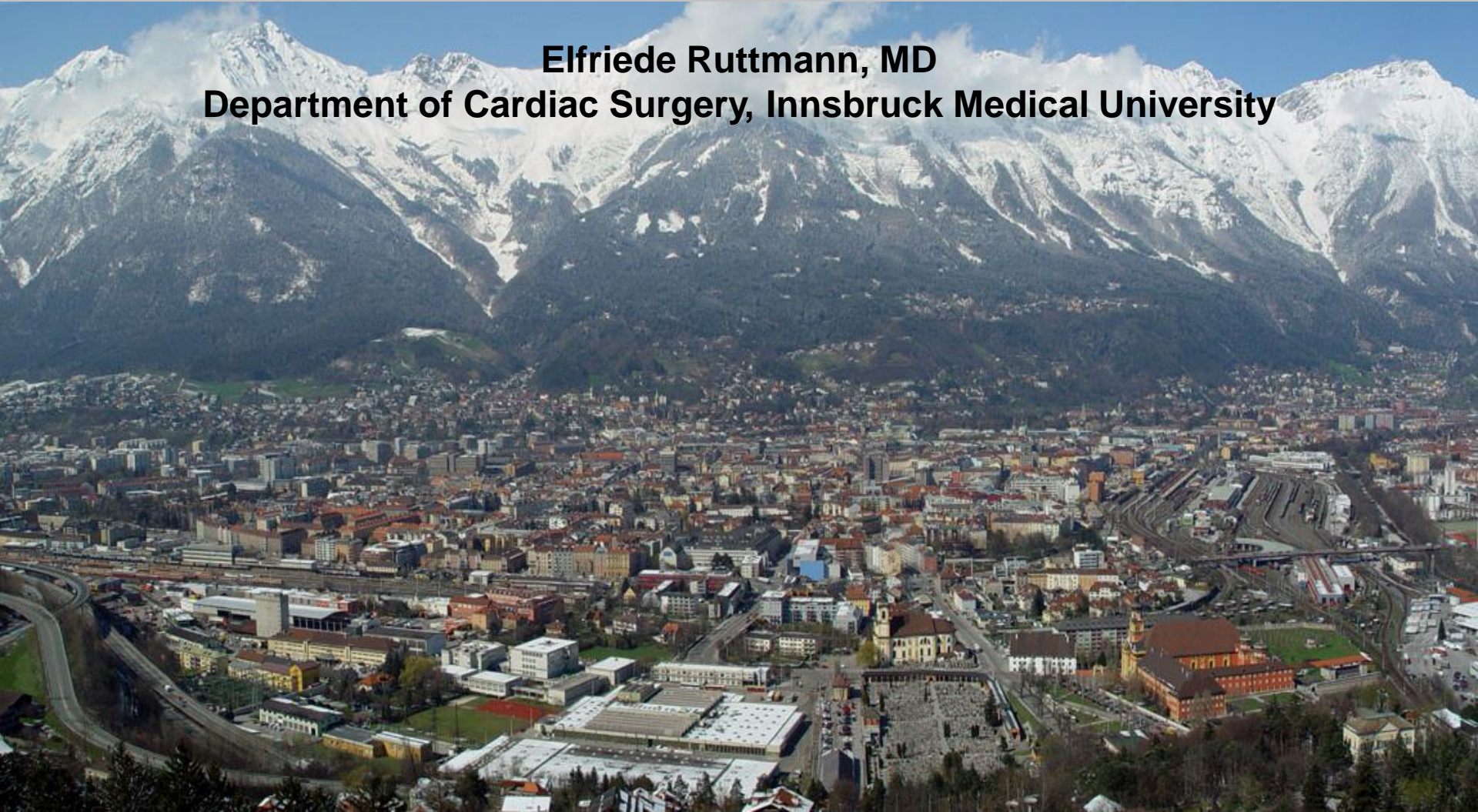


# **Epidemiology and treatment of cold injuries in urban vs. remote areas**

## **Extracorporeal assisted rewarming for treatment of hypothermia-induced cardio-circulatory arrest**

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# Accidental hypothermia - Epidemiology



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US: approx. 700 deaths from hypothermia annually

Ireland: annual death rate approx. 18.1 per million inhabitants

Austria (8 mio.inhabitants): 120 avalanche victims per year  
approx. 100 drowning deaths per year

Herity B et al. Hypothermia and mortality and morbidity.  
An epidemiological analysis. J Epid Comm Health 1991;45:19-23.

