Treatment of accidental hypothermia: a prospective clinical study

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Summary and conclusions

A 15-year prospective study was carried out of 44 patients with accidental hypothermia (mean age 60 years) admitted to an intensive therapy unit. The lowest core temperature recorded in each patient ranged from 20.0 to 34.3°C. The precipitating factors were poisoning (by drugs, alcohol, or coal gas) in 25 cases and various illnesses in 19. Rewarming was achieved in 42 patients by applying a radiant heat cradle over the torso, and in two patients by mediastinal irrigation with warmed fluids. Twelve patients died, but only two during the period of rewarming.

Thus rewarming may be consistently and safely achieved irrespective of the cause of hypothermia, and normal body temperature may be regained as rapidly as is compatible with adequate tissue perfusion and oxygenation. Surface rewarming of the torso is perhaps the simplest technique available, but internal rewarming procedures may be desirable or essential in the presence of, for example, profound hypothermia, severe hypotension, or ventricular fibrillation. Mortality was attributable to underlying factors or disease and not to hypothermia.

Introduction

Accidental hypothermia is traditionally the pathophysiological state in which central temperature has been reduced unintentionally to below 35°C. Two main subdivisions are recognised: (1) hypothermia due to exposure of otherwise healthy individuals to cold, wet, or windy conditions; and (2) hypothermia occurring in the very young or the elderly (often secondary to some underlying illness) and in the general population (secondary to drugs and alcohol). Patients in the second category are surprisingly common in urban populations, and mortality is high: the reported figures vary from 40% to over 80%.¹ Some advances in treatment have been made within the past decade, but there is still no universally agreed policy.² Several key issues remain unresolved including the optimum rate of rewarming, the need for intravenous fluids, the role of oxygen administration and positive-pressure ventilation, and the indications for drugs.

We have carried out a 15-year prospective study of patients presenting with accidental hypothermia in an urban environment. During the course of the study we have made brief statements on treatment^{3,4} but have not presented detailed results.

Patients and methods

From 1963 to 1978, 44 patients suffering from accidental hypothermia were referred from the medical units and the accident and emergency department at this hospital. From 1968 treatment was carried out in the intensive therapy unit.

MONITORING

On admission the patient's general condition was preliminarily assessed and arterial blood samples withdrawn for detailed biochemical and haematological analyses. A chest radiograph and full-lead electrocardiogram were obtained. Radial artery and central venous catheters were inserted for measurement of heart rate, and systemic arterial and central venous blood pressure; thermocouples were placed in the rectum and on the great toe for measurement of central and peripheral temperatures. Heart rate, arterial pressure, temperatures, and the tracing from lead II of the electrocardiogram were continuously displayed on a bedside monitor. Respiratory rate and inspired oxygen concentration were recorded in patients breathing spontaneously, and more detailed information in those being ventilated. Bladder catheterisation permitted accurate measurement of urine output. No exhaustive investigation was carried out at this stage to elicit the cause of hypothermia.

TREATMENT

Rewarming was achieved in 42 of the patients by applying a radiant heat cradle over the torso, the skin being protected by a thin sheet. Active rewarming was discontinued at about 35°C to allow for the usual spontaneous further rise in temperature of 2-3°C. The two patients not rewarmed by this method underwent thoracotomy and mediastinal irrigation with warmed fluids. Intravenous fluids, which were warmed before infusion, were administered to reduce haemoconcentration; restore circulating blood volume; and maintain arterial pressure, central venous pressure, and urine output at satisfactory levels.

Oxygen was administered to maintain the arterial pressure of oxygen (P_{O_2}) (corrected for temperature) within the normal range; indications for intermittent positive-pressure ventilation included (1) a combination of hypoxaemia and arterial pressure of CO_2 (P_{CO_2}) over about 4.7 kPa (35 mm Hg) (corrected for temperature); (2) evidence of deteriorating pulmonary gas exchange; (3) coma; and (4) cardiovascular instability. Throughout rewarming the cardiovascular and respiratory indices outlined above were observed carefully and appropriate action begun when required; biochemical and haematological disturbances were likewise detected early and remedied. No special consideration was given to the fact that the patients were hypothermic, although hypotension was more often tolerated without recourse to pharmacological agents, and arterial P_{CO_2} was maintained at values below the normal range in patients receiving ventilation.

The patients were followed up for one month after the episode of hypothermia. Postmortem examination was performed in 10 of the 12 patients who died.

