Avalanche survival and medical management

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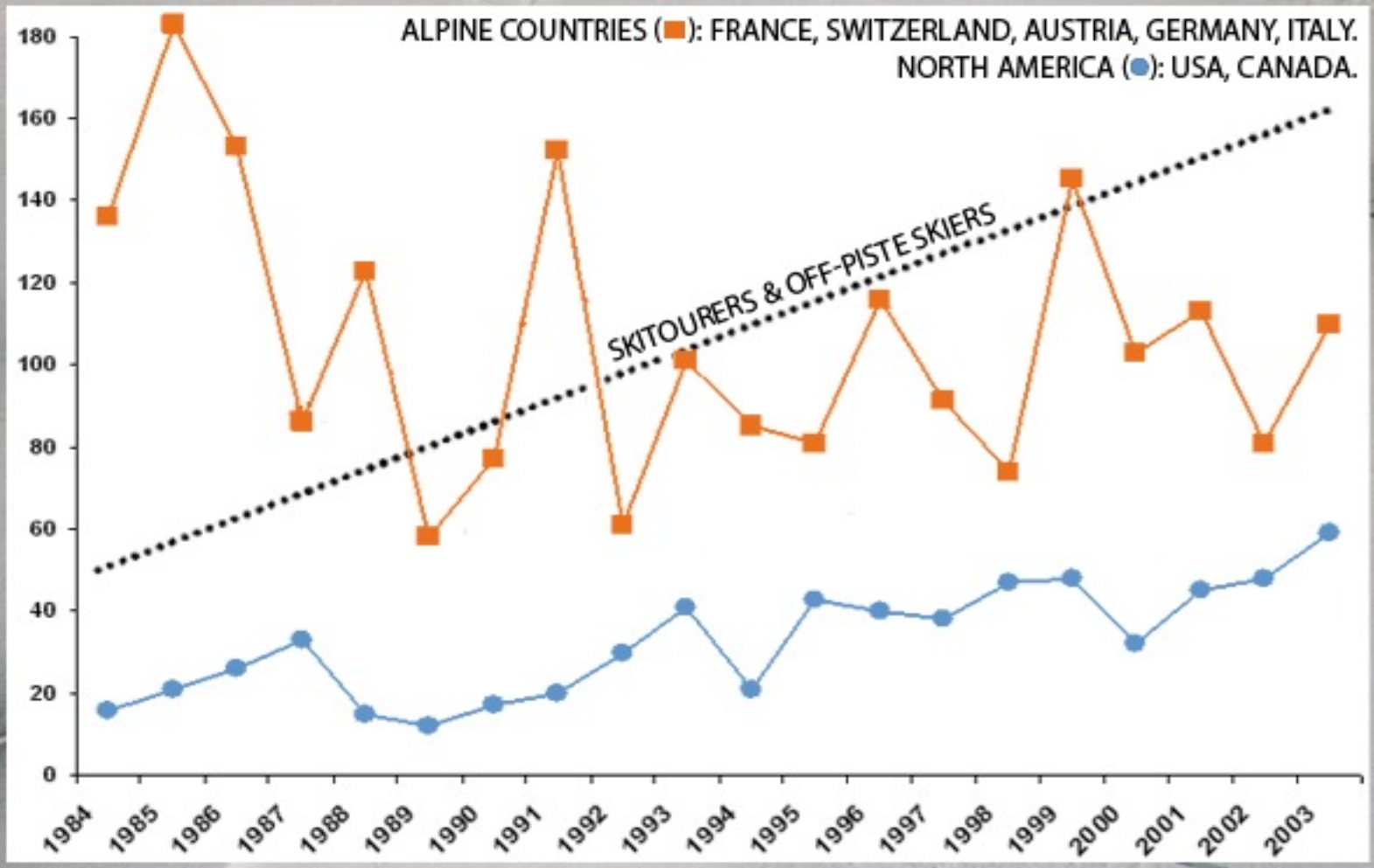
1. Features of avalanche burial
2. Outcome
3. Treatment
4. Hypothermic vs. normothermic CA
5. Intermittent CPR

Features of avalanche burial

ANNUAL AVALANCHE DEATHS

1984 – 2003 (n = 2782)



Critical burial: a burial in which the head and chest are buried under snow

Non-critical burial: head and chest not buried under snow

Pasquier M et al. Resuscitation 184 (2023):109708

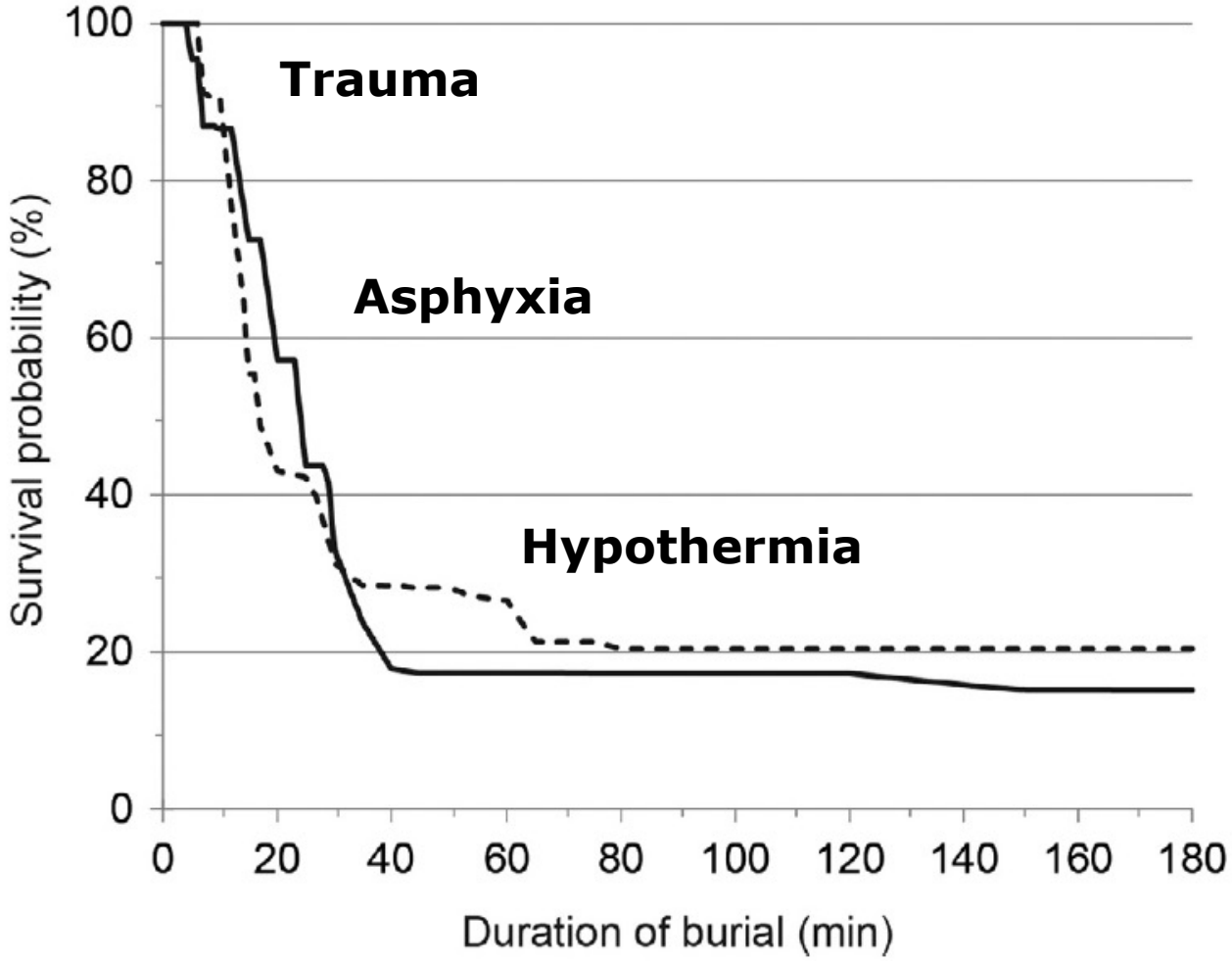


Fig. 2. Survival curve for Austria (solid line) and Switzerland (dashed line) for completely buried victims between 2005 and 2013.

Procter E, et al. Resuscitation 2016; Aug: 105:173-6. doi: 10.1016/j.resuscitation.2016.06.001. (1):56-61

HIGH ALTITUDE MEDICINE & BIOLOGY
Volume 00, Number 00, 2021

DOI: 10.1089/ham.2020.0222

Extreme Cooling Rates in Avalanche Victims: Case Report and Narrative Review

Christof Mittermair,[1] Eva Foidl,[2] Bernd Wallner,[3,4] Hermann Brugger,[4,5] and Peter Paal[5,6]

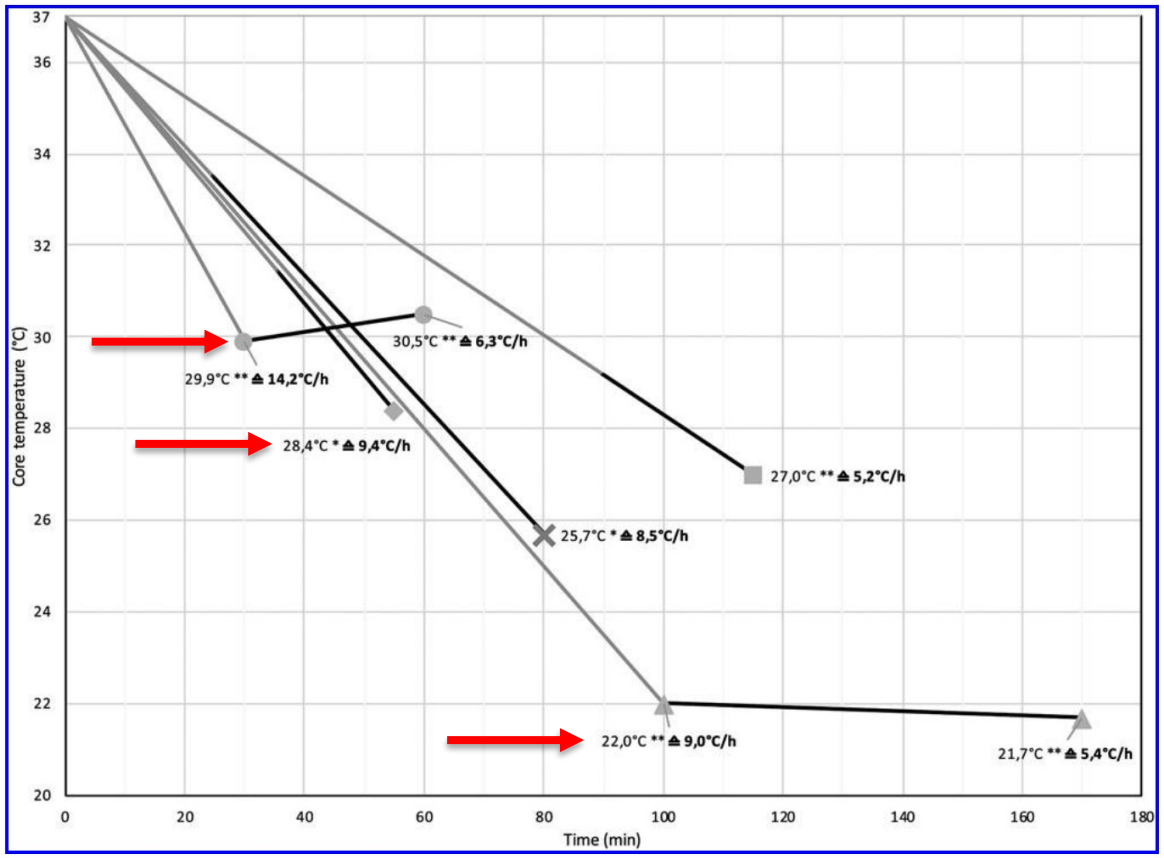


FIG. 1. Core temperature of avalanche victims related to time after burial. *Grey lines* denote time of burial, and *black lines* denote postburial exposure. *Grey numbers* indicate core temperature (°C), and *black numbers* indicate cooling rates (°C/h). *Esophageal, **epitympanic temperature measurement. ● *Partial burial* (Strohle et al., 2015). ■ *Complete burial* (Putzer et al., 2010). ◆ *Complete burial* (Pasquier et al., 2015). ✖ *Complete burial* (Present case report). ▲ *Complete burial* (Oberhammer et al., 2008).

