyxia and withhold resuscitation (Class I, LOE A).

3.3.2. Rescue collapse

Collapse of hypothermic avalanche victims during rescue is associated with lethal arrhythmias, according to case reports.[31,35] Mechanical stimulation has been shown to produce lethal arrhythmias in a porcine model of hypothermia.[37] A core-temperature of 32 °C is considered the threshold for ventricular fibrillation.[38]

Recommendations. ECG monitoring[2] should be applied upon extrication and continued during transport, using maximum amplification if complexes are small (Class I, LOE B).

Mechanical irritation of hypothermic victims should be minimized, avoiding excessive limb extension, rough transport and unnecessary chest compressions (Class I, LOE B).

Transport victims in the horizontal position (Class I, LOE C).

3.3.3. Core-temperature

Accidental hypothermia has been defined as “an unintentional reduction in core-temperature <35 °C.”[13,15,38] Hypothermia may be staged using the “Swiss staging” system (based on clinical findings as well as core temperatures),[13,15,39] which corresponds with the system of Danzl.[38] Hypothermia is often combined with asphyxia and trauma, rendering clinical signs unreliable. Oesophageal temperatures are more reliable than other temperatures[40] and are recommended in intubated patients.[13,38,41] Alternatively, epitympanic temperatures are reasonably accurate in the non-intubated patient not in cardiac arrest, given a non-obstructed ear canal and correct application including insulation from cold air.[10,42] In a cold environment only thermistor-based, not infrared-based, epitympanic thermometers correlate well with core-temperature.[42] In human studies epitympanic, brain and bladder temperatures correlated well,[43] while rectal temperatures lagged behind oesophageal temperatures during rewarming.[36,40]

Recommendations. Don’t rely on clinical hypothermia staging alone when asphyxia and/or trauma occur (Class I, LOE C).

Obtain core-temperatures when hypothermia has management significance, with an oesophageal probe in the intubated or epitympanic thermistor probe in the non-intubated victim (Class I, LOE B).

Rectal temperature may be used to gauge hypothermia initially (Class IIa, LOE B).

3.3.4. Insulation

Afterdrop refers to continued decline in temperature after removal from cold. All guidelines recommend insulation from further cooling and most recommend removal of wet clothing,[4,11,15,38] which may however increase heat loss in a cold, windy environment. Manikin studies found that increasing insulation over wet clothing produced a similar reduction in heat loss compared to removing clothing[44] and that a windproof outer wrap over the insulation assembly is necessary.[45]

Recommendations. Hypothermic victims should be insulated against further heat loss with dry, low-conductivity, whole-body assemblies covered in a windproof and water-resistant outer shell[3] (Class I, LOE B).

Remove wet clothing only if the victim can be insulated effectively; cut clothing cautiously if victim has a hypothermia staging of moderate or worse (Class I, LOE C).

3.3.5. Out-of-hospital rewarming

Applying heat packs may improve comfort although core-temperature may not be increased.[46] Warmed humidified oxygen provides limited benefit.[13,14] Warmed infused fluids provide only minimal contribution to rewarming, with a hypothetical rise of 0.3 °C L^{-1} of 40 °C fluid,[47] and are difficult to keep warm in the field.

Recommendations. Apply safe heat sources such as covered chemical heat packs to the trunk (Class IIb, LOE B).

Maintain infusate at 38–42 °C (Class IIb, LOE B).

3.3.6. Oxygen

Adequate oxygenation may help reduce the risk of post-rescue collapse as it is known to improve myocardial stability.[38] Pulse-oximetry is inaccurate with cold exposure due to peripheral vasoconstriction as well as device malfunction, high altitude and bright ambient light.[48]

Recommendations. Apply supplemental oxygen to significantly hypothermic victims (Class IIb, LOE C).

Pulse-oximetry may be unreliable (Class IIb, LOE B).

3.3.7. Advanced airway

Advanced airway placement provides oxygenation and airway protection from aspiration and is low risk for triggering malignant arrhythmias.[49] Depolarizing neuromuscular paralytics (e.g. succinylcholine) may increase the serum potassium level and affect subsequent decisions.

Recommendation. Consider the impact of depolarizing paralytics on serum potassium if the latter is planned for resuscitation or advanced rewarming decisions (Class I, LOE B).

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[2] ECG monitoring may be performed with a monitor-defibrillator or an AED. AED monitoring is best with a device that has a monitor window.

[3] These may be purpose-built rescue bags with insulated hoods, or assemblies of blankets enclosed in aluminium foil combined with head protection.

Table 2
Staging and management of hypothermic avalanche victims.