Lazar HL. The treatment of hypothermia. N Engl J Med 1997;337:1545-7.

Bundesministerium für Inneres: Lawinenstatistik 2003/2004

# Accidental hypothermia - Definitions



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decline of body core temperature below  $35^{\circ}\text{C}$

severe hypothermia ( $<28^{\circ}\text{C}$ ) causes cardio-circulatory instability and circulatory arrest

however

reduced oxygen consumption ( $-5\%/^{\circ}\text{C}$ ) enables to perform resuscitation even after prolonged hypothermic cardiac arrest

# Severe hypothermia – Treatment options



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hypothermic circulatory arrest and hypothermia are frequently used in cardiac surgery (e.g. aortic repair)

extracorporeal circulation (ECC) is the therapy of choice in resuscitation of hypothermic patients with cardio-circulatory arrest

alternatives: pleural a/o peritoneal lavage

2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardio-vascular care: Part 10.4:Hypothermia. *Circulation* 2005;112:IV-136-IV-138.

# Severe hypothermia – Preconditions



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optimum mechanism of cooling

whole body cooling with subsequent

circulatory arrest instead of warm

hypoxic arrest followed by cooling

(asphyxia)

precondition for restoration of spontaneous circulation

(ROSC) and survival

# Accidental hypothermia - Causes



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exposure to cold environment (urban)

avalanche victims, crevasse, skiing (alpine)

immersion/submersion („near-drowning“)



# Treatment options I



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## emergency extracorporeal circulation (ECC)

therapy of choice in hypothermic cardiac arrest

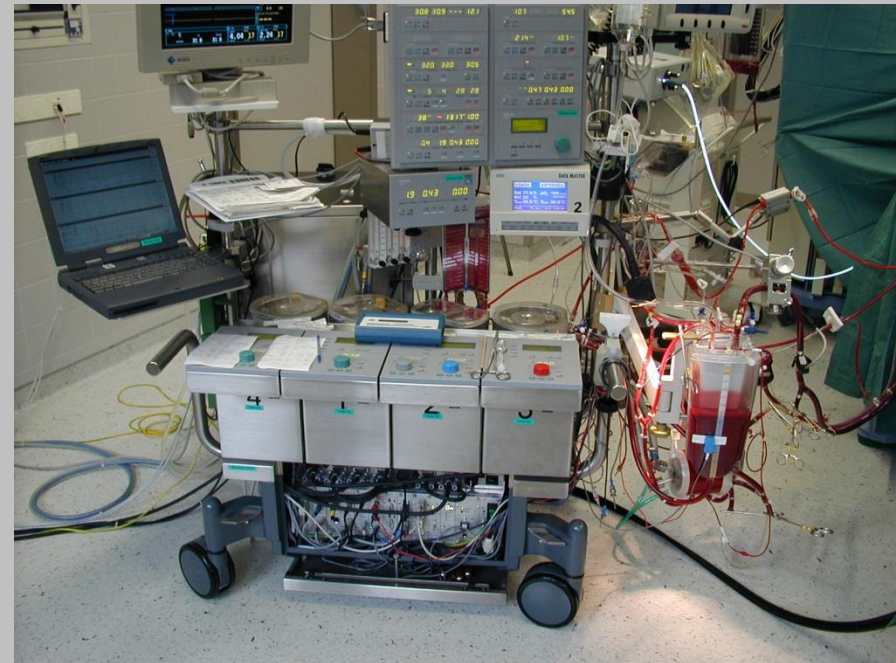
femoral access possible

support time limited to

several hours

open system (reservoir)

target ACT > 480 sec.



# Treatment options II



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## extracorporeal membrane oxygenation (ECMO)

