Severe Accidental Hypothermia Treated in an ICU*

Prognosis and Outcome

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Study objectives: **To assess the characteristics and outcomes of patients admitted to an ICU for severe accidental hypothermia, and to identify risk factors for mortality.**
Methods: **All consecutive patients admitted to an ICU between January 1, 1979, and July 31, 1998, with a temperature of ≤ 32°C were retrospectively analyzed. Rewarming was always conducted passively with survival blankets and conventional covers. Prognostic factors were studied by means of univariate analysis (Mann-Whitney *U* and χ^2 tests) and multivariate analysis (logistic regression).**
Results: **Forty-seven patients were enrolled (mean ± SD age, 61.7 ± 16 years). Five patients had a cardiac arrest before ICU admission. Patient characteristics at ICU admission were as follows: temperature, 28.8 ± 2.5°C; systolic BP, 85 ± 23 mm Hg; heart rate, 60 ± 24 beats/min; Glasgow Coma Scale, 10.4 ± 3.7; and simplified acute physiology score (SAPS) II, 50.9 ± 27. Mechanical ventilation was necessary in 23 cases, and 22 patients in shock received vasoactive drugs. The mean length of stay in the ICU was 6.7 ± 9 days. Eighteen patients (38%) died, but ventricular arrhythmia was never the cause. Univariate analysis identified several prognostic factors ($p < 0.05$): age (57 ± 16 years vs 69 ± 14 years), systolic arterial BP (93 ± 20 mm Hg vs 71 ± 21 mm Hg), blood bicarbonate level (23.5 ± 5.2 mmol/L vs 16.6 ± 6.2 mmol/L), SAPS II score (35.3 ± 19.5 vs 72 ± 21), mechanical ventilation (34% vs 81%), vasopressor agents (42% vs 82%), rewarming time (11.5 ± 7.2 h vs 17.2 ± 7 h), and discovery of the patient at home (2.3% vs 54.5%). The initial temperature did not influence vital outcome (28.9 ± 2.6°C vs 28.6 ± 2.2°C). Only the use of vasoactive drugs (odds ratio, 9; 95% confidence interval, 1.6 to 50.1) was identified as a prognostic factor in the multivariate analysis.**
Conclusion: **Severe accidental hypothermia is a rare cause of ICU admission in an urban area. Its mortality remains high, but there is no overmortality according to the SAPS II-derived prediction of death. Shock, requiring treatment with vasoactive drugs, is an independent risk factor for mortality, while initial core temperature is not. It remains to be determined whether aggressive rather than passive rewarming procedures are better.** ***(CHEST 2001; 120:1998–2003)***

Key words: rewarming; severe hypothermia; shock

Abbreviation: SAPS = simplified acute physiology score

Hypothermia is defined by a central temperature of < 35°C. Moderate hypothermia (32°C to 35°C) is classically[1] distinguished from severe hypothermia (28°C to 32°C) and major hypothermia (< 28°C). The most severe cases necessitate rapid admission to an ICU because the prognosis is grim, with a mortality rate between 12%[2] and 80%.[3] Between 50 and 100 people die each year from hypothermia in France (incidence, 0.13 deaths per 100,000 inhabitants),[4] and 700 to 800 people die each year from hypothermia in the United States (0.3 deaths per 100,000 inhabitants).[5,6] Hypothermia in otherwise healthy subjects (following mountain accidents or cold-water immersion) can be profound (< 20°C), while "urban" hypothermia usually occurs in fragile subjects (*eg*, the elderly, alcoholics, drug addicts), and the temperature is rarely < 25°C.