RETROSPECTIVE STUDY

During the period of the prospective study an additional 89 hypothermic patients were treated by other doctors at this hospital along conventional—that is, less aggressive—lines. These patients did not constitute a properly planned control group, but we nevertheless determined their fate retrospectively. We recovered 77 adequate case records, from which we made a preliminary analysis.

Results

The mean age of the 44 patients in the prospective study was 60 years, most being aged 40-70 years. The lowest core temperature recorded in each patient ranged from 20.0 to 34.3°C (table I), and in 37 cases (84%) was below 32.3°C, the temperature indicating medically important primary hypothermia.⁵

Poisoning was the precipitating factor in 25 cases. Drugs were the

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TABLE 1—Lowest recorded core temperatures in all 44 patients with accidental hypothermia 1963-78

°C	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
No of patients	1			3	2		2	3	5	5	5	4	9	3	2

precipitating factor in 18: longer-acting barbiturates in two (plus nitrazepam (one case) and phenothiazine (one)); other barbiturates in eight (plus alcohol (one case) and trichloral (one)); and other drugs in eight (namely, tryptazole and alcohol, phenothiazine, meprobamate (two cases), fluphenazine, tryptophan, diazepam, and tryptazole). Alcohol was the precipitating factor in four patients (two of whom were taking pentobarbitone), and coal-gas poisoning in three. In the 19 remaining patients various illnesses were found: cardiovascular accident (four), endocrine disease (four), malnutrition and dehydration (three, in two of whom alcohol was also a precipitating factor), malignancy (two), myocardial infarction (one), pneumonia (one), old age (one), injury (one), skin disease (one), and mental disability (one).

CLINICAL AND LABORATORY DATA

Heart rates tended to be slower at lower temperatures, but the relation was not as striking as might have been expected. There was no consistent relation between arterial blood pressure and temperature, although in 10 of the earlier patients initial blood pressure on admission was unrecordable. (This occurred before measurement of intra-arterial blood pressure became routine.) Of the 34 patients whose admission electrocardiogram had been retained, over half had arrhythmias, including seven patients with atrial fibrillation and three with ventricular fibrillation (of whom two survived).

Seventeen patients (39%) had obvious respiratory inadequacy on clinical examination: nine were apnoeic and eight nearly so. Initial chest x-ray films showed patchy opacification in 12 out of 30 patients (40%), and five more patients subsequently developed radiological changes. Blood-gas analysis confirmed the high incidence and severity of disturbances of pulmonary gas exchange. In most of the patients in whom analysis was performed during spontaneous air breathing arterial P_{O_2} was less than 7.3 kPa (55 mm Hg; fig 1); and in those breathing oxygen either spontaneously or via a ventilator the mean alveolar-arterial differences in P_{O_2} were 33 and 47 kPa (248 and 353 mm Hg) respectively. Mean arterial PCO_2 in the whole group was 4.3 kPa (32 mm Hg; fig 2), which accounted for a normal mean arterial pH of 7.38 units in the presence of a mean base deficit of 9 mmol (mEq)/l.

The biochemical findings were similar to those previously reported in patients with accidental hypothermia.⁶ Haemoconcentration was common, as were thrombocytopenia and leucocytosis as shown by

FIG 1—Arterial P_{O_2} in patients breathing (air) spontaneously, and alveolar-arterial P_{O_2} difference ($\Delta A-a_{O_2}$) in patients breathing (oxygen) spontaneously and receiving ventilation (IPPV) at lowest temperature; crosses indicate means, and bars standard deviations.

Conversion: SI to traditional units—Respiratory indices: 1 kPa $\approx$ 7.5 mm Hg.

haematological analysis, although the leucocytosis generally became less pronounced once the volume of circulating fluid had been restored.

FIG 2—Arterial PCO_2 in patients breathing spontaneously and receiving ventilation; crosses indicate means, and bars standard deviations.

Conversion: SI to traditional units—Respiratory indices: 1 kPa $\approx$ 7.5 mm Hg.

TREATMENT

No patient was adversely affected by any of the manoeuvres used for monitoring purposes or treatment. Reflex cardiac slowing and induced arrhythmias were not seen.