Contributing factors to fast cooling are

- **sweating**
- **impaired consciousness**
- **no shivering**
- **wearing thin monolayer clothing**
- **head and hands uncovered**
- **an air pocket, and development of hypercapnia**
- **being slender**

EVERY SECOND COUNTS

DETERMINING THE POSITION WITH AN AVALANCHE BEACON TAKES 3-5 MINUTES AND EXTRICATING THE VICTIM FROM 1M WITH A SHOVEL TAKES 10-15 MINUTES

Outcome

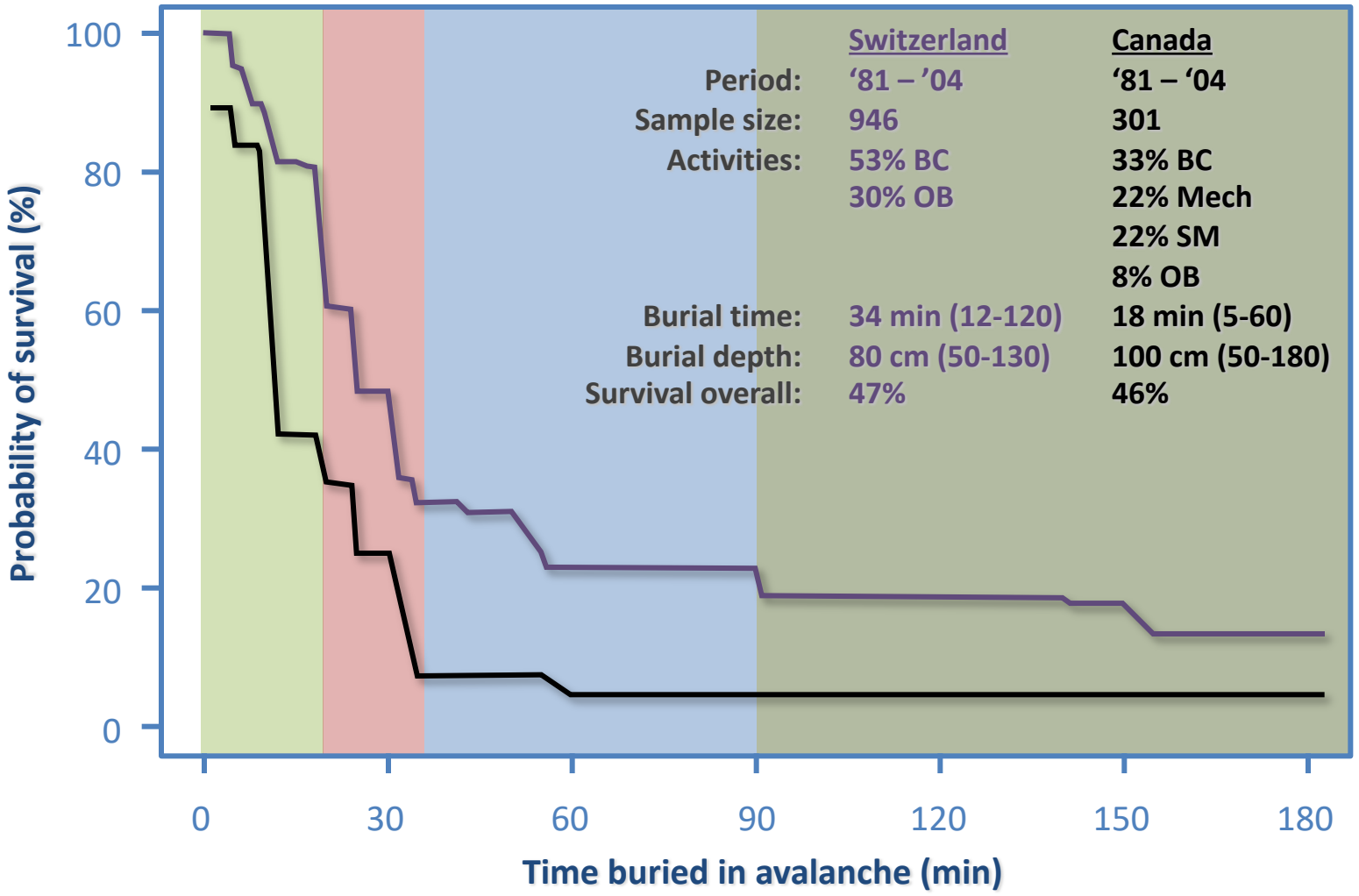
MORTALITY RATES

n = 2049

	TOTAL NUMBER OF VICTIMS	EXTENT OF BURIAL	
		Critical	Non-critical
EXTRICATED ALIVE	1603 (78.2%)	369 (48.7%)	1233 (95.6%)
EXTRICATED DEAD	446 (21.8%)	389 (51.3%)	57 (4.4%)
RESPECTIVE TOTALS	2049 (100%)	758 (37%)	1290 (63%)

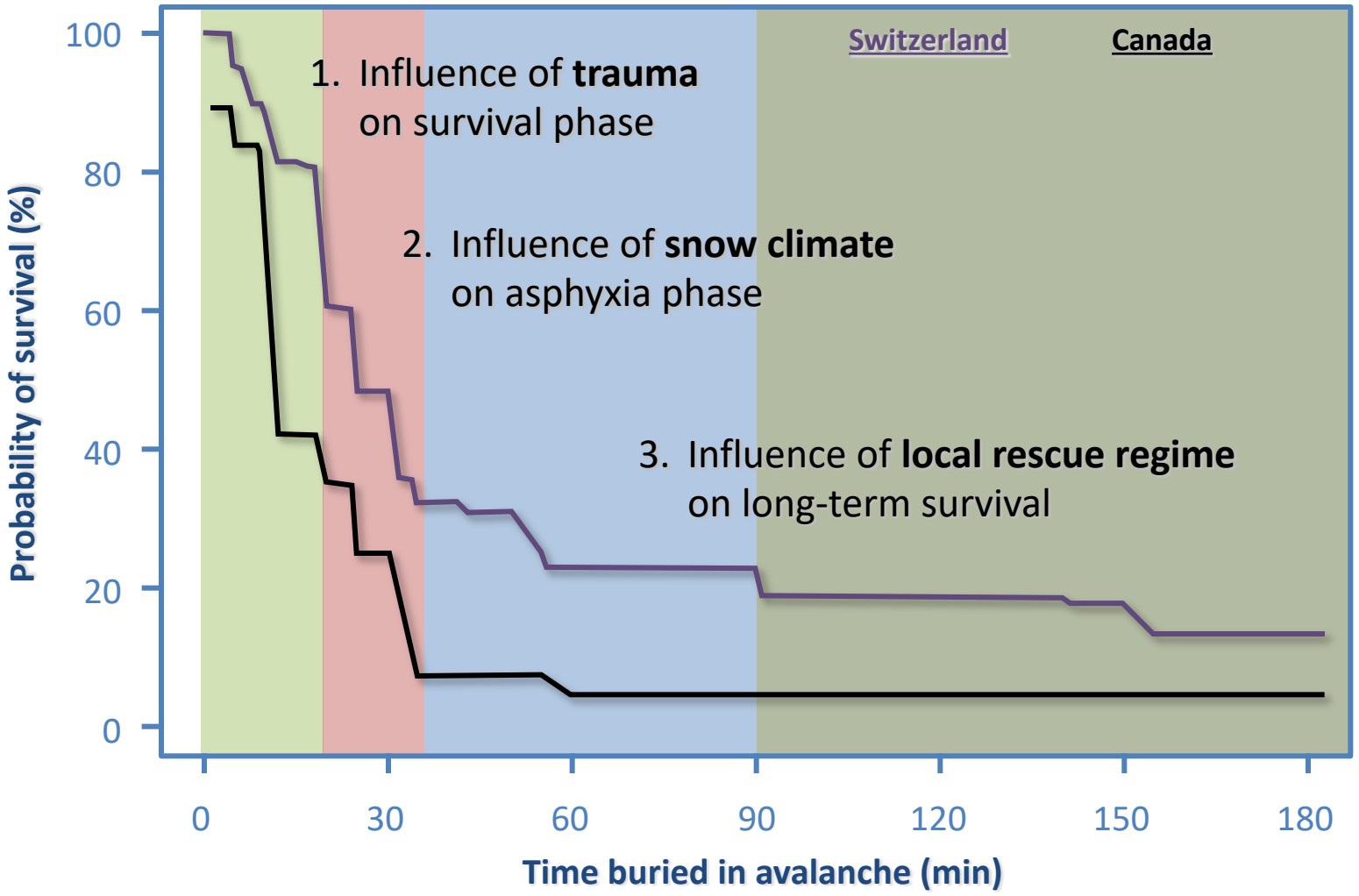
ANALYSIS OF THE COMPREHENSIVE DATA ON VICTIMS EXTRICATED ALIVE OR DEAD
IN ALL AVALANCHE ACCIDENTS IN SWITZERLAND 1981 – 2001 ACCORDING TO EXTENT OF BURIAL
* ALL P VALUES < 0.001 (PEARSON'S CHI-SQUARE)
Brugger H, Durrer, B, Adler-Kastner L, Falk M, Tschirky F. Resuscitation 2001

Avalanche survival in Canada vs. Switzerland



Haegeli P, Brugger H, et al. CMAJ 2011 Apr 19;183(7):789-95

Avalanche survival in Canada vs. Switzerland



Haegeli P, Brugger H, et al. CMAJ 2011 Apr 19;183(7):789-95

Hypothermic vs. normothermic CA

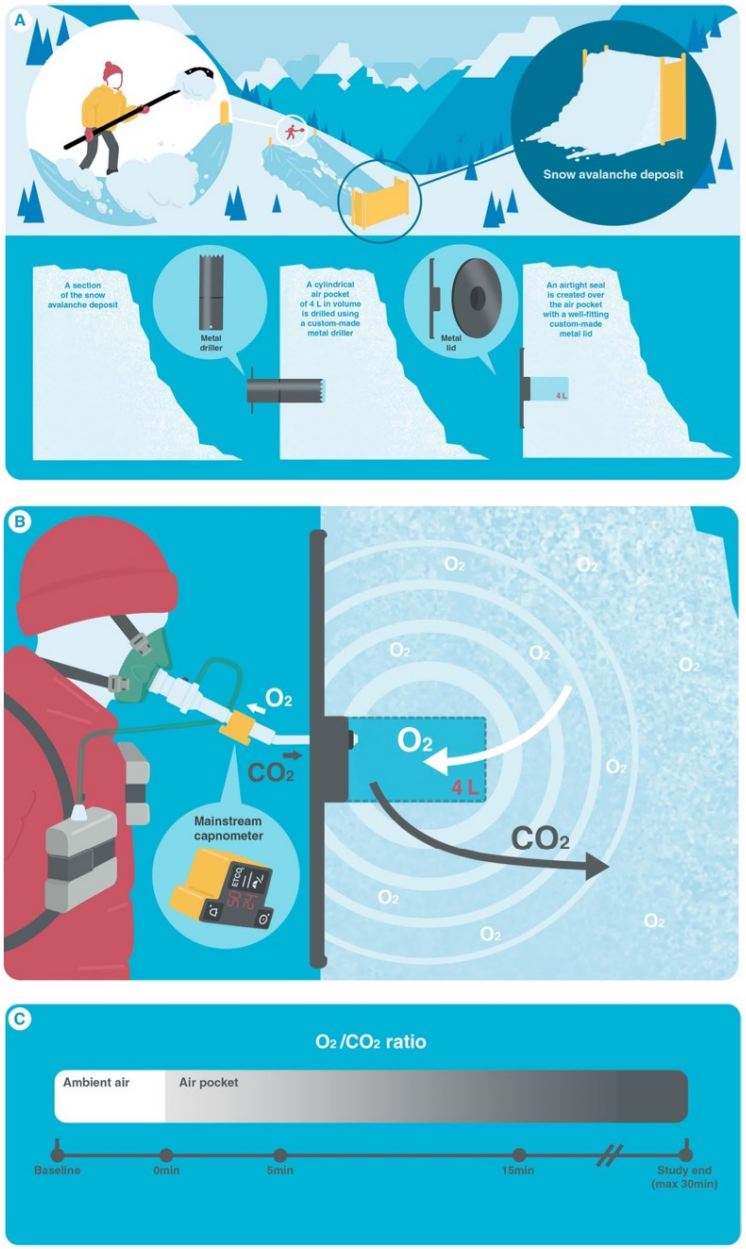
SCIENTIFIC REPORTS

OPEN

Effects of snow properties on humans breathing into an artificial air pocket – an experimental field study

Received: 23 June 2017
Accepted: 1 December 2017
Published online: 15 December 2017

Giacomo Strapazzon[1], Peter Paal[2,3], Jürg Schweizer[4], Markus Falk[1], Benjamin Reuter[4], Kai Schenk[1,5], Hannes Gatterer[5], Katharina Grasegger[1], Tomas Dal Cappello[1], Sandro Malacrida[1], Lukas Riess[6] & Hermann Brugger[1,6]



Strapazzon G, et al. Scientific Reports, volume 7, Article number: 17675 (2017)