Centrifugal pump

insertion can be performed percutaneously

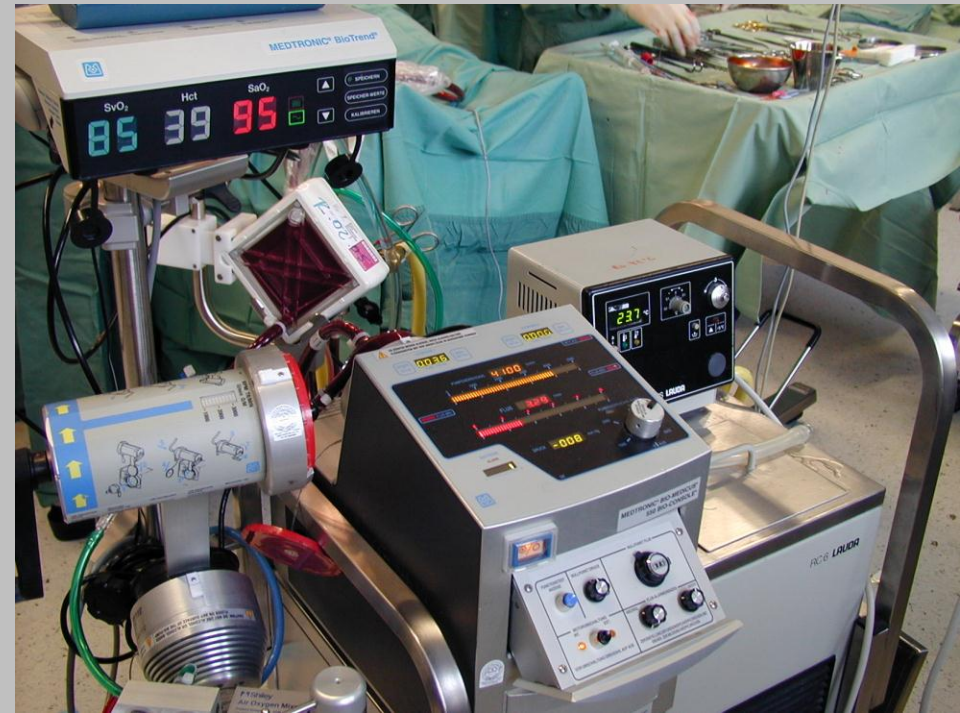
portable system

single pulmonary support when v-v

support time up to several weeks

closed system

target ACT 180 – 200 sec.



# Aim



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resuscitation and rewarming by ECMO support has never been reported for hypothermia-induced cardiac arrest

evaluate independent predictors for ROSC and survival

to investigate whether prolonged ECMO support is an independent predictor for survival of hypothermic cardiac arrest

# Study population



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consecutive series of 59 patients admitted with  
hypothermic cardio-circulatory arrest from 1987 to 2006

inclusion criteria: cardio-circulatory arrest and  
extracorporeal-assisted resuscitation attempts

patients resistant to defibrillation

mean age  $31 \pm 16$  yrs

mean body core temp.  $24.6 \pm 3.7^{\circ}\text{C}$

22 avalanche victims

drowning in 21 patients

exposure to cold in 8 patients

crevasse in 6



# Resuscitation - Techniques



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emergency ECC resuscitation (femoral access, sternotomy in small children) in 34 patients

emergency ECMO-assisted resuscitation in 25 patients  
(percut. femoral access, sternotomy in too small children)  
prolonged support in ROSC patients)



# Results



**TABLE 1. Overview of hypothermic patients who have been resuscitated by the use of extracorporeal techniques (n = 59 patients)**

	ECC group (1987–1996) n = 34 patients	ECMO group (1996–2006) n = 25 patients	P value
Age in years (mean, SD)	28 ± 16	36 ± 19	.068
Male gender (n, %)	28 (82.4%)	21 (84.0%)	.72
Cause of hypothermia-related cardiocirculatory arrest			
Avalanche	16 (47.1%)	6 (24.0%)	
Drowning	11 (32.4%)	11 (44.0%)	
Crevasse	3 (8.8%)	4 (16.0%)	
Exposure to cold	4 (11.8%)	4 (16.0%)	.34
Body core temperature at admission in degrees Celsius (mean, SD)	24.6 ± 2.9	24.2 ± 4.7	.66
Burial/Submersion Time in Minutes (mean, SD)	94 ± 85 min	92 ± 134 min	.94
Serum potassium at admission in mmol/L (mean, SD)	7.8 ± 4.4	6.9 ± 3.7	.45
pH at admission (mean, SD)	6.7 ± 0.27	6.7 ± 0.28	.64
Cardiac rhythm at admission			
Asystole	18 (52.9%)	13 (52.0%)	
Ventricular fibrillation	15 (44.1%)	10 (40.0%)	
Pulseless electrical activity	1 (2.9%)	2 (8.0%)	.68

*ECC*, Extracorporeal circulation; *ECMO*, extracorporeal membrane oxygenation; *SD*, standard deviation.

