



Clinical Paper

Outcome of avalanche victims with out-of-hospital cardiac arrest[☆]Luca Moroder^a, Birgit Mair^{a,b}, Hermann Brugger^c, Wolfgang Voelckel^{b,d}, Peter Mair^{a,b,*}^a Department of Anaesthesiology and Critical Care Medicine, Medical University of Innsbruck, Anichstrasse 35, 6020 Innsbruck, Austria^b Christophorus Emergency Medical Helicopter Service, Schubertring 1-3, 1010 Vienna, Austria^c Institute of Mountain Emergency Medicine, EURAC Research, Viale Druso 1, 39100 Bolzano, Italy^d Department of Anaesthesiology and Critical Care Medicine, AUVA Trauma Hospital Salzburg, Dr.-Franz-Rehrl-Platz 4, 5010 Salzburg, Austria

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ABSTRACT

Study background: Previous studies focused on the outcome of avalanche victims with out-of-hospital cardiac arrest (OHCA) after long duration of burial (>35 min); the outcome of victims with short duration (≤ 35 min) remains obscure.

Aim of the study: To investigate outcome of avalanche victims with OHCA.

Methods: Retrospective analysis of avalanche victims with OHCA between 2008 and 2013 in the Tyrolean Alps.

Results: 55 avalanche victims were identified, 32 of whom were declared dead after extrication without cardiopulmonary resuscitation (CPR), all with long duration of burial. In the remaining 23 CPR was initiated at scene; three were partially and 20 completely buried, nine of whom suffered short and 11 long duration of burial. All nine victims with short duration of burial underwent restoration of spontaneous circulation (ROSC) at scene, four of them after bystander CPR, five after advanced life support by the emergency physician. Two patients with ROSC after short duration of burial and bystander CPR survived to hospital discharge with cerebral performance category 1. None of the 11 victims with long duration of burial survived to hospital discharge, although six were transported to hospital with ongoing CPR and three were supported with extracorporeal circulation.

Conclusions: In this case series survival with favourable neurological outcome was observed in avalanche victims with short duration of burial only if bystander CPR was immediately performed and ROSC achieved. Strategies for reducing avalanche mortality should focus on prompt extrication from the snow and immediate bystander CPR by uninjured companions.

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1. Introduction

Several publications have highlighted the possibility of survival in avalanche victims with long duration of complete burial and out-of-hospital cardiac arrest (OHCA) due to the protective effects of accidental hypothermia that can develop after more than 35 min snow burial.^{1–3} Recommendations for the triage and management of arrested avalanche victims with duration of burial exceeding 35 min have been published.⁴ Asphyxia, however, is considered the main underlying pathology for cardiac arrest, while hypothermia is a rare reason for cardiac arrest in avalanche accidents.^{5–7} With the use of avalanche transceivers many completely buried

victims can be extricated from the snow within less than 35 min and resuscitated by bystanders, if necessary.^{6,8,9} The outcome of patients presenting with OHCA after short duration of burial (up to 35 min) has not yet been studied. In such cases asphyxia or trauma, but not hypothermia, may be the cause of cardiac arrest.^{5,6,9,10} The current study evaluated the pre-hospital and in-hospital resuscitation measures and outcome of patients with OHCA in a consecutive series of avalanche victims.

2. Methods

After Ethics Committee approval all rescue missions conducted for avalanche accidents in the Austrian state of Tyrol during five consecutive winter seasons (October 2008 to June 2013) were reviewed. Rescue missions involving at least one victim with OHCA were identified and included in this retrospective observational study.

[☆] A Spanish translated version of the abstract of this article appears as Appendix in the final online version at <http://dx.doi.org/10.1016/j.resuscitation.2015.01.019>.

* Corresponding author at: Department of Anaesthesiology and Critical Care Medicine, Medical University of Innsbruck, Anichstrasse 35, 6020 Innsbruck, Austria. E-mail address: p.mair@uki.at (P. Mair).

Table 1
Patient characteristics and outcome of partially buried avalanche victims ($n=3$) with out-of-hospital cardiac arrest.

Patient	Rhythm	CT* (°C)	pH*	Lactate* (mmol L ⁻¹)	Potassium* (mmol L ⁻¹)	Outcome	Cause of death	Remarks
Male, 38 years [#]	PEA	–	–	–	–	Died on scene	Multisystem trauma	ALS stopped on scene
Male, 33 years	PEA	30	7.00	12.4	3.6	Died after 2 days	Brain injury, spinal shock	Spine fracture C ₁ /C ₂ , spinal cord lesion, brain oedema
Male, 49 years [#]	VF	22	6.95	10.0	3.8	Died after 5 h	Intractable bleeding	Multisystem trauma, rewarming with ECMO

[#] Witnessed cardiac arrest, PEA = pulseless electrical activity, VF = ventricular fibrillation, CT = core body temperature, * at hospital admission, ALS = advanced life support by emergency physician, ECMO = extracorporeal membrane oxygenation.