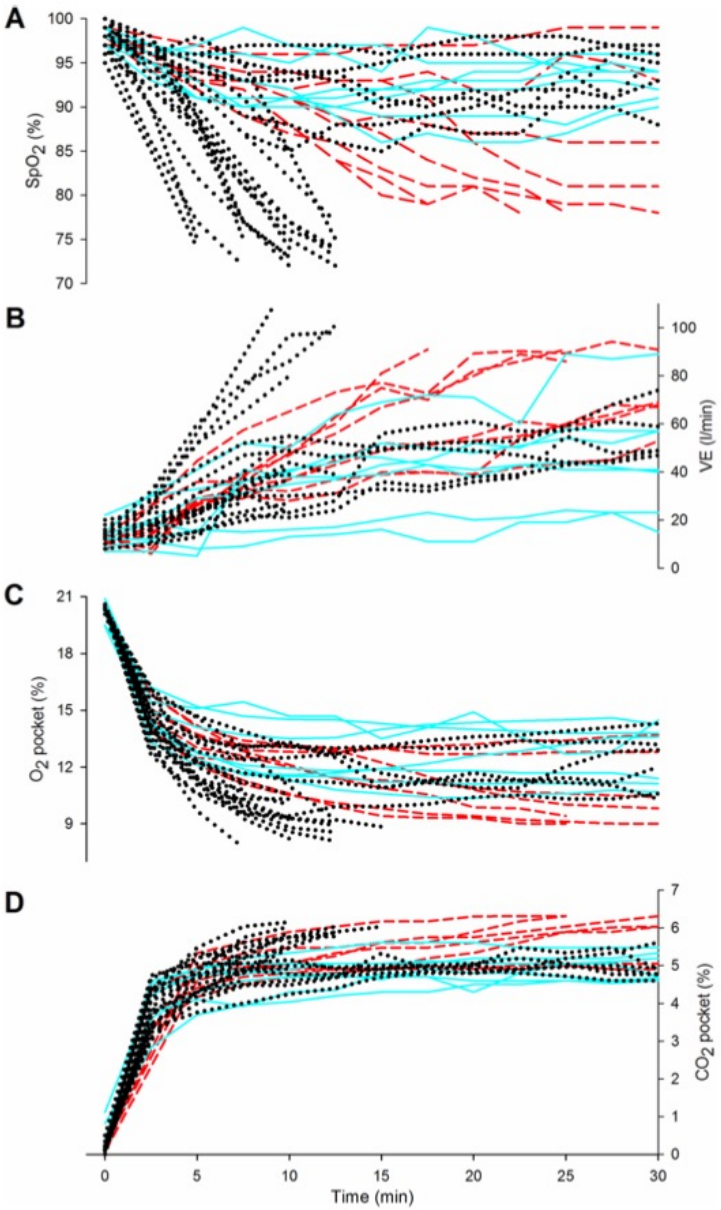


Figure 4. Curves of individual respiratory-gas and ventilatory parameters during the tests. (**A**) Peripheral oxygen saturation (SpO_2). (**B**) Minute respiratory volume (VE). (**C**) Oxygen concentration in the air pocket (O_2 pocket). (**D**) Carbon dioxide concentration in the air pocket (CO_2 pocket). Dashed red line represents tests done breathing into an air pocket surrounded by snow density $\leq 250\,kg/m^3$, solid blue line by snow density between $251–350\,kg/m^3$ and dotted black line by snow density $> 350\,kg/m^3$ (n = 36 for **A**; n = 35 for **B,C** & **D**).

Strapazzon G, et al.
Scientific Reports, volume 7,
Article number: 17675 (2017)

Resuscitation 105 (2016) 173–176

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Burial duration, depth and air pocket explain avalanche survival patterns in Austria and Switzerland☆

Emily Procter[a,b], Giacomo Strapazzon[a,*], Tomas Dal Cappello[a], Benjamin Zweifel[c], Andreas Würtele[d], Andreas Renner[a], Markus Falk[a,e], Hermann Brugger[a]

Table 2
Factors affecting survival in victims buried ≤180 min in Austria and Switzerland (n = 500) based on a logistic regression analysis.

Variable	Level	Austria and Switzerland (n = 500)		
		OR	95% CI	p-value
Duration of burial (min)	≤15 (reference)	–	–	<0.001
	16–35	8.7	5.01–15.10	<0.001
	36–60	18.11	8.72–37.62	<0.001
	>60	28.67	12.72–64.63	<0.001
Burial depth (cm)	≤40 (reference)	–	–	<0.001
	41–80	2.41	1.20–4.87	0.014
	81–120	4.05	2.01–8.17	<0.001
	>120	4.92	2.41–10.05	<0.001

OR, odds ratio; CI, confidence interval.

Table 3
Rate of survival with and without an air pocket for burial ≤180 min (Austrian data, n = 273).

Duration of burial (min)	Air pocket	Survived n (%)	Died n (%)	p-value
≤15	No	25 (69)	11 (31)	<0.001
	Yes	122 (95)	6 (5)	
>15	No	3 (4)	63 (96)	<0.001
	Yes	29 (67)	14 (33)	

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

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 Anesthesiology and Critical Care Medicine, AUVA Trauma Hospital Salzburg, Dr.-Franz-Rehrl-Platz 4, 5010 Salzburg, Austria

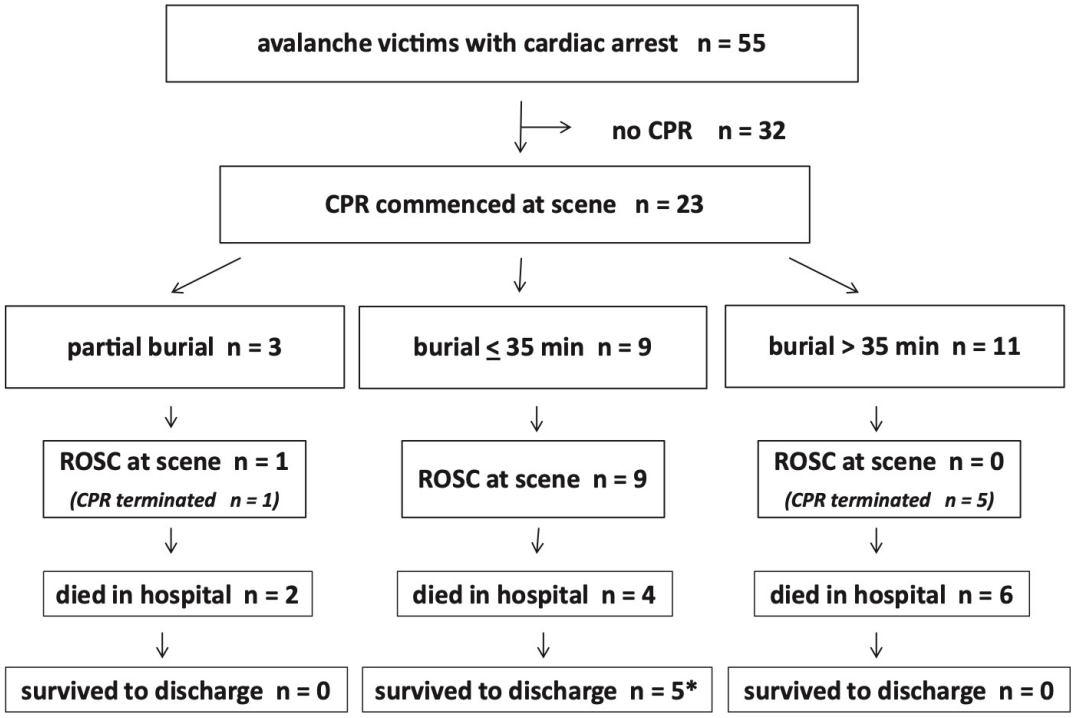


Fig. 1. Management and outcome of avalanche victims with out-of-hospital cardiac arrest ($n = 55$). Abbreviations: * two of five survived with full neurological recovery (cerebral performance category 1). ROSC = restoration of spontaneous circulation.

Moroder L, et al. Resuscitation. 2015 Apr;89:114-8. doi: 10.1016/j.resuscitation.2015.01.019.

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.

Moroder L, et al. Resuscitation. 2015 Apr;89:114-8. doi: 10.1016/j.resuscitation.2015.01.019.

Hypothermic cardiac arrest

Revised Swiss Staging

	Stage 1	Stage 2	Stage 3	Stage 4
Clinical findings[1]	"Alert" from AVPU	"Verbal" from AVPU	"Painful" or "Unconscious" from AVPU Vital signs present	"Unconscious" from AVPU **AND** No detectable vital signs[2]
Risk of cardiac arrest[3]	**Low**	**Moderate**	**High**	**Hypothermic cardiac arrest**
Oxygen	According to good clinical practice, (goal: $SpO_2 > 94\%$)[4]	+	+	+
Carbohydrats	Warm sweet tea, sweet bars	Glucose i.v./ i.o.[5]	Glucose i.v. / i.o.[5]	-
Active movement	+	-[6]	-	-
Passive rewarming	+	+	+	+
Active rewarming	(+)	+	+	+
Cautious mobilization / horizontal transport if possible	-	+	+	-
Defibrillation pads		+	+	+
Intubation			to be considered	+
Hypothermia CPR				+
Defibrillation				+[7]

Musi M, et al Resuscitation 2021. May;162:182-187

Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Clinical characteristics and outcomes of witnessed hypothermic cardiac arrest: A systematic review on rescue collapse

C. Frei[a], T. Darocha[b], G. Debaty[c], F. Dami[d], M. Blancher[c], P.N. Carron[d], M. Oddo[e], M. Pasquier[d,]*

- Hypothermic CA only <30 ° C
- **Survival** at hospital discharge **73%**
- **Neurologically favourable outcome 89%**

Resuscitation. 2019 Apr;137:41-48. doi: 10.1016/j.resuscitation.2019.02.001.

Resuscitation 90 (2015) 46–49

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Commentary and concepts

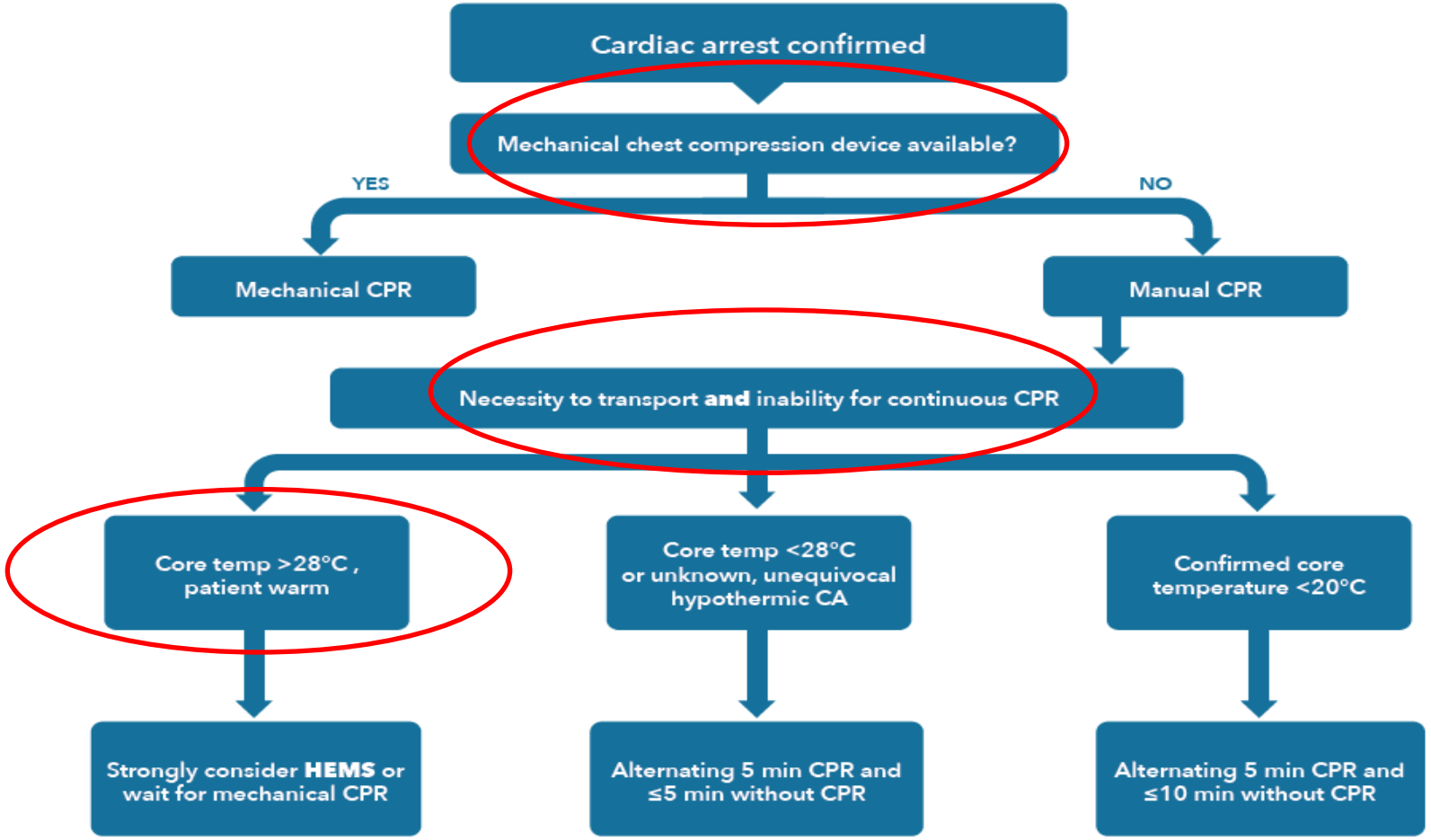
Delayed and intermittent CPR for severe accidental hypothermia☆