# Study population



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**TABLE 2. Univariate comparison of possible predictive parameters associated with survival of severe hypothermia associated with cardiocirculatory arrest**

	<b>Nonsurvivors n = 47 patients</b>	<b>Survivors n = 12 patients</b>	<b>P value</b>
Age in years (mean, SD)	29.5 ± 16.7	38.3 ± 20.1	.20
Male gender (n, %)	41 (87.2%)	9 (75.0%)	.37
Asphyxia-associated cause (Avalanche, Drowning) (n, %)	40 (85.1%)	4 (33.3%)	.001
ECMO-assisted resuscitation (n, %)	16 (34.0%)	9 (75.0%)	.02
Burial/submersion time in minutes (if avalanche or drowning)	94.7 ± 86	92.2 ± 134.6	.44
Body core temperature at admission (mean, SD)	24.5 ± 0.68	24.2 ± 0.35	.77
Asystole at admission (n, %)	27 (57.4%)	4 (33.3%)	.20
Lactate at admission (mean, SD)	136.9 ± 64.2	118.1 ± 59.0	.57
pH at admission (mean, SD)	6.64 ± 0.24	6.80 ± 0.32	.026
Potassium at admission (mean, SD)	8.1 ± 4.30	4.9 ± 1.90	.014
Activated clotting time in seconds (mean, SD)	201.7 ± 45.5	204.7 ± 32.0	.92

*SD*, Standard deviation; *ECMO*, extracorporeal membrane oxygenation.

# Results



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Reestablishment of contractility  
in 33 patients (56.0%)

ROSC (weaning from assisted circulation)  
in 32 patients (54.2%)

Hospital survival 12 patients (20.3%)

Survivors: median ICU stay 15 days

**TABLE 3. Causes of death in patients with restoration of spontaneous circulation (ROSC) (n = 21 patients)**

	ECC group n = 14 patients	ECMO group n = 7 patients
Pulmonary edema	9 (64.3%)	0 (0%)
Multiorgan failure	2 (14.3%)	3 (50%)
Brain death	2 (14.3%)	3 (42.9%)
Aortic dissection/retroperitoneal hematoma	0 (0%)	1 (16.7%)
Bleeding	1 (7.1%)	0 (16.7%)
Median time from ROSC to death (hours, range)	23 (0.5–110)	42 (18–216)

*ECC*, Extracorporeal circulation; *ECMO*, extracorporeal membrane oxygenation; *ROSC*, return of spontaneous circulation.



# Results – Predictors for survival

**TABLE 4. Results of the multivariate logistic regression analysis to evaluate independent predictors for survival of accidental hypothermia with cardiocirculatory arrest (n = 59 patients)**

	Wald	Relative risk	95% confidence interval	P value
Asphyxia-related cause of hypothermia (avalanche, drowning)	6.2	0.09	0.01–0.60	.013
ECMO-assisted resuscitation	4.2	6.61	1.2–49.3	.042
Potassium at admission (per mmol/L)	2.8	0.62	0.36–1.1	.09
pH at admission	0.018	0.89	0.02–83.8	.89

*ECMO*, Extracorporeal membrane oxygenation.

## Prolonged extracorporeal membrane oxygenation-assisted support provides improved survival in hypothermic patients with cardiocirculatory arrest