Data on accident and rescue mission characteristics were retrieved from accident reports of the Tyrolean Avalanche Forecast Centre and from mission protocols of the rescue services involved. Data included date and location of the avalanche accident, burial status of the victims (partially buried, completely buried), type of rescue for completely buried victims (bystander rescue or rescue by the organized rescue team) and duration of burial. A victim was considered partially buried when his head was unburied and the victim was able to breathe. A victim was considered completely buried when his head was under the snow and he was at risk of suffocating. Duration of burial is considered short for durations up to 35 min and long if duration exceeds 35 min.

Medical parts of the mission protocols were reviewed by two of the authors (L.M., P.M.) to retrieve available information concerning the victim's medical condition and pre-hospital therapy. Pre-hospital data included circumstances of cardiac arrest (witnessed, unwitnessed), type of CPR (no CPR, bystander CPR, advanced life support [ALS] by an emergency physician) and outcome of pre-hospital CPR efforts (terminated at scene, ongoing CPR until hospital admission, ROSC after bystander CPR or ROSC after ALS by an emergency physician). In-hospital data included termination of CPR, duration of intensive care unit stay, transfer from outside hospital to Innsbruck Medical University Hospital and survival and neurological outcome using the Cerebral Performance Category Scale. In addition, for all patients admitted to Innsbruck Medical University systolic blood pressure, core temperature, pH (not temperature corrected), serum potassium and serum lactate concentrations and whole body computed tomography (CT) scan findings on admission were retrieved from hospital charts.

3. Results

A total of 55 victims with OHCA were identified in 41 avalanche rescue missions and included in this retrospective study. Of the 55

avalanche victims 32 (58%) were declared dead at scene without any attempt at resuscitation. Of these 32 patients six were only partially buried and showed signs of severe trauma on external examination. The remaining 26 victims were completely buried and duration of snow burial exceeded 35 min in all 26 victims (median 155 min, range: 60 min to 14 days). In 23 (42%) of the 55 avalanche victims CPR was commenced at scene: in 21 immediately after being extricated without signs of life and in 2 when witnessed cardiac arrest occurred after extrication. CPR was commenced in three partially buried victims, in nine completely buried victims with short duration of burial and in 11 completely buried victims with long duration of burial.

3.1. Outcome of partially buried victims

None of the three partially buried victims survived to hospital discharge (patient characteristics, therapeutic interventions and outcome, see Table 1). Death was related to trauma in all three patients. One of the victims was already in cardiac arrest when the rescue team arrived. Two victims sustained witnessed cardiac arrest after rescue team arrival: one with severe accidental hypothermia developed ventricular fibrillation shortly after extrication (core temperature at scene was 20.5 °C, at hospital admission 22 °C) another victim with critical multisystem trauma sustained pulseless electrical activity during winch evacuation.

3.2. Outcome of completely buried victims with short duration of burial (less than 35 min)

ROSC at scene was achieved in all nine patients. In four patients after bystander CPR before medical teams arrived at scene (all 4 extricated by comrade rescue within 20 min of burial) and in five patients after ALS administered by an emergency physician (4 of 5 were extricated by comrades within 20 min of burial and

Table 2
Patient characteristics and neurological outcome at hospital discharge of survivors ($n=5$) with restoration of spontaneous circulation after short duration of burial (up to 35 min).

Patient	Duration of burial (min)	ROSC after	GCS	SBP* (mmHg)	CT* (°C)	pH*	Lactate* (mmol L ⁻¹)	Total body CT scan*	ICU stay (days)	CPC
Male, 49 years	10	BLS	14	150	35	7.29	4.1	Lung oedema	2	1
Male, 25 years	15	BLS	3	80	31.5	7.31	8.8	Bilateral lung contusion, pneumothorax	2	1
Female, 30 years	15	BLS	3	110	30	7.12	12.0	Normal	16	4
Male, 26 years	20	BLS	4	140	28	7.02	11.9	Brain oedema	10	4
Male, 31 years	20	ALS	4	100	24	6.85	19.9	Pulmonary infiltration, aspiration, brain oedema	22	4

ROSC = restoration of spontaneous circulation, BLS = bystander CPR, ALS = advanced life support by emergency physician, GCS = best pre-hospital Glasgow Coma Score after ROSC, SBP = systolic blood pressure, CT = core body temperature, * at hospital admission, CPC = Cerebral Performance Category.

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