Les Gordon[a,b], Peter Paal[c,d,*], John A. Ellerton[e,d], Hermann Brugger[f,g,d], Giles J. Peek[h,i,j], Ken Zafren[k,l,d]

[a] University Hospitals of Morecambe Bay Trust, Royal Lancaster Infirmary, LA1 4RP, United Kingdom
[b] Langdale Ambleside Mountain Rescue Team, United Kingdom
[c] Department of Anaesthesiology and Critical Care Medicine, University Hospital Innsbruck, Austria
[d] International Commission for Mountain Emergency Medicine (ICAR MEDCOM), Austria
[e] Birbeck Medical Group, Penrith, Cumbria, United Kingdom
[f] Institute of Mountain Emergency Medicine, EURAC Research, Bolzano, Italy
[g] Medical University Innsbruck, Austria
[h] East Midlands Congenital Heart Centre, United Kingdom
[i] Glenfield Hospital, Leicester LE3 9QP, United Kingdom
[j] EuroELSO Steering Committee, United Kingdom
[k] Division of Emergency Medicine, Department of Surgery, Stanford University School of Medicine, Stanford, CA, USA
[l] Medical Director, Alaska Mountain Rescue Group, USA

ICPR DELAYED AND INTERMITTENT CPR IN HYPOTHERMIC PATIENTS WHEN CONTINUOUS CPR IS NOT POSSIBLE DURING DIFFICULT RESCUE MISSIONS

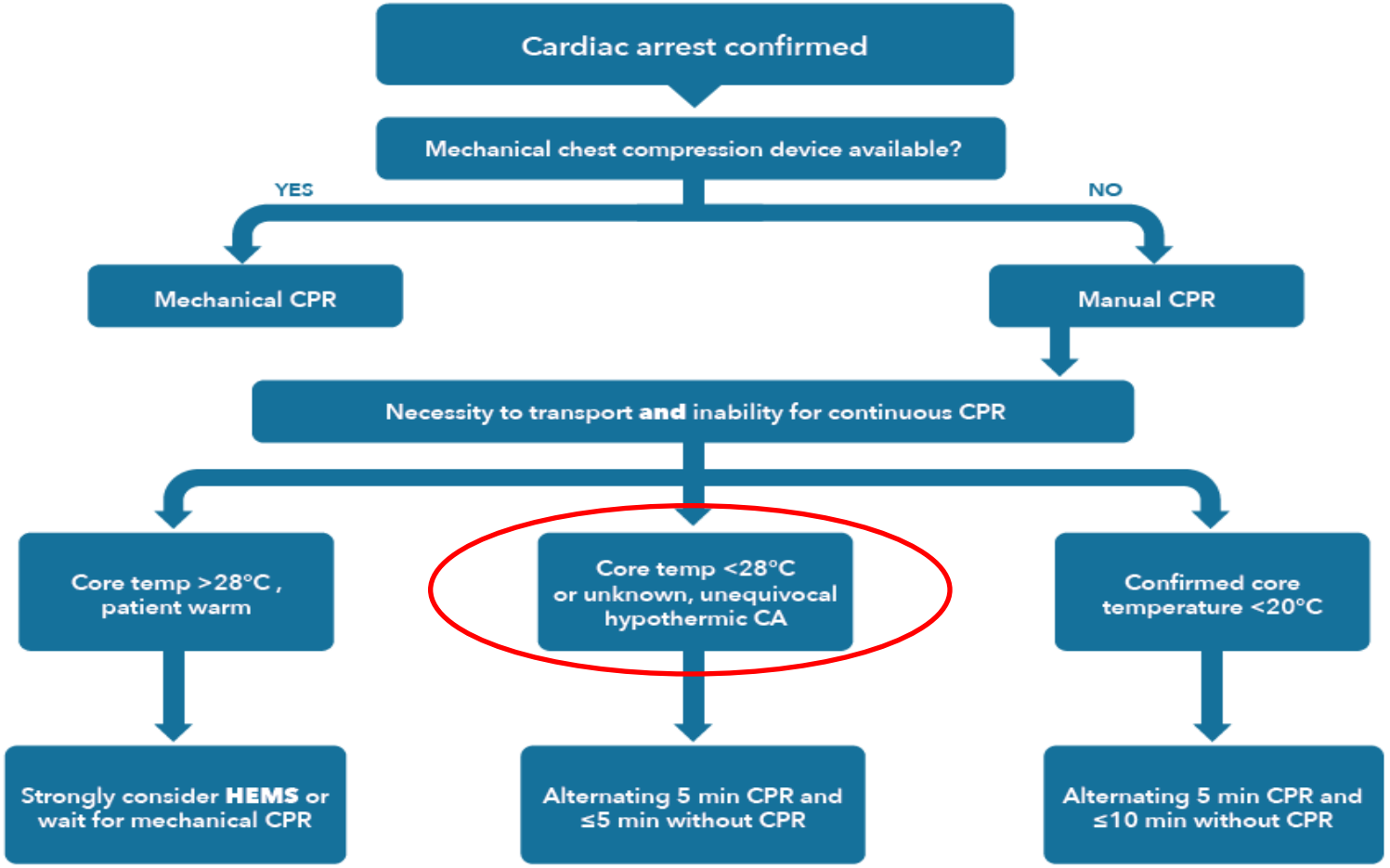
EUROPEAN RESUSCITATION COUNCIL



Lott C, et al. Resuscitation 2021. Apr;161:152-219

ICPR DELAYED AND INTERMITTENT CPR IN HYPOTHERMIC PATIENTS WHEN CONTINUOUS CPR IS NOT POSSIBLE DURING DIFFICULT RESCUE MISSIONS

EUROPEAN RESUSCITATION COUNCIL



Lott C, et al. Resuscitation 2021. Apr;161:152-219

Treatment

RESUSCITATION 184 (2023) 109708

Available online at ScienceDirect

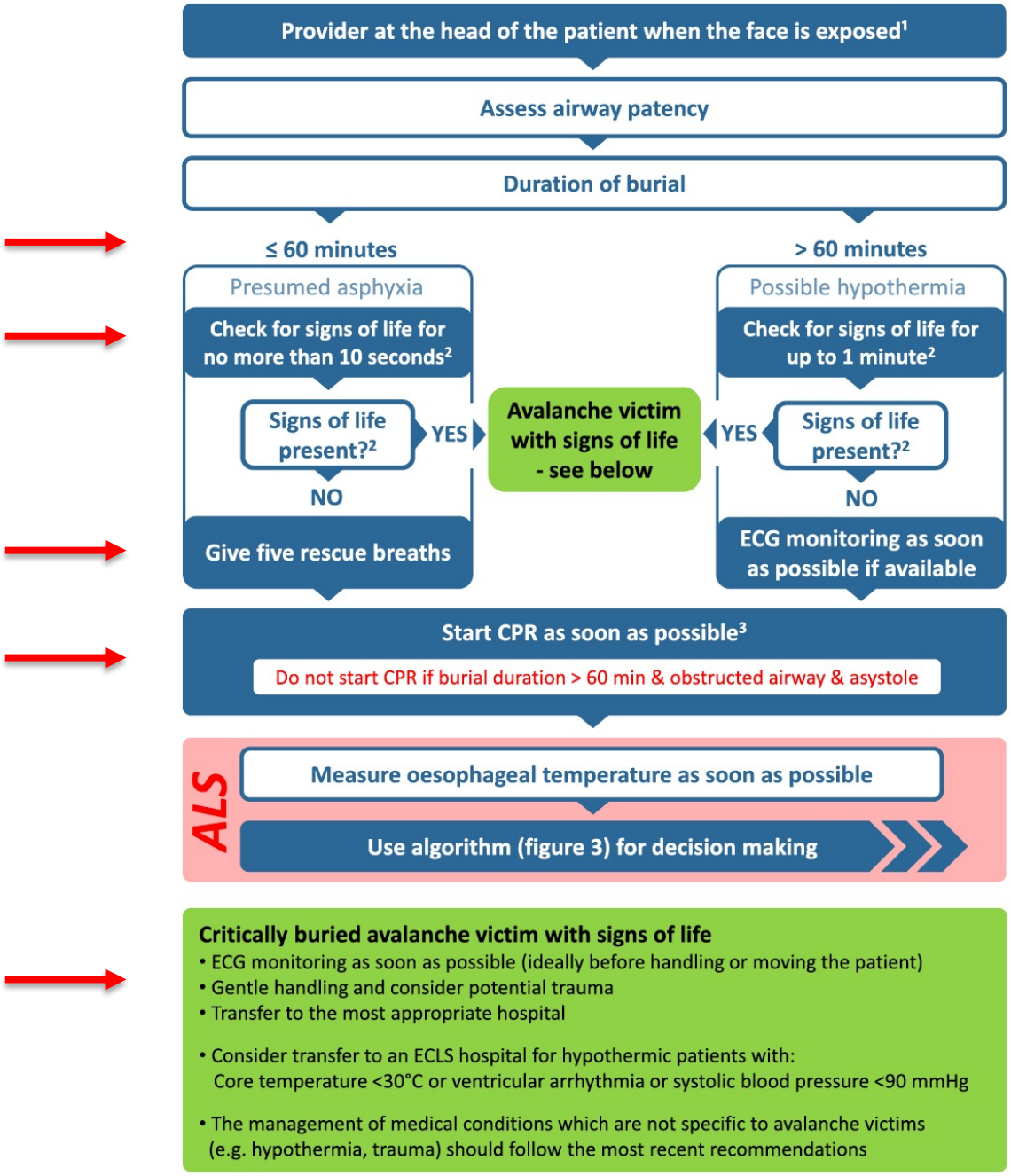
Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

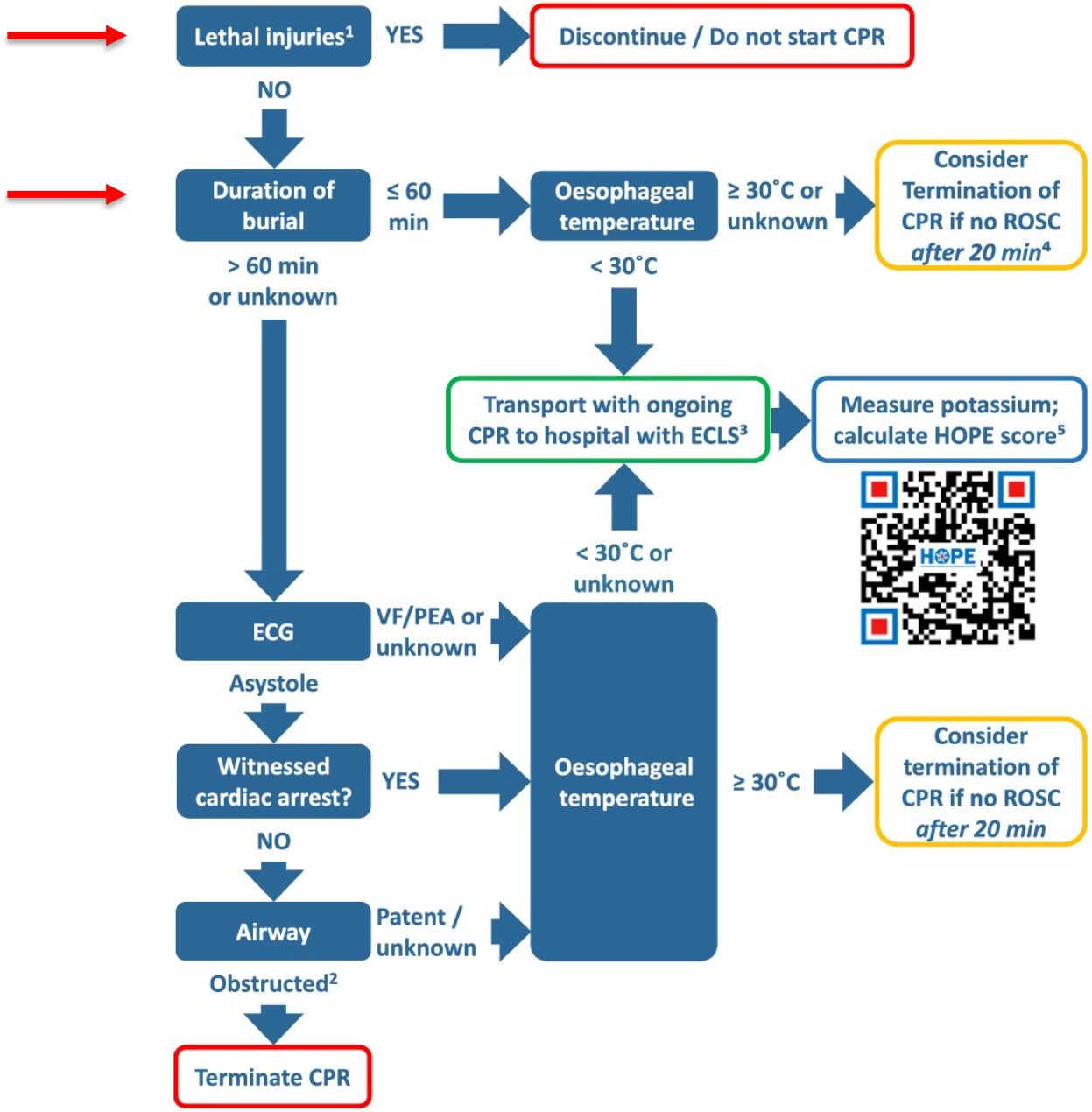
Review

On-site treatment of avalanche victims: Scoping review and 2023 recommendations of the international commission for mountain emergency medicine (ICAR MedCom)

M. Pasquier[a,b,*], G. Strapazzon[c,d,e], A. Kottmann[f,a,g,b], P. Paal[h,e], K. Zafren[i,j,b], K. Oshiro[k,l,b], C. Artoni[m], C. Van Tilburg[n,o,b], A. Sheets[p,q,b], J. Ellerton[b], K. McLaughlin[r,s,b], L. Gordon[t,u,b], R.W. Martin[o,m], M. Jacob[v,b], M. Musi[w,b], M. Blancher[x,b], C. Jaques[y], H. Brugger[c,d,e]



Pasquier M et al. Resuscitation 184 (2023):109708



Pasquier M et al. Resuscitation 184 (2023):109708

Managing multiple avalanche casualties

PLOS ONE

RESEARCH ARTICLE

A concept for optimizing avalanche rescue strategies using a Monte Carlo simulation approach

Ingrid Reiweger[1☯]*, Manuel Genswein[2☯], Peter Paal[3,4], Jürg Schweizer[5]

Reiweger I, et al. PLoS One 2017; 12(5): e0175877.