Rewarming was achieved at a mean rate ($\pm$ SEM) of $1.13 \pm 0.09^\circ\text{C}/\text{hour}$. The mean duration of rewarming was 8.03 ± 0.85 hours. Figure 3 shows the course of uneventful active rewarming; the patient breathed spontaneously throughout. Most patients (41) received some intravenous fluids during this period, the mean volume infused being 2.1 ± 0.2 l. Dextrose (5%) and saline were the fluids most frequently infused, but plasma and blood were given occasionally; potassium was administered as indicated by sequential biochemical analyses; calcium was not normally given. Oxygen (mean maximum concentra-

FIG 3—Uneventful rewarming from 23.6°C in a 48-year-old man who had taken butobarbitone and alcohol before prolonged exposure to cold.

tion 65%) was administered to 40 patients, and intermittent positive-pressure ventilation with warmed humidified gas to 21 (48%). At the end of rewarming the standard criteria for weaning from the ventilator were observed, and adequate spontaneous ventilation was usually achieved without difficulty.

The most troublesome problem during rewarming was hypotension, which was regarded as more severe than usual (systolic blood pressure less than about 70 mm Hg) in 14 of the 44 patients (32%). Seven of these patients received drugs aimed at increasing blood pressure and thereby improving perfusion to vital organs. Four were given the vasoconstrictor metaraminol: one responded well, a second had a variable response, and two showed no response; while three received

drugs with a major inotropic action on the heart (dopamine and isoprenaline); all responded well, and urine output improved appreciably in the two given dopamine. One patient was given the alpha-adrenotropic blocking agent thymoxamine because of persistent vasoconstriction towards the end of rewarming; a moderate response occurred.

Steroids had been administered to seven patients before referral; only small doses had been given and the effect was impossible to judge. Antibiotics were not administered prophylactically, but 24 patients (55%) received various antibiotics when bacteriological examination confirmed clinically important infection (usually of respiratory origin).

MORTALITY

The overall mortality in the *prospective* study was 27% (12 patients). Only two patients (5%) died during rewarming; both deaths occurred in the early years of the study (1965 and 1968), one because mechanical ventilation was stopped prematurely and the other from inadequate fluid repletion. The remaining 10 patients all died after regaining normal body temperature (table II).

TABLE II—Details of patients who died

Case No	Year	Age (years) and sex	Precipitating and associated factors	Day of death	Cause of death
1	1965	77M	Coal-gas poisoning	1*	Respiratory failure during rewarming
2	1968	65M	Alcoholism; anaemia	1*	Cardiac failure during rewarming
3	1970	80M	Coal-gas poisoning; cerebrovascular accident	2	Cerebrovascular accident†
4	1967	84F	Cerebrovascular accident	3	Cerebrovascular accident†
5	1970	69F	Myocardial infarction	4	Further myocardial infarction
6	1974	66M	Hypertension	4	Subarachnoid haemorrhage; bronchopneumonia
7	1974	56M	Chronic respiratory disease; diarrhoea and vomiting; dehydration	4	Cardiac arrest (serum calcium 1.2 mmol/l; 4.8 mg/100 ml)
8	1969	59M	Pituitary tumour	4	Meningitis
9	1978	78M	Tuberculous bronchopneumonia; cerebrovascular accident	10	Acute renal failure; cerebral softening
10	1969	60M	Reticulosis; anaemia	11	Reticulosis; bronchopneumonia
11	1964	69F	Myxoedema; rheumatoid arthritis; anaemia; myocardial infarction	12	Septic shock; perforated stercoral ulcer
12	1974	80F	Melaena; dehydration; inanition	19	Myocardial infarction

* Patient died during rewarming.

† Postmortem examination was not carried out.

We considered in greater detail three of the several factors that might have been expected to affect the ultimate outcome in patients suffering from hypothermia—namely, age, temperature on admission, and nature of the principal precipitating condition. The mean age of non-survivors (71 ± 9 years) was significantly greater ($p < 0.001$) than that of survivors (50 ± 17 years), but there was no significant difference in temperature between the two groups. The patients in whom poisoning was the principal precipitating factor appeared to have a considerably better prognosis (two out of 25 died) than the others (10 out of 19 died; $\chi^2 = 8.7$, $p < 0.005$). The temperature on admission in the two groups did not differ ($28.8 \pm 0.7^\circ\text{C}$ in the poisoned patients and $29.6 \pm 0.55^\circ\text{C}$ in the others), but the mean age of the two groups was significantly different (44 ± 15 years in the poisoned patients who survived and 64 ± 10 years in the non-poisoned patients who survived; $p < 0.001$); there was no significant difference in mean age between the two groups of patients who died. Age did not significantly differentiate survivors and non-survivors in the group of non-poisoned patients.