Management of hypothermia combines symptom-

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atic treatment and rewarming. Rewarming can be passive external, active external, or active internal.[7,8] Passive external rewarming (covers, warm room) leads to a body temperature increment of 0.5 to 1°C/h, while active external rewarming[9–11] (lamp, hot bath, fluidized bed) can achieve increments of 1 to 2°C/h. Active internal rewarming can be achieved with several methods, including circulation of warmed, humidified air[12,13] through the airways via a facial mask or tube (1 to 1.5°C/h); infusion of warmed fluid[14] (40 to 42°C) in the gastric, colonic, pleural,[15] peritoneal, or pericardial cavities[16] (2 to 2.5°C/h); hemodialysis[17] with a dialysis bath warmed to 40°C (2 to 3°C/h); and extracorporeal circulation[18] using a heat exchanger (up to 15°C/h). Aggressive rewarming by means of cardiopulmonary bypass improves the functional and vital prognosis of healthy subjects with very profound hypothermia,[19] but the use of this method for other patients is controversial, depending above all on local practices. A better knowledge of prognostic factors could help to guide this therapeutic choice. We therefore analyzed, in a retrospective study, the mortality rate and prognostic factors in patients with severe hypothermia admitted to our ICU.

Materials and Methods

This retrospective study was conducted from January 1, 1979, to July 31, 1998. Only patients with severe hypothermia (central temperature < 32°C) were included. The rewarming methods were only passive because there is no documented superiority of active techniques to treat urban hypothermia. This management did not change in our unit over the course of the study.

Data Acquisition and Analysis

On ICU admission, the following data were obtained: age, sex, cause of hypothermia, place of discovery (indoors or outdoors), patient's status, cardiac arrest before ICU admission, core central temperature, neurologic status (Glasgow Coma Score), systolic arterial BP, heart rate, blood gases, blood chemistry (sodium, potassium, glucose, urea, creatinine, bicarbonate, calcium, hepatic enzymes, and amylase), CBC count, and chest radiography. ECG deserved specific attention, with analysis of rhythm, variations of the isolectric line, Osborn J wave, and its amplitude, QT interval.[20] The following were subsequently analyzed: simplified acute physiology score (SAPS) at 24 h,[21] rewarming time (temperature > 35°C), complications, need for mechanical ventilation and vasoactive drugs, and death (date, place, and cause).

Temperature monitoring was performed with a hypothermic rectal catheter (Hewlett Packard; Evry, France), and rewarming was always based on external passive means, with survival blankets, synthetic covers, and a heater in the room. Considering the retrospective nature and type of the study, institutional review board approval was not required. Our ICU database is registered to the French authority (Commission Nationale Informatique et Liberte). Results are expressed as mean ± 1 SD. Prognostic factors were studied by univariate analysis using the Mann-Whitney *U* and the χ^2 tests, assuming significance at a $p < 0.05$, and using multivariate analysis with the logistic regression method (calculated odds ratio and 95% confidence interval). The SAPS II score was not included in the multivariate analysis because it integrates several variables already studied in the univariate analysis.

Results

During the study period, 12,100 patients were admitted in the ICU. Of these patients, 65 patients were coded as having hypothermia (temperature < 35°C), 4 patient charts were not found, and 14 patients were excluded because their temperatures were > 32°C. Forty-seven patients (0.4%) were thus studied (26 men and 21 women). Their characteristics are given in Table 1.

Five patients had a cardiac arrest before hospital admission. Twenty-four patients were found at home: drug intoxication (n = 4), falls in elderly subjects (n = 11), cardiogenic shock (n = 1), infectious shock (n = 1), major alteration of general status (n = 1), status epilepticus (n = 1), and undetermined causes (n = 5). Twenty-three patients were found outdoors: acute alcohol intoxication (n = 9), drug intoxication (n = 2), falls (n = 2), severely altered mental status (n = 1), and undetermined causes (n = 9). Most of the patients had one or multiple underlying diseases: chronic alcohol intoxication (n = 22), psychiatric disorders (n = 7), hypertension (n = 4), diabetes mellitus (n = 3), epilepsy (n = 3), liver cirrhosis (n = 1), AIDS (n = 1), and cancer (n = 2). Eight patients were homeless.