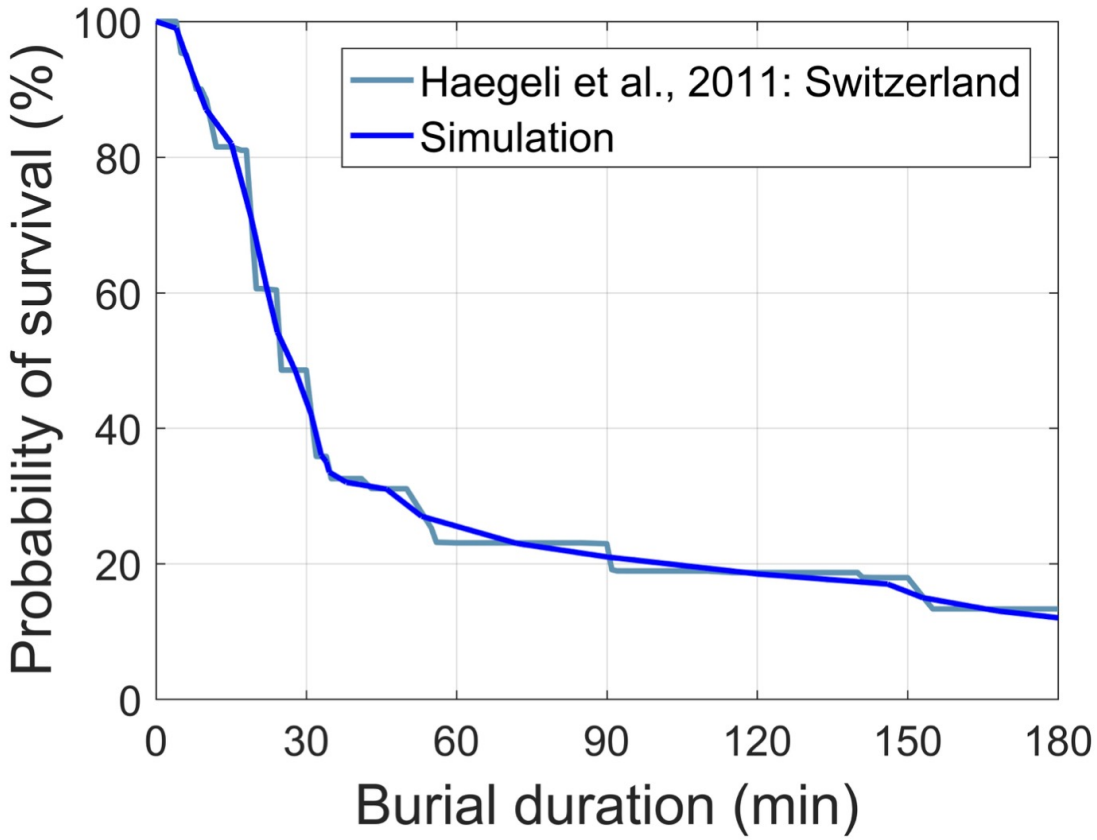


Fig 3. Survival chances of an avalanche burial as a function of burial time. For the simulation a smooth interpolation (blue line) of the avalanche survival curve based on Swiss accident data was used, adapted from [10].

Reiweger I, et al. PLoS One 2017; 12(5): e0175877.

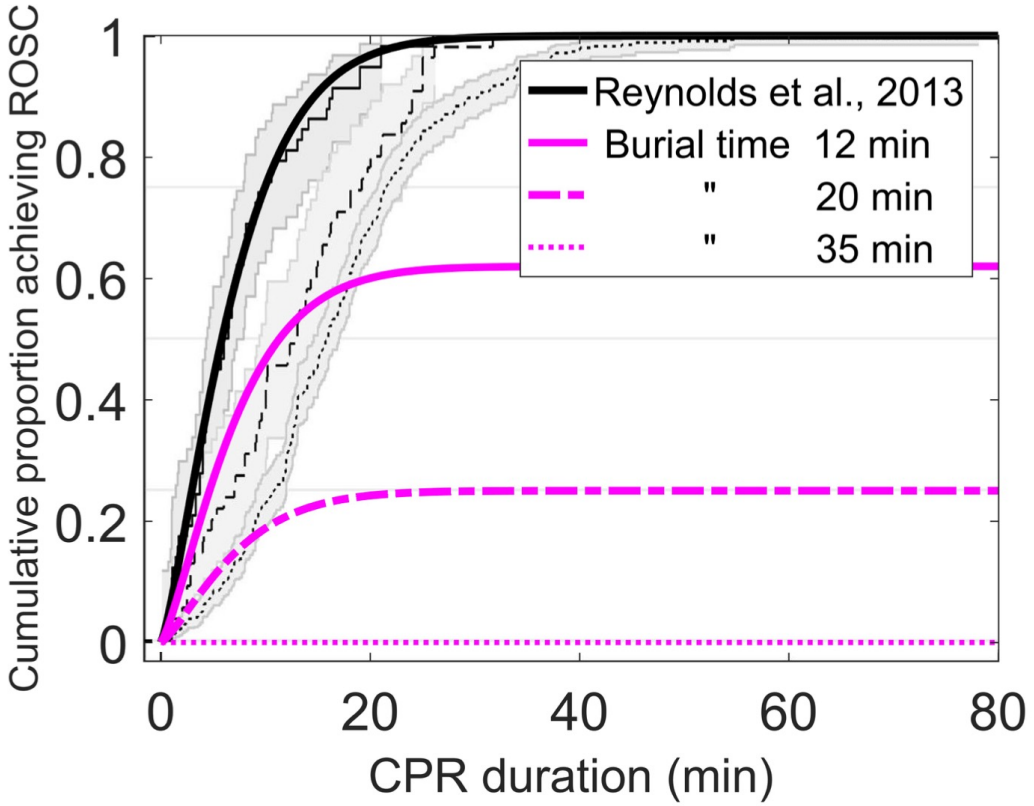
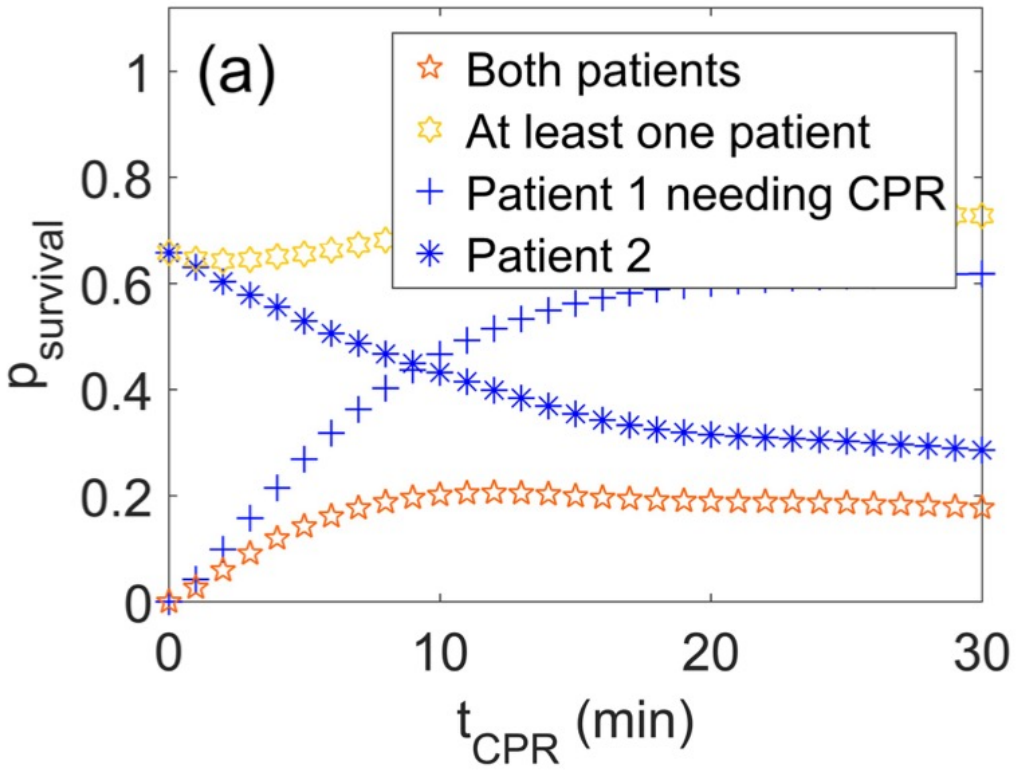


Fig 4. Probability of achieving return of spontaneous circulation (ROSC) depending on the duration of the cardiopulmonary resuscitation (CPR). The magenta curves refer to the three scenarios of burial time for patient 1, namely 12, 20, and 35 min; adapted from Reynolds *et al.* [15]. The maxima of the magenta curves are calculated according to the data from Moroder *et al.* [18].

Reiweger I, et al. PLoS One 2017; 12(5): e0175877.



- Optimized strategies can be calculated with the Monte Carlo method
- With limited personnel CPR<20 min

Reiweger I, et al. PLoS One 2017; 12(5): e0175877.

International Journal of
Environmental Research and Public Health

MDPI

Article

AvaLife—A New Multi-Disciplinary Approach Supported by Accident and Field Test Data to Optimize Survival Chances in Rescue and First Aid of Avalanche Patients

Manuel Genswein [1,*], Darryl Macias [2], Scott McIntosh [3], Ingrid Reiweger [4], Audun Hetland [5] and Peter Paal [6]

Genswein M, et al. Int J Environ Res Public Health. 2022 Apr 26;19(9):5257. doi: 10.3390/ijerph19095257.