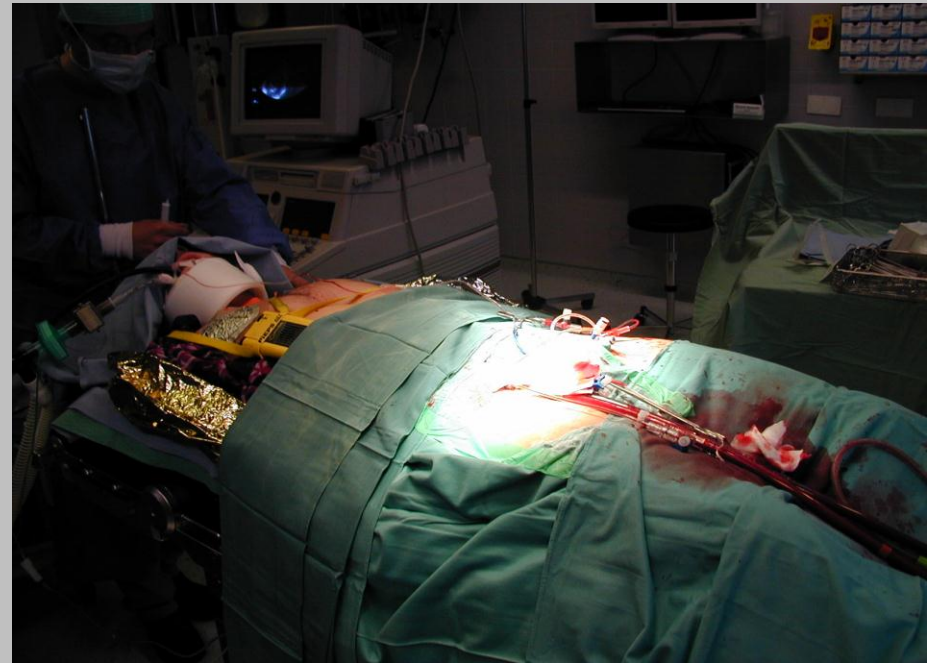


# Results



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ROSC was achieved in 32 patients (54.2%) and was similar in both treatment groups (50% vs. 56.5%,  $p=0.48$ ) survival was significantly higher in the ECMO group (8.8% vs. 34.8%,  $p=0.015$ )



# Conclusions



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asphyxia-related cause of hypothermia was the most predictive parameter for survival of hypothermia (HR: 0.11)

ROSC patients with prolonged ECMO support had a more than 6 fold higher chance for survival

laboratory parameters cannot be used to justify termination of resuscitation

**Mair P, et al. Prognostic markers in patients with severe accidental hypothermia and cardiocirculatory arrest. Resuscitation 1994;27:47-54.**

# Conclusions



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severe reperfusion edema was the predominant death cause in patients in whom ROSC could be re-established

in the ECC group (9 out of 14 patients, 64.4%)  
none in the ECMO group

prolonged ECMO support can treat severe pulmonary edema for several days

**Vretenar DF, et al.. Cardiopulmonary bypass resuscitation for accidental hypothermia. Ann Thorac Surg 1994;58:895-8.**

**Farstad M, et al. Rewarming from accidental hypothermia by extracorporeal circulation. A retrospective study. Eur J Cardio-Thorac Surg 2001;20:58-64.**

# Conclusions



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during the cooling period the intravascular volume escapes  
from the circulation due to extravasation

during the rewarming period the opposite effect occurs

relevant when rewarming by i.v. administration of  
warm fluids is performed

⇒ cardiac decompensation  
pulmonary edema

**Lauri T. Cardiovascular responses to an acute volume overload in deep hypothermia.  
Eur Heart J 1996;17:606-611.**

# Conclusions



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severe diastolic dysfunction is frequently seen when performing therapeutically induced hypothermia and rewarming during cardiac surgery

severe stiffness of the left ventricle may aggravate ischemia-reperfusion edema of the lung during rewarming

**Velvis H, et al. Depression of cardiac function after deep hypothermic circulatory arrest in deeply anesthetized neonatal lambs. J Thorac Cardiovasc Surg 1996;11:359-66.**

**Tveita T, et al. Left ventricular dysfunction following rewarming from experimental hypothermia. J Appl Physiol 1998;85:2135-2139.**

# Conclusions



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**neither epinephrine nor vasopressin or amiodarone are able to increase defibrillation success or outcome in hypothermia below 30°C**

**epinephrine and vasopressine have demonstrated to increase coronary perfusion pressure but both emergency drugs had no impact on ROSC or survival in hypothermia**

**Schwarz B, et al. Neither vasopressin nor amiodarone improve CPR outcome in an animal model of hypothermic cardiac arrest. Acta Anesthesiologica Scandinavica 2003; 47:1114-1118.**

**Kornberger E, et al. Effects of epinephrine in a pig model of hypothermic cardiac arrest and closed-chest CPR combined with rewarming. Resuscitation 2001; 50: 301-308.**

**Krismer AC, et al.. Cardiopulmonary resuscitation during severe hypothermia in pigs: does epinephrine or vasopressin increase coronary perfusion pressure?**

**Anesth Analg 2000;90:69-73.**

# Conclusions



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many cardio-thoracic centers do not provide ECMO support

largest consecutive series of extracorporeal-assisted resuscitation

lack of randomisation, ECC group is historical

As a consequence we strongly recommend prolonged ECMO-assisted resuscitation and support instead of ECC in treating hypothermic cardiac arrest patients