The mean temperature at ICU admission was 28.8 ± 2.5°C. Seventeen patients had major hypothermia (< 28°C; Fig 1), including 7 patients with a body temperature of ≤ 26°. Univariate analysis identified three factors correlated with the degree of

Table 1—*Characteristics of Patients Upon Admission and of ICU Stays (n = 47)

Variables	Data
ICU admission	
Age, yr	61.7 ± 16 (28–90)
Temperature, °C	28.8 ± 2.5 (22–32)
Systolic BP, mm Hg	85 ± 23 (40–130)
Heart rate, beats/min	60 ± 24 (15–130)
Glasgow Coma Scale	10.4 ± 3.7 (3–15)
HCO_3^-, mmol/L	21 ± 6.5 (9–34)
Potassium, mmol/L	3.96 ± 1.17 (2–6.4)
ICU stay	
SAPS II	50.9 ± 27 (13–107)
Patients receiving mechanical ventilation	23 (49)
Vasoactive drugs	22 (47)
ICU length of stay, d	6.7 ± 9 (1–36)

*Data are presented as mean ± SD (range) or No. (%).

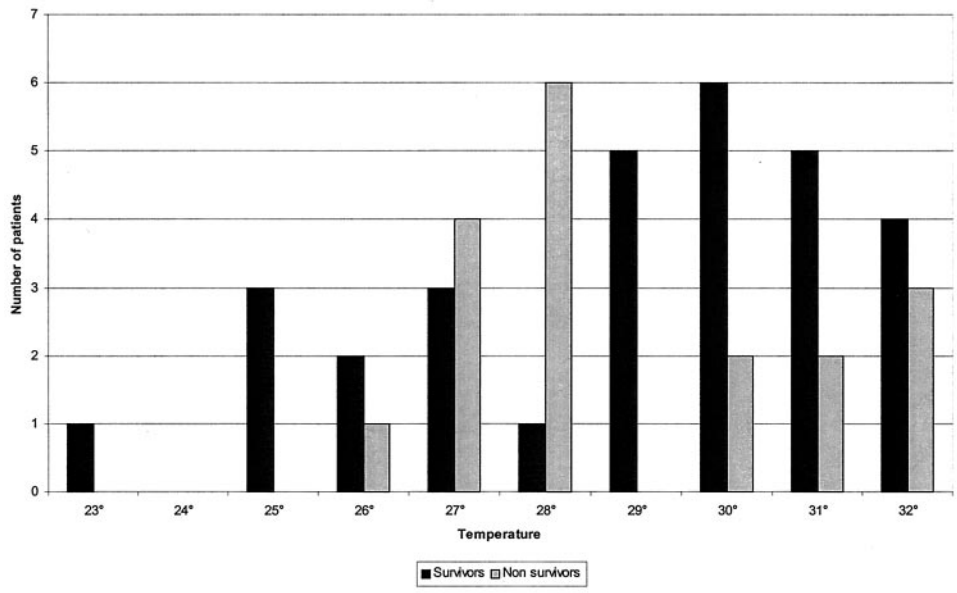

FIGURE 1. Distribution of patients according to the temperature at ICU admission and vital status at ICU discharge.

hypothermia: systolic arterial BP ($p < 0.03$), presence of the J wave (27.6 ± 2.4°C vs 30.2 ± 1.5°C, $p < 0.01$), and amplitude of the J wave (1 to 15 mm; $p < 0.001$)

Biological abnormalities were nonspecific, reflecting only the gravity of shock. Chest radiographic findings were normal in 36 patients and showed unilateral lung opacity in 5 patients and bilateral lung opacities in 6 patients. Twenty-seven patients were in sinus rhythm, 10 patients had atrial fibrillation, and the remainder could not be analyzed because of tremor. Heart rate was < 60 beats/min in 27 patients and < 40 beats/min in 10 patients. Osborn's J wave was present in 18 patients, and 28 patients had a significant prolongation of the QT interval. Only one patient had ventricular tachycardia, which was successfully treated by external electric shock. The ECG evolution of the patient with an initial temperature of 22°C is shown in Figure 2.