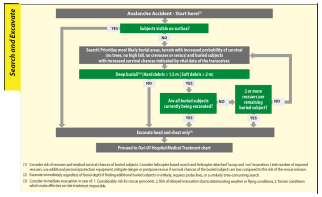
AvaLife

A Survival Chance Optimized Decision Support Tool
& Avalanche Patient Protocol

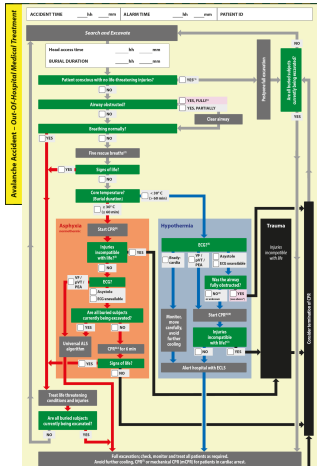
- ***Effective Search & Excavation & Medical Treatment***
- ***Focus available resources on the most life-saving tasks***
- ***Decision support tool with integrated patient protocol***

AvaLife Overview of Modules

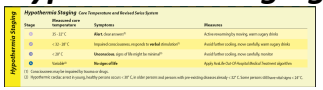
Search and Excavate



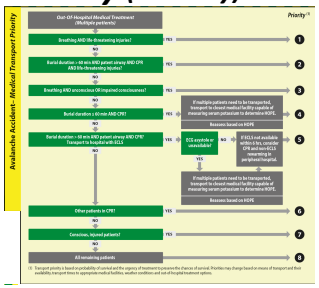
Out-Of-Hospital Medical Treatment



Hypothermia Staging



Medical Transport Priority (ALS only)

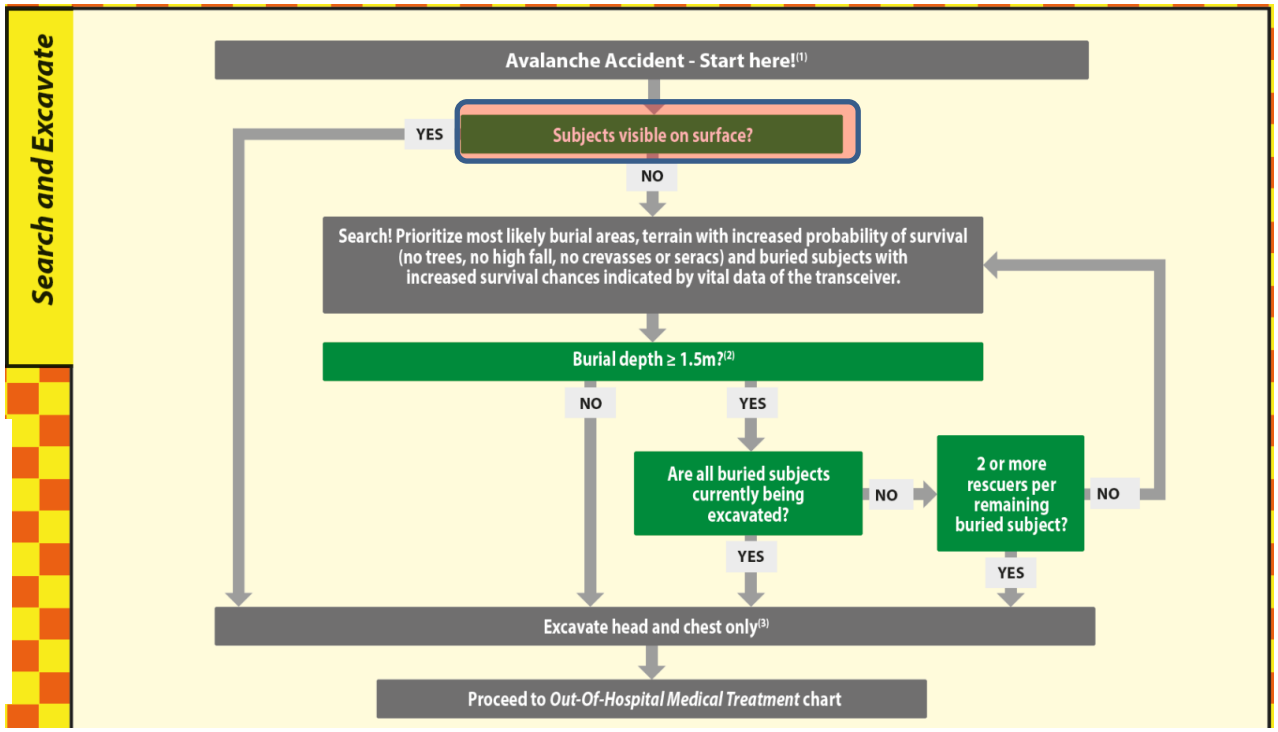


iCPR

In-Hospital Medical Treatment (ALS only)