CT	Swiss staging[a]	Danzl[b]	Treatment	Transfer
35–32 °C	Hypothermia I: conscious, shivering	Mild hypothermia	• Move actively • Drink warm, sweetened fluids[c] • Insulation	Nearest ED
32–28 °C	Hypothermia II: impaired consciousness, without shivering	Moderate hypothermia	• Gently extricate and immobilize horizontally • Continuously monitor with ECG and core temperature • Full body insulation • Apply chemical heat packs to trunk • Administer oxygen • Place iv or io line, without considerably delaying transport	Stable circulation: hospital with active rewarming facilities Unstable circulation: hospital with ECMO/CPB
28–24 °C	Hypothermia III: unconscious	Severe hypothermia	Additionally - • Protect upper airway: Recovery position or if reasonable advanced airway management • Try to avoid depolarizing paralytic agents • Withhold or carefully dose drugs (slow metabolism!)	Stable circulation: hospital with active rewarming facilities Unstable circulation: hospital with ECMO/CPB
<24 °C[d]	Hypothermia IV: no vital signs	Severe and profound (<20 °C) hypothermia	Additionally - • Standard CPR • Avoid excessive defibrillation attempts	Hospital with ECMO/CPB

[a] Durrer et al.[39] This Swiss staging system was adopted by the 2010 ERC Guidelines for Resuscitation. The clinical signs in the Swiss staging system reflect the effect of hypothermia only. Considering that consciousness can be impaired by asphyxia and trauma, core temperature measurement is necessary to assess the severity of hypothermia.[13]
[b] Danzl.[38]
[c] If transport delayed >2 h and no signs of trauma that would necessitate anaesthesia.
[d] 13.7 °C is the lowest core temperature recorded in a survivor of accidental hypothermia.
ALS, advanced life support; CT, core temperature; ECMO/CPB, extracorporeal rewarming/cardiopulmonary bypass; ED, emergency department.

3.3.8. CPR

In severely hypothermic patients respirations and pulse may be indistinct.

Recommendations. Check carefully for vital signs and ECG activity for up to 1 min (Class IIb, LOE C).

Initiate CPR if signs of life are absent at standard BLS rates (Class IIa, LOE B).

3.3.9. Defibrillation

Defibrillation of severely hypothermic patients (<28 °C) presenting with ventricular fibrillation is unsuccessful in most cases, though defibrillation thresholds vary individually and successful defibrillation with core-temperatures as low as 25.6 °C has been reported.[50] Due to the paucity of animal and human studies and conflicting results, experts disagree on the application of defibrillation with core-temperatures <30 °C.[13,14] The 2010 ERC-guidelines[13] recommend a maximum of three defibrillations at <30 °C while the 2010 AHA-guidelines[14] recommend standard defibrillation while rewarming.

Recommendations. Use standard defibrillations when indicated, regardless of core-temperature; repetitions beyond three attempts may be delayed until core-temperature >30 °C and should be avoided if they cause interruption of CPR and/or transport to rewarming (see *Transport*) (Class IIa, LOE B).

3.3.10. ALS medications

Similar to defibrillation, experts disagree on the effectiveness of advanced life support (ALS) drug therapy with core-temperatures <30 °C.[13,14] The 2010 ERC-guidelines[13] recommend no ALS drugs, while the 2010 AHA-guidelines[14] allow vasopressors in cardiac arrest. Vasopressors may induce arrhythmias and increase risk of frostbite. Drug metabolism is decreased with low core-temperature.[51]

Recommendation. It may be reasonable to consider vasopressors concurrently with rewarming strategies (Class IIb, LOE B).

3.3.11. Transport

For hypothermic victims with a perfusing rhythm, active external rewarming such as forced-air rewarming is successful.[13,14,38] For severely hypothermic victims in cardiac arrest, extracorporeal rewarming resulted in return of spontaneous circulation (ROSC) in 23 of 186 and survival to hospital discharge in 8 of 186 avalanche victims examined in a systematic review of seven case series and reports.[12] Complications after extracorporeal rewarming commonly include pulmonary oedema,[31,52] which may explain improved survival with extracorporeal membrane oxygenation (ECMO) compared to cardiopulmonary bypass (CPB).[52]

Recommendations. For victims with core-temperature <32 °C but no cardiac instability, i.e. systolic blood pressure ≥90 mmHg and no ventricular arrhythmias, and core-temperature >28 °C, transport to the nearest appropriate hospital for active external and minimally invasive rewarming (i.e. warm environment; chemical, electrical, or forced air heating packs or blankets; warm iv-fluids) is recommended[15] (Class I, LOE B).

Hypothermic victims with a patent or unknown airway, with cardiac instability or a core-temperature <28 °C, or in cardiac arrest, should be transported to a centre with ECMO or CPB; if ECMO/CPB is not available transport to an appropriate hospital for alternative active internal rewarming (e.g. thoracic lavage) with continued CPR is recommended (Class I, LOE B).

Notify the ECMO/CPB centre before departure (Class IIa, LOE C).