Eighteen patients died (38%). Sixteen deaths occurred in the ICU (11 deaths occurred in the first 48 h), but no patients died of ventricular arrhythmia. Four of five patients who received cardiopulmonary resuscitation initiated in the prehospital setting died. There were no deaths among the 15 patients hospitalized for acute intoxication (drug or alcohol). Interestingly enough, there was only one death among the seven patients with core body temperature of ≤ 26°C. Nine patients died in the period from 1979 to 1988, and nine patients died in the period from 1989 to 1998.

The results of univariate analysis of prognostic factors are shown in Table 2. The initial temperature did not influence vital outcome. Most parameters reflecting the initial gravity correlated strongly with the mortality rate. Patients found at home, patients whose hypothermia was not linked to acute intoxication, and patients who underwent warming slowly had a higher mortality rate. In multivariate analysis, only the use of vasopressor agents was associated with mortality (odds ratio, 9; 95% confidence interval, 1.6 to 0.1; $p < 0.01$).

DISCUSSION

Hypothermia is a rare cause of admission to the ICU, with only 65 cases during the 19-year period of this study (approximately 3 cases per year, representing 0.4% of ICU admissions). Other teams[9,22] have reported a similar incidence of three to four patients per year. In Paris, the emergency medical ambulance service[23] recorded 30 cases of hypothermia in the 14-month period from October 1986 to December 1987 (approximately 1 case per 1,000 calls). This frequency is probably underestimated, because the Paris fire service also manages some hypothermic patients.

Mortality among hypothermic patients is highly variable according to this study (12 to 80%). It depends on the cause of hypothermia, the patient's age and background, the delay before treatment, and, probably, in some cases, the rewarming modality. In our study, the mortality rate was 38%. Other

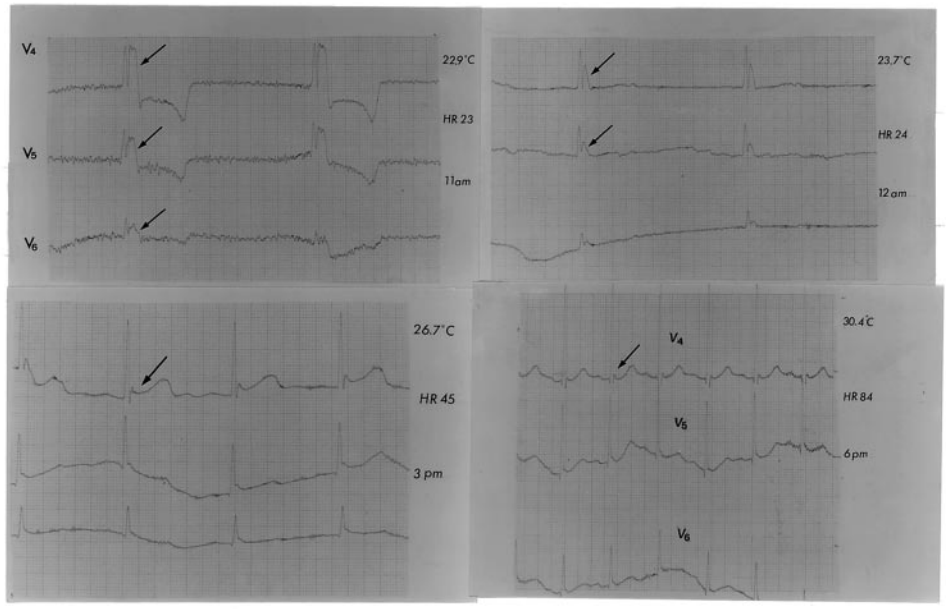

FIGURE 2. Characteristic ECG modifications observed in patients with profound hypothermia. The first tracing shows a bradycardic rhythm with a baseline artifact due to muscle tremors hiding the P wave, and Osborn wave (arrows). The following tracing shows the ECG evolution of the patient with an initial temperature of 22°C.