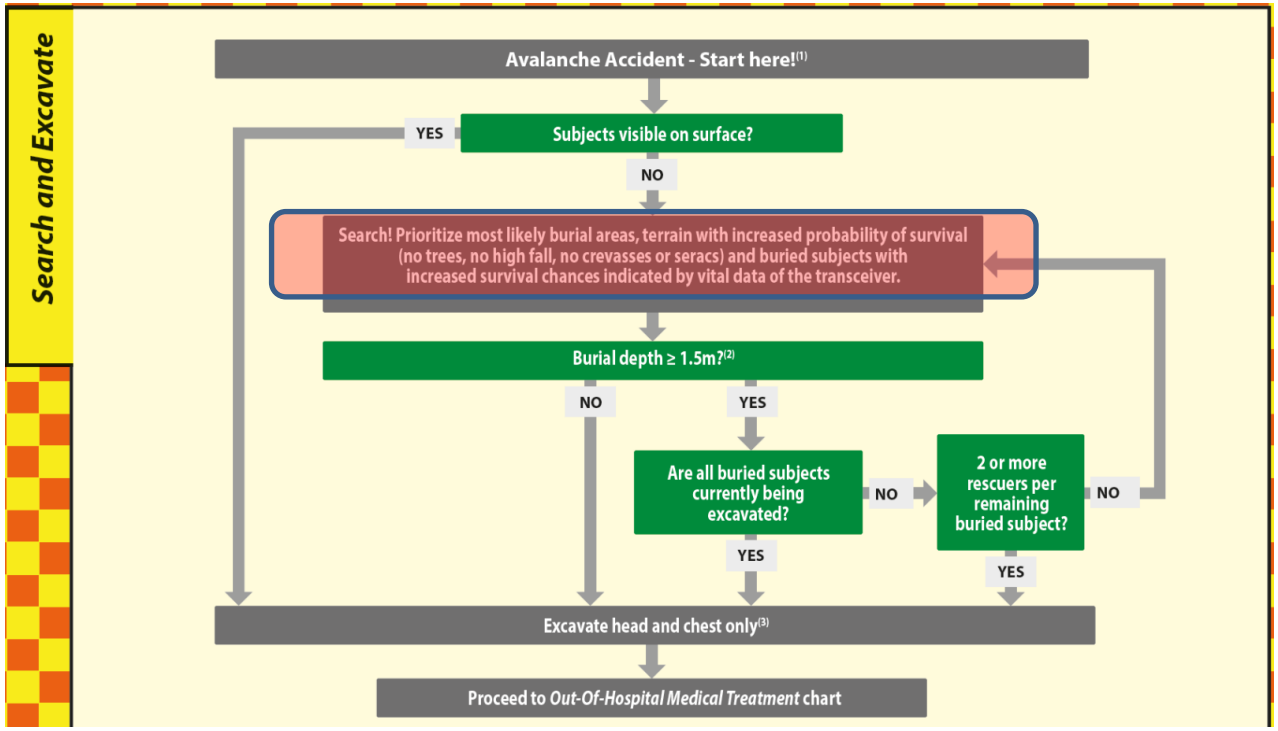
AvaLife Modules

Search and Excavate



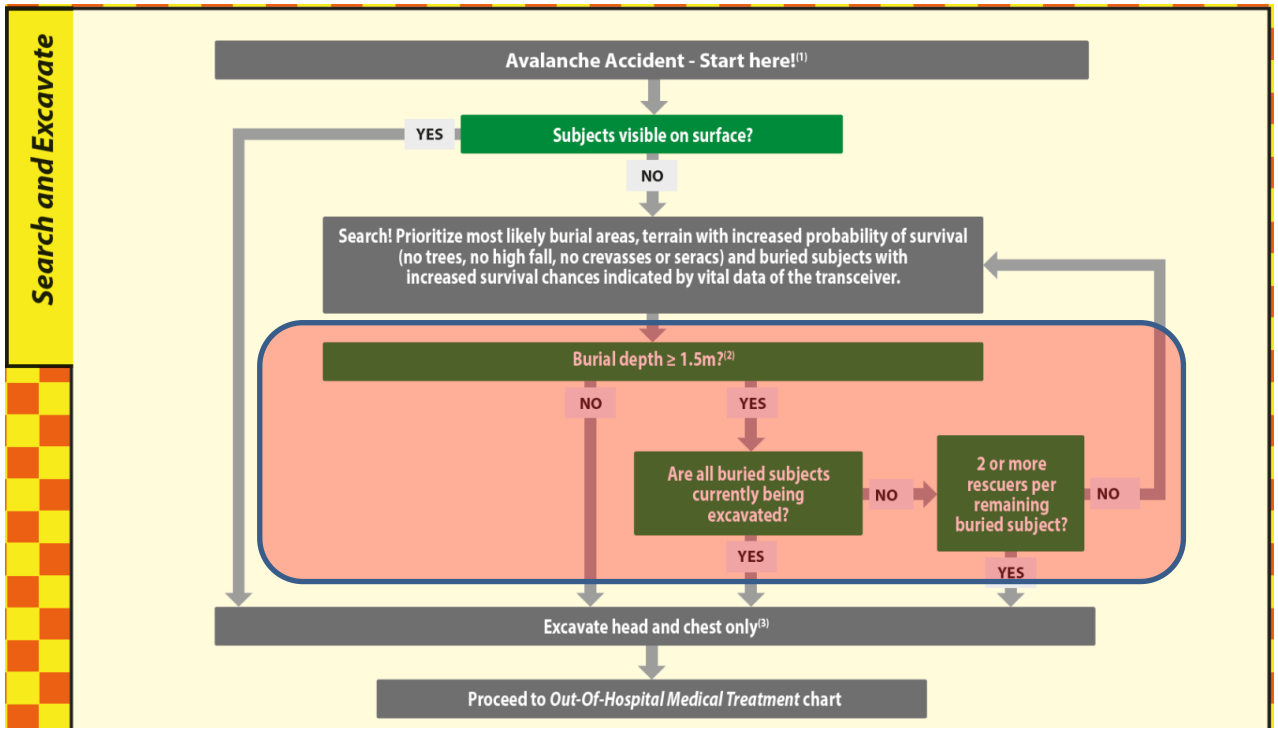
AvaLife Modules

Search and Excavate



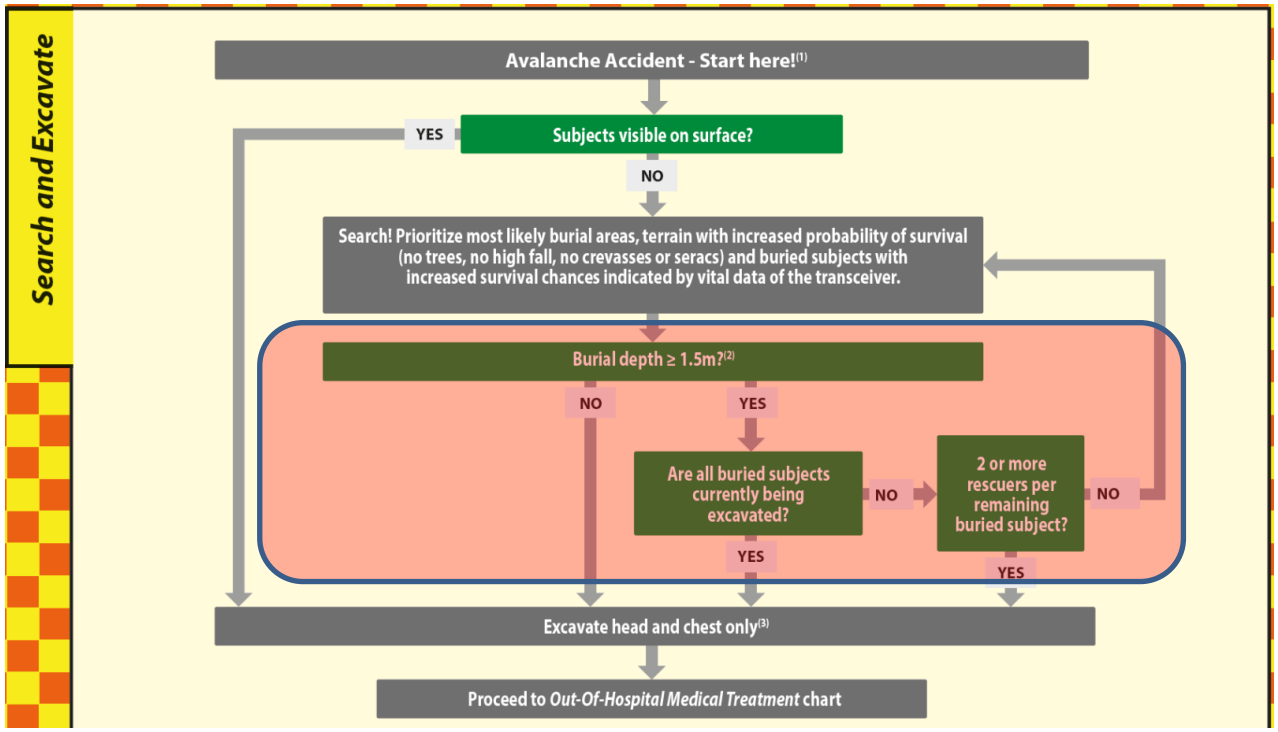
AvaLife Modules

Search and Excavate

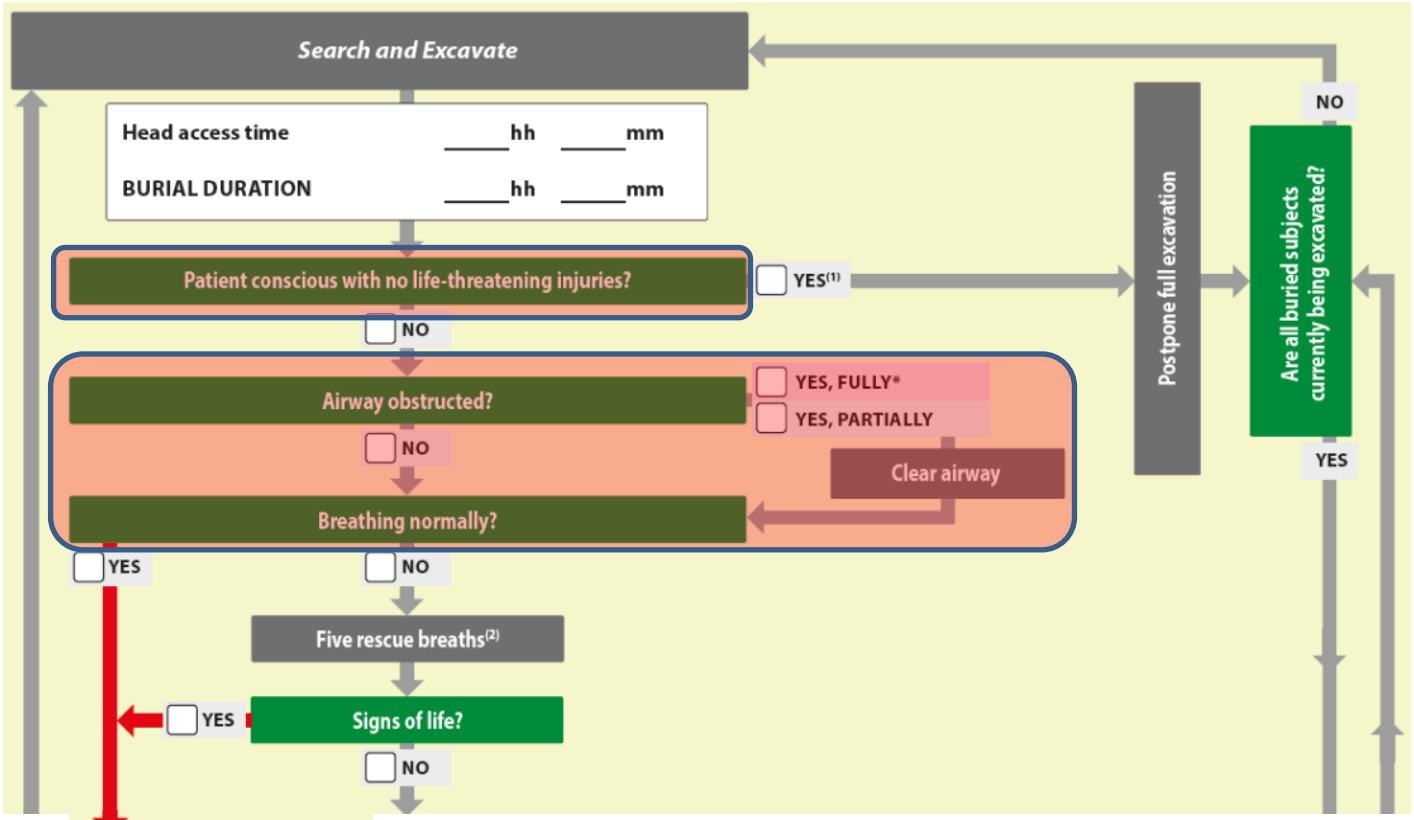


AvaLife Modules

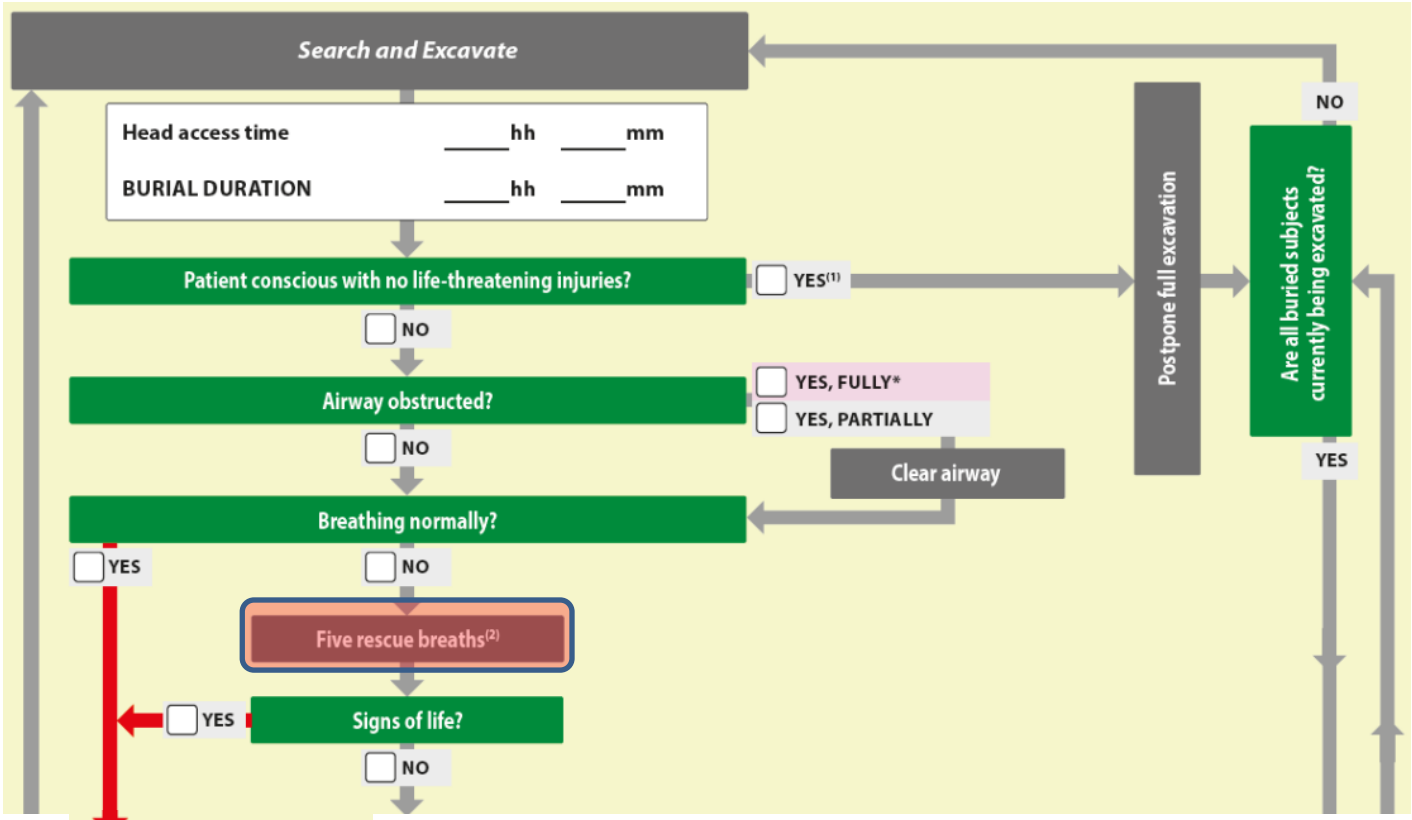
Search and Excavate



AvaLife *Out-Of-Hospital-Medical Treatment*

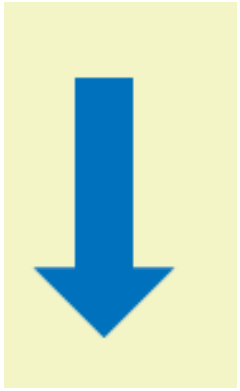


AvaLife *Out-Of-Hospital-Medical Treatment*

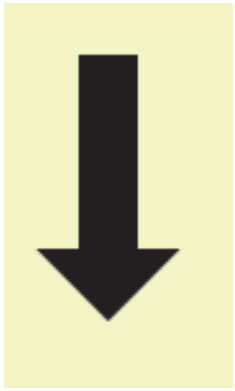


Asphyxia
Normothermic

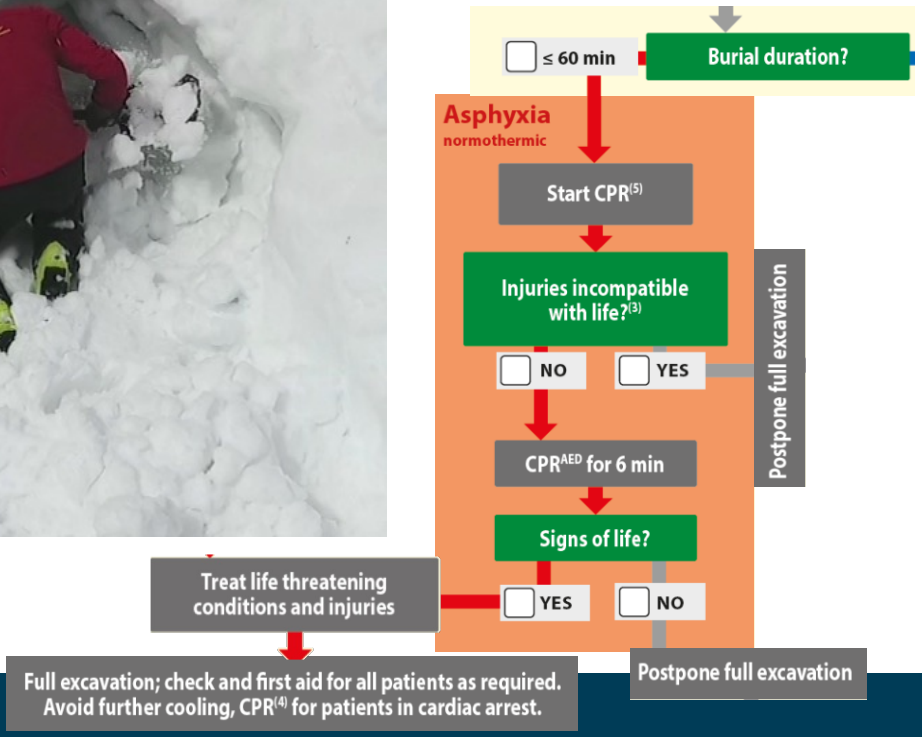
Hypothermia

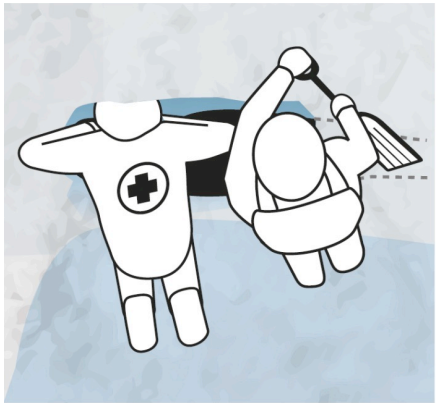


Trauma
Minimal Survival Chances

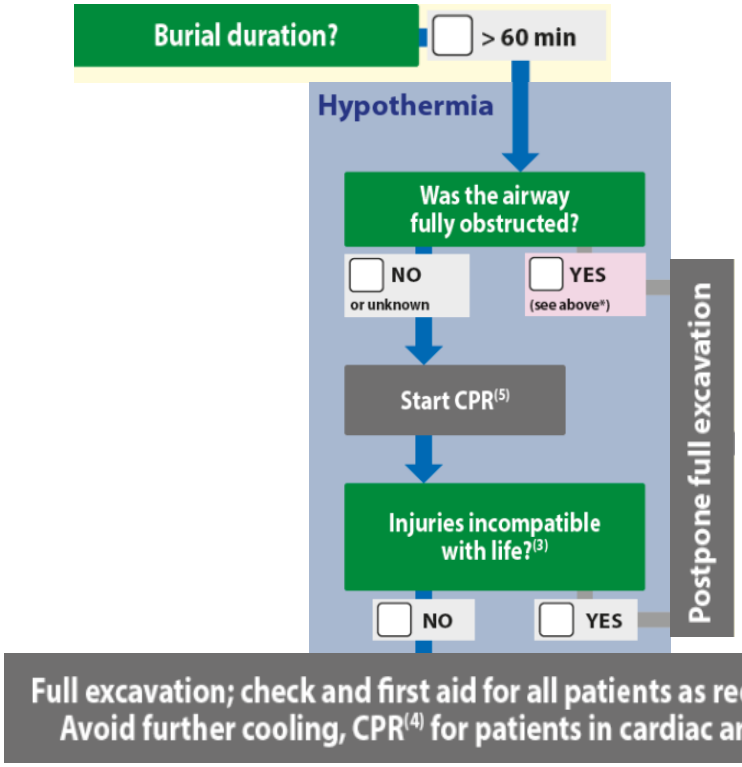


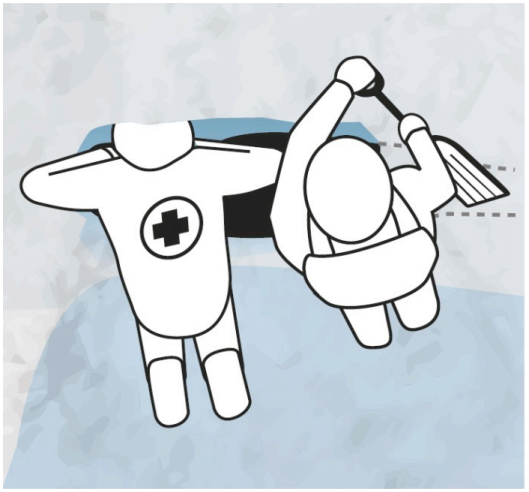
AvaLife *Out-Of-Hospital-Medical Treatment* *(Asphyxia, normothermic)*