3.3.12. Serum potassium

Serum potassium was predictive of survival for hypothermic cardiac arrest victims in a systematic review of prognostic factors in avalanche resuscitation,[12] with higher levels and poorer survival in asphyxiated victims. The highest admission serum potassium with ROSC was 8 mmol L^{-1},[8] while the highest level with survival was 6.4 mmol L^{-1}.[33] In accidental hypothermia of any origin the highest admission potassium of a survivor was 11.8 mmol L^{-1} in a 31-month-old child exposed to freezing weather.[53]

Recommendations. For hypothermic victims in asystolic cardiac arrest where duration of burial or airway patency is unknown or where a decision for prolonged resuscitation or long transport to a centre for ECMO/CPB needs confirmation, a serum potassium <8 mmol L^{-1} would indicate continued action, >12 mmol L^{-1} would indicate termination of resuscitation and 8–12 mmol L^{-1} in an adult victim should be considered with other factors (Class I, LOE A).

3.3.13. Prognosis

Asphyxia markedly reduces survival in hypothermic cardiac arrest despite extracorporeal rewarming.[6–8,52] The lowest core-temperature reported to date for a survivor of accidental hypothermia is 13.7 °C in a victim trapped in a waterfall gully[30] and 19 °C in a victim of avalanche burial.[5]

Recommendation. Victims of hypothermic cardiac arrest found with a patent or unknown airway and who are otherwise deemed possible survivors should be resuscitated until rewarmed to a core-temperature >32 °C before a final decision is made (Class I, LOE C).

3.4. General measures

3.4.1. Oral fluids

Two Cochrane Systematic Reviews and the practice guideline of the American Society of Anesthesiologists found no evidence of adverse effects from clear fluids up to 2 h prior to surgery in otherwise healthy patients with no abnormal risk of regurgitation or aspiration.[54]

Recommendations. Alert victims not requiring sedation or anaesthesia within 2 h may drink warmed, clear, calorie-containing, non-alcoholic, non-caffeinated fluids to sustain hydration and spontaneous rewarming (Class IIb, LOE B).

3.4.2. Activity

Recommendation. Alert mildly hypothermic victims (35–32 °C) may exercise to rewarm (Class IIa, LOE C).

3.4.3. Organized rescue

Recommendations. Organized rescue teams should mobilize promptly, ideally by helicopter, and should include clinicians skilled in mountain emergency medicine and be staffed according to the number of buried victims (Class IIa, LOE C).

Dogs and handlers may accompany organized rescue teams to find completely buried victims. Once all victims have been located there is no use for dogs and handlers (Class IIa, LOE C).

All staff should have appropriate safety equipment, especially avalanche transceivers and airbags (Class I, LOE B).

Medical equipment should include core-temperature and ECG monitor/defibrillator devices and appropriate medications; all instruments should be insulated and have fully-charged batteries (Class I, LOE B).

The potential risk to the rescuers must be evaluated, taking *less risk after longer burials* (Class IIb, LOE C).

3.4.4. Triage

A multiple casualty incident may initially overwhelm rescuers, and limited resources should be allocated to those most likely to survive.[55]

Recommendations. When resources are overwhelmed by multiple victims in cardiac arrest priority should be given to those with a cardiac rhythm, a higher core-temperature and other favourable factors (Class IIb, LOE B).

3.5. Termination of CPR

The very poor survival of patients suffering prehospital normothermic asystolic cardiac arrest has resulted in validated EMS termination-of-resuscitation rules that have been incorporated into a guideline for mountain rescue (Class IIb, LOE C).[56]

Recommendations. Resuscitation may be terminated (or withheld) when rescuer safety is unacceptably high, lethal injuries such as decapitation or truncal transection have occurred, the body is completely frozen, a valid do-not-resuscitate order exists, or limitations in transport or other logistics render resuscitation futile (Class I, LOE C).

Resuscitation may be terminated in unwitnessed cardiac arrest when, after 20 min of resuscitation, there has been no ROSC with no shock advised by AED or only asystole seen on ECG with no hypothermia or other special circumstance warranting extended CPR (Class IIa, LOE A).

4. Conclusions

The algorithm for the management of avalanche victims is shown in Fig. 2. If lethal injuries are excluded and the body is not frozen, the rescue strategy is governed by the duration of snow burial and, if not available, by the victim's core-temperature. If burial time ≤35 min (or core-temperature ≥32 °C) rapid extrication and standard ALS is important. If burial time >35 min and core-temperature <32 °C, treatment of hypothermia including gentle extrication, full body insulation, ECG and core-temperature monitoring is recommended, as well as advanced airway management if appropriate. Unresponsive patients presenting with vital signs should be transported to a hospital capable of active external and minimally invasive rewarming such as forced air rewarming. Patients with cardiac instability or in cardiac arrest (with a patent airway) should be transported with uninterrupted CPR to an ECMO/CPB rewarming centre. Management should include spinal precautions and other trauma care as indicated.

Conflicts of interest statement

None of the authors have a commercial or industrial conflict of interest. H.B., J.B., B.D., P.P. and K.Z. have published on hypothermia. H.B. receives support as the head of the Institute of Mountain Emergency Medicine, EURAC research.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2012.10.020.

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