studies[22,24] of patients with a similar degree of hypothermia (< 32°C) managed with passive external rewarming have reported higher mortality rates (52% and 63%, respectively). The Swiss multicenter study[25] published in 1991, which grouped together mountain accidents and urban hypothermia treated with active internal rewarming, reported a mortality rate similar to ours (38.5%). In a prospective Scottish study[9] including 44 patients rewarmed by means of an active external method, the mortality rate was only 27% but 50% of the patients had acute intoxication. In the 2-year North American prospective multicenter study[26] published in 1987, involving 428 patients from 11 US states and British Colombia in Canada, the overall mortality rates were 17% and 23%, respectively, among patients with a temperature of < 32.2°C, but the patients were younger than patients in our study. A mortality rate of 17% was also found in the 1995 Dutch multicenter study[27] of 427 patients with hypothermia not due to immersion, but no information was given on severity.

Table 2—*Study of Prognostic Factors by Univariate Analysis*

Factors	Survivors (n = 29)	Nonsurvivors (n = 18)	p Value
Age, yr	57 ± 16	69 ± 14	0.01
Temperature at ICU admission, °C	28.8 ± 2.6	28.6 ± 2.2	NS
Systolic BP, mm Hg	9.3 ± 2	7.1 ± 2.1	0.001
Heart rate, beats/min	58.2 ± 20	62.6 ± 30	NS
Glasgow Coma Scale	11.2 ± 3.2	9.2 ± 4.1	NS
HCO_3^-, mmol/L	23.5 ± 5.2	17.5 ± 6.2	0.003
SAPS II	35.3 ± 19.5	72 ± 21	0.0001
Rewarming time, h	11.5 ± 7.5	17.2 ± 7	0.03
Mechanical ventilation	10 (34.4)	13 (72.2)	0.005
Vasoactive drugs	8 (27.5)	14 (77.7)	0.001
Acute intoxications	15 (51.7)	0 (0)	
Alcohol, No.	12		
Drugs, No.	6		
No acute intoxication	14 (49.3)	18 (100)	0.002
Found indoors	10 (34.4)	14 (77.7)	
Found outdoors	19 (65.6)	4 (22.3)	0.006

*Data are presented as mean ± SD or No. (%) unless otherwise indicated. NS = not significant.

Contrary to most reports in the literature,[20,24,28,29] but similar to the Scottish[9] and American[26] studies, none of our patients died of ventricular arrhythmia. In a French retrospective report[24] of 24 patients similar to our population in terms of degree of hypothermia and rewarming method, 2 of the 13 deaths were attributed to ventricular fibrillation (1 death at hospital admission at 24.5°C, and the other death during rewarming at 34°C). It seems, however, that ventricular arrhythmia is more frequent in young patients with very severe hypothermia. In a Swiss study[20] of 15 asystolic patients who were successfully rewarmed by means of cardiopulmonary

bypass (mean initial temperature, 21.8 ± 2.5°C), 10 patients had ventricular fibrillation initially.