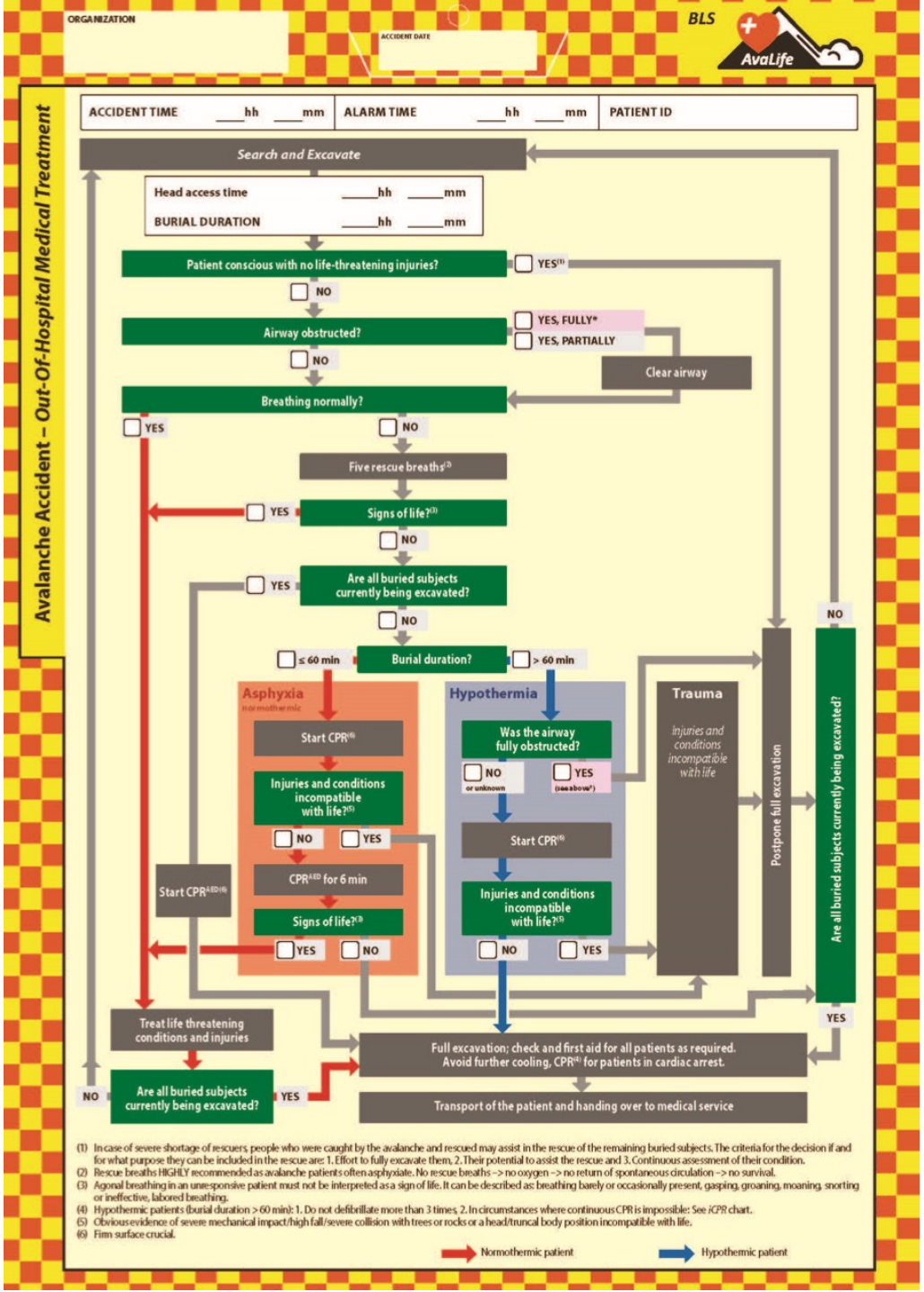




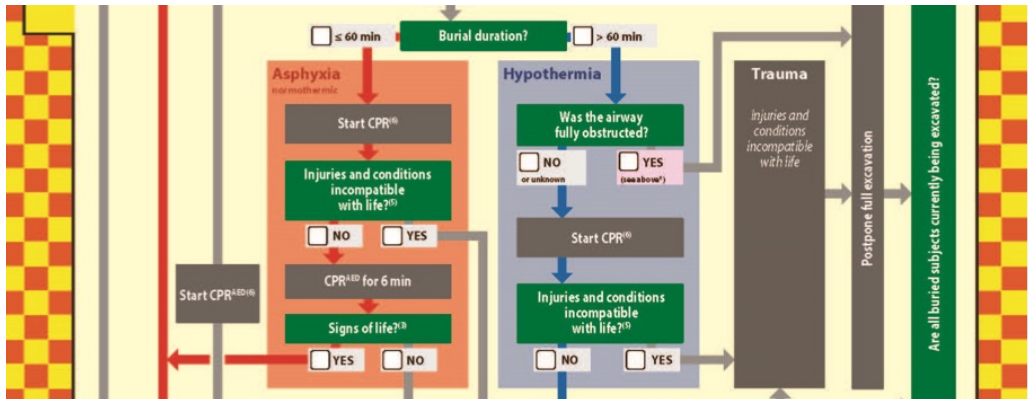
AvaLife *Out Of-Hospital Medical Treatment* *(Hypothermia)*







Genswein M, et al. Int J Environ Res Public Health. 2022 Apr 26;19(9):5257. doi: 10.3390/ijerph19095257.



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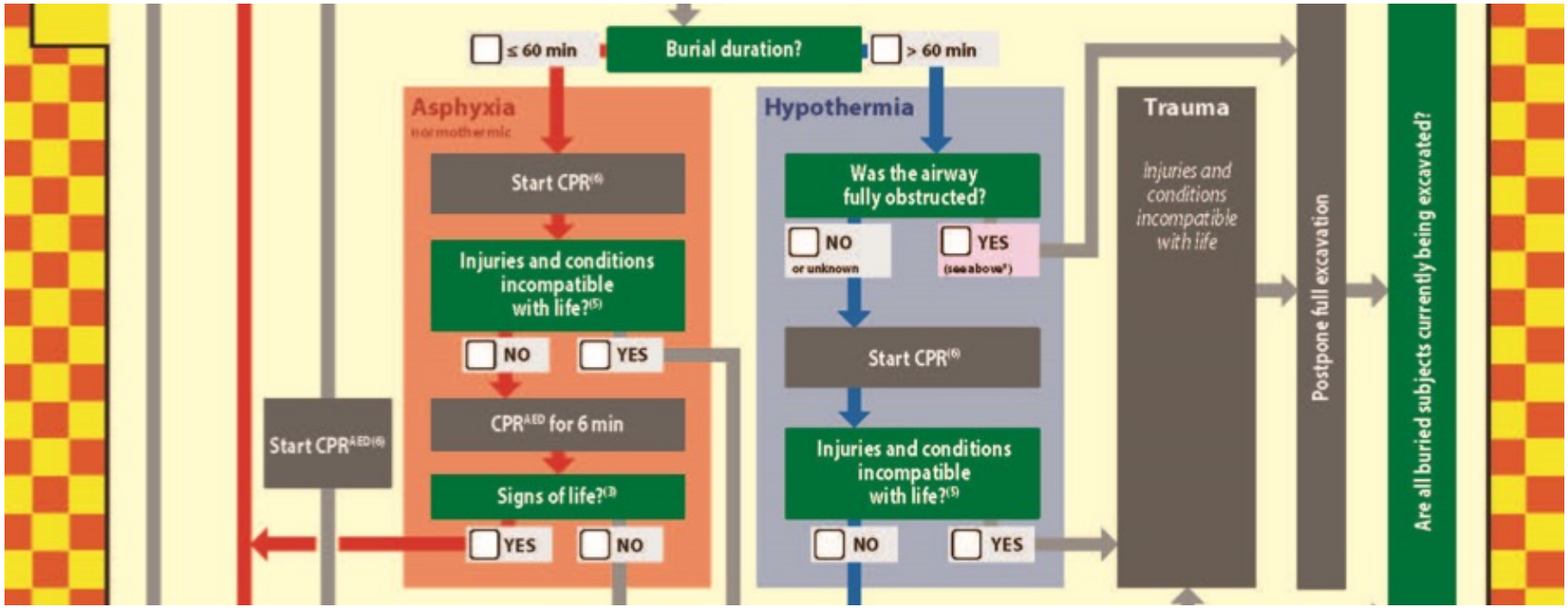
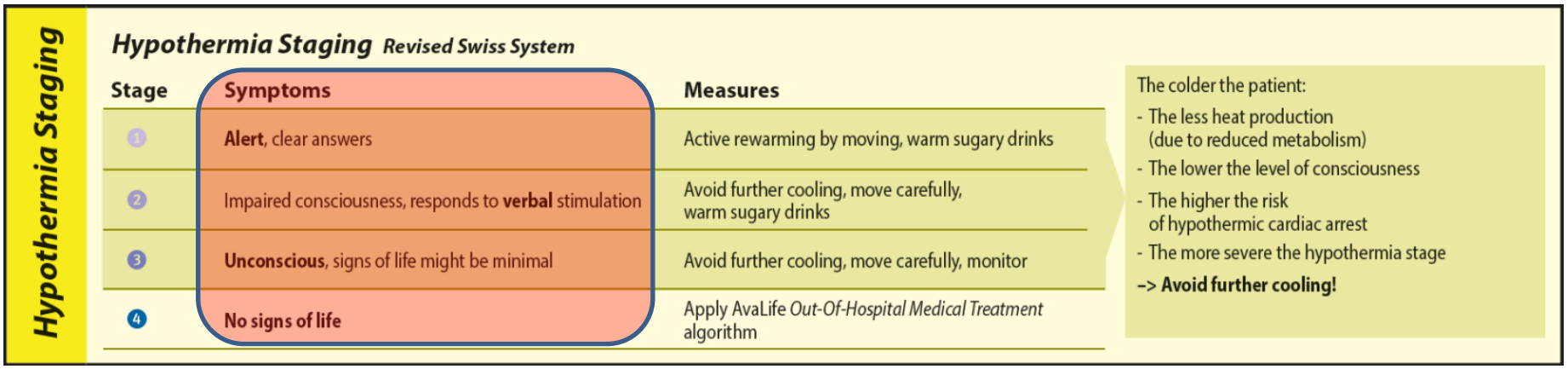


Genswein M, et al. Int J Environ Res Public Health. 2022 Apr 26;19(9):5257. doi: 10.3390/ijerph19095257.

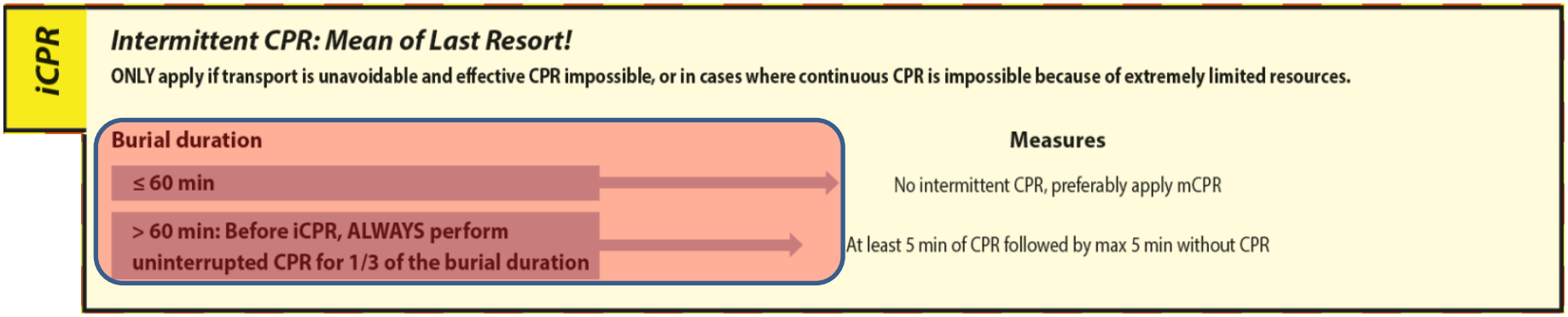
AvaLife Modules

Hypothermia Staging *(BLS version)*



AvaLife Modules

iCPR *(BLS version)*



Conclusions

- Asphyxiation common
- Good outcome with
  - short burial
  - ROSC on BLS or
  - long burial and hypothermia
- AvaLife can be used for single and multiple burial scenario with lack of resources
- CPR duration 6min in reverse triage, otherwise continuous unlimited CPR
- Treatment in appropriate hospital


Thank you
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