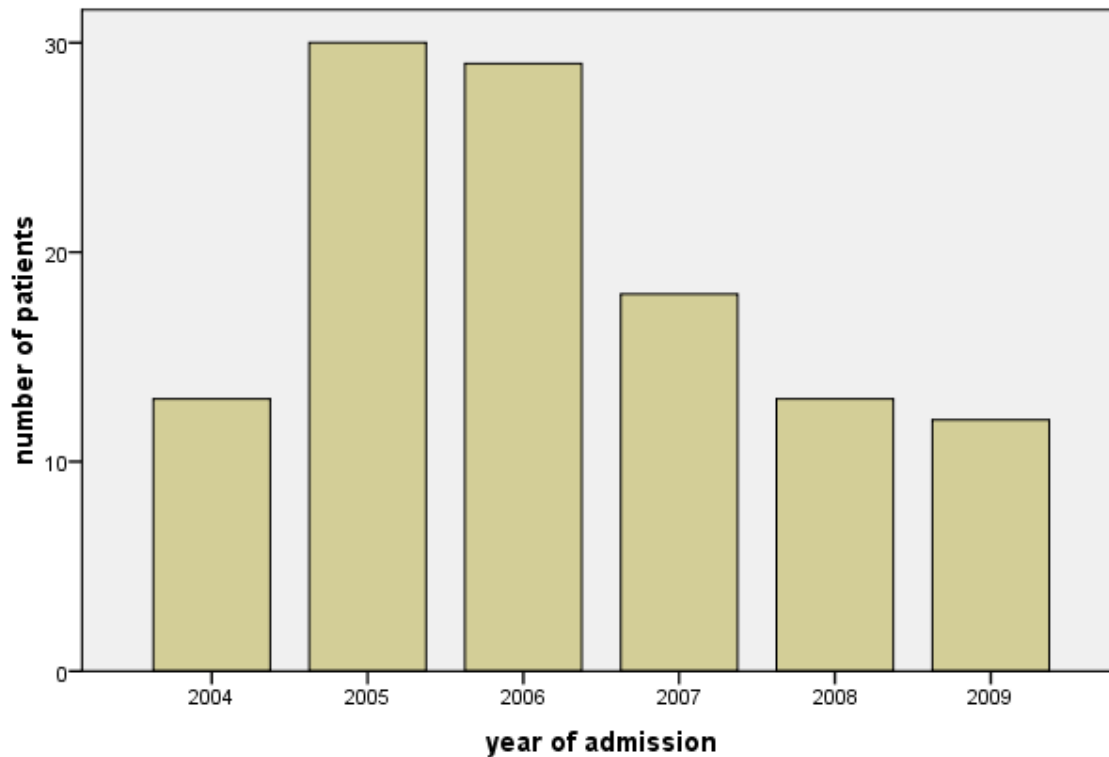
# Epidemiology of hypothermia Innsbruck 2004 to 2009



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Data from Trauma Registry & perfusionist database Innsbruck

hospital admission due to hypothermia



decline of hospital  
admissions  
due to hypothermia  
Since 2007

decline in accidental  
hypothermia ??????

or

decline of admissions in  
Innsbruck ????

# Epidemiology of hypothermia Innsbruck 2004 to 2009



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115 patients

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CPR prior to hospital admission	45 (39.1%)
Cardiac arrest at admission	29 (25.2%)
ECMO assisted resuscitation	23 (20%)
Survival	83 patients (72.2%)
Causes of hypothermia	
Avalanche	25 patients (21.7%)
Exposure to cold environment	26 (22.6%)
Drowning	15 (13.0%)
Crevasse	5 (4.3%)
Skiing accident	15 (13.0%)
Road accident	15 (13.0%)
Climbing	3 (2.6%)
Accident+ exposure to cold	11 (9.6%)
Alpine related	64 (55.7%)
Suicide attempts	7 (6.1%)

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**More than 50% of hypothermic admissions due to alpine related activities**

# Epidemiology of hypothermia Innsbruck 2004 to 2009



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115 patients

2004 - 2009

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Polytrauma	29 patients (25.2%)
Traumatic brain injury	24 (20.9%)
Chest trauma	30 (26.1%)
Abdominal trauma	9 (7.8%)
Pelvic fracture	17 (14.8%)
Lower limb injuries	38 (33.0%)
Spine fracture	
Cervical spine	4 (3.5%)
Thoracic vertebrae	16 (13.9%)
Lumbar vertebrae	2 (1.7%)
Multiple site fractures	8 (7.0%)

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**1 out of 4 additional  
polytraumatism**

**Body core temperature in patients with cardiac arrest significantly lower  
( $23.8 \pm 4.2$  vs.  $29.8 \pm 2.7$  °C;  $p < 0.001$ )**

Thank you for your attention !



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