Our univariate analysis identified severity factors: old age, low BP, low blood bicarbonate level, high SAPS II, need for mechanical ventilation or vasoactive drugs, discovery of the patient at home, hypothermia not due to acute intoxication, and long delay before rewarming. Age was also highly significantly associated with prognosis in other studies,[9,22,27] except for the American series,[26] in which the mean age was 53 years (compared with 62 years in our study). The high mortality rate among patients found at home (77%) relative to those found outdoors (23%) may be explained by the older age of the former (69.7 years vs 49.7 years) and, probably, by later discovery. In the American study,[26] the difference in mortality between these two patient categories was smaller (55% vs 45%), but the percentage of patients discovered at home was lower. The prognosis of hypothermia due to acute intoxication (drug or alcohol) is clearly better than that of hypothermia due to other causes (0% vs 56% mortality rates in our series), mainly because of the younger age of the former patients (49.5 years vs 72.3 years). This confirms the results of the Scottish study[9] (two deaths in 25 cases of acute intoxication, vs 53%), a 10-year French retrospective study[22] of 35 hypothermic patients (no deaths among five patients with drug intoxication), the Paris SAMU study[23] (70% cases of acute intoxication, overall mortality rate of 27%), and the Bellevue hospital experience.[29] As in other studies,[9,24,29] the baseline temperature was not a factor of poor prognosis in our study (Fig 2). The American study[26] showed a significant difference by univariate analysis, which disappeared in multivariate analysis. In our seven patients with body temperatures $\leq 26°$, there was only one death. This low mortality is in contrast with the study by White[29] in New York City, documenting a 50% mortality when the body temperature was $< 26°C$. In the event of mountain accidents and cold-water immersion when temperatures are $< 20°C$, baseline temperature is a major prognostic factor and to our knowledge, survival has never been reported at $< 15.2°C$ in children[30,31] and $< 13.7°C$ in adults.[32]

The rewarming rate and the delay after the accident seem to be most important prognostic factors. The rewarming delay was significantly longer in the patients who subsequently died in our study (17.2 ± 7 h vs 11.5 ± 7.5 h, $p < 0.03$). In 1974, a French team[24] noted that the mortality rate in patients whose temperature was increased regularly by 0.5 to 1°C/h during passive external rewarming was 31%, compared to 100% in patients who were not rewarmed or who were rewarmed too slowly ($< 0.5°C/h$). The North American study[26] also showed significantly slower rewarming in the first hour in patients who died. In the study by White,[29] if in-hospital rewarming required > 12 h, this was a grave prognostic sign. The slower rewarming rates may also reflect underlying host problems such as poor circulating volume.

Major hyperkalemia (> 10 mmol/L) is a factor of poor prognosis only in asphyxiated avalanche victims.[33–35] In our multivariate analysis, the use of vasopressor agents (reflecting the severity of shock) was the only factor associated with mortality. Shock was also associated with a poor prognosis in the study by White.[29] Danzl et al[36] found five risk factors also reflecting initial severity: cardiac arrest before hospital admission, low BP, elevated blood urea, need for mechanical ventilation, and gastric intubation. A prognostic score for hypothermia (ranging from 0 to 40) was proposed on the basis of these five parameters.[36] Based on a logistic regression model, the Swiss multicenter study[25] identified four parameters (age, asystole, hyperkalemia, and acute poisoning) that together were predictive of vital outcome in 87% of cases.

To our knowledge no randomized prospective studies have yet compared the different rewarming methods. Published series, using different rewarming methods, are not comparable because of major differences in patient populations. Danzl et al,[36] using their prognostic score, analyzed patients' outcomes according to the rewarming method. No significant difference was found between the different methods, but there was a trend favoring active internal rewarming by gastric or colonic lavage and another trend against active external rewarming with hot baths or electric blankets. Recently, Walpoth et al[19] reported a survival rate of 47% in 32 young patients with asystole treated with extracorporeal circulation. The global long-term neurologic outcome of the 15 survivors was excellent, with nine full recoveries, three cases of minor CNS sequel, and two minor and one major sequel of the peripheral nervous system. These results confirm the value of this rewarming method for young patients with very severe hypothermia.

Severe hypothermia is rare but potentially lethal, justifying immediate admission to the ICU. In our multivariate analysis, shock was identified as the only risk factor for mortality while initial core temperature was not. Hypothermia without shock can be treated by passive external rewarming. The best therapeutic approach for hypothermia associated with shock necessitating the use of vasoactive drugs (mortality rate > 60%) is more controversial. If passive external rewarming is ineffective within the first few hours, a more aggressive method may be warranted.

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