Analysis of the data from the *retrospective* group of 77 patients showed that most were aged 60–90 years and the lowest individual recorded temperatures ranged from 20.0 to 34.7°C ; 54 (70%) were below 32.2°C . The overall mortality was 60% (46 patients), 36 of these patients (78%) dying during rewarming in the first three days after admission. The mean age of the non-survivors was 73 ± 2 years and of the survivors 67 ± 3 years; the mean central temperature of the non-survivors was $29.6 \pm 0.5^\circ\text{C}$ and of the survivors $31.7 \pm 0.4^\circ\text{C}$ ($p < 0.005$). Nineteen of the 77 patients were hypothermic as a result of drug or alcohol abuse, alcohol abuse being more common; six of

these patients died (32%). Most of the patients (58) had either some serious underlying illness or no obvious cause for hypothermia; 40 of these patients died (69%). The difference in mortality between the patients who had abused drugs or alcohol and the others was significant ($\chi^2 = 6.8$; $p < 0.01$).

Discussion

TREATMENT

One of the more controversial aspects of treatment concerns the rate and technique of rewarming. Rapid external rewarming has been used largely, though by no means exclusively, for younger patients suffering from hypothermia of fairly brief duration,^{7–9} while rapid internal rewarming has usually been reserved for patients with profound hypothermia whose resuscitation by simpler methods proved to be difficult or impossible.^{10–12}

In the elderly rapid external rewarming fell into disrepute after the reports of Rees¹³ and Duguid *et al*¹⁴; the latter attempted active rewarming in six patients, all of whom died. Since then most doctors concerned with managing urban patients with hypothermia have opted for passive external rewarming. Restoration of normal body temperature by using this technique may take 24 hours, or longer if there are cardiorespiratory complications, with the result that many patients die while still hypothermic (41 out of 100 consecutive patients in one series¹⁵).

Only two patients in the present series died during the rewarming period—and none in the past decade. Thus active rewarming is safe even in the elderly hypothermic patient, and previously reported problems associated with active rewarming of these patients probably had other explanations—for example, hypoperfusion and hypoxia. The importance of fluid repletion and correcting hypoxaemia, including using mechanical ventilation if indicated, is now clear.¹⁶ Cardiorespiratory collapse during rewarming may be avoided, and the incidence of longer-term pulmonary complications appears to be reduced.

This study has also shown that invasive monitoring and treatment manoeuvres are not in themselves harmful. If ventricular fibrillation was precipitated by these manoeuvres^{5, 17} factors other than hypothermia per se were apparently responsible—for example, hypoxia,¹⁸ hypotension or acidosis,¹⁹ or awkward movement.²⁰

The complex interaction between drugs and hypothermia suggests that the use of all drugs should be restricted during rewarming. In the present study vasoactive agents were occasionally used for persistent hypotension. Two points may be noted: the hypotension of hypothermia may be more apparent than real (because of diminished pulse pressure), and it usually responds to fluid infusion alone. Vasoconstrictors have proved disappointing, but selective use of inotropic agents may be rewarding.^{21, 22}

MORTALITY

Comparing mortality between groups of patients is complicated by the variability of such factors as age, severity and duration of hypothermia, and nature of precipitating condition. Thus although the overall mortality of 27% in the prospective study is the lowest recorded, it was favourably influenced by the proportion of patients admitted with hypothermia induced by poisoning. More important, we believe, is the elimination of deaths during the rewarming phase, irrespective of the factor(s) precipitating the hypothermia.

A more aggressive approach to treatment (including rewarming) has the advantages that the period of close monitoring may be reduced and the underlying condition more rapidly diagnosed. Whether many lives are saved remains to be ascertained by controlled study, but the evidence suggests that few of the patients in the prospective study died of factors attributable to hypothermia (particularly respiratory complications). This

could not be stated with any conviction for the patients in the retrospective study, many of whom died while still hypothermic and before a definite diagnosis was made.

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Paget's disease of bone: the Lancashire focus

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Summary and conclusions

The radiological prevalence of Paget's disease of bone has been studied in 31 towns in Britain. A remarkably localised area of high prevalence has been shown in Lancashire. Although environmental influences seem dominant in the aetiology of the disease, no hypothesis about the environmental cause of the Lancashire focus can be advanced.

Introduction

In a recent survey of the radiological prevalence of Paget's disease of bone in 14 towns in England and Wales the highest prevalences recorded were in three towns in Lancashire.¹ To investigate further this apparent focus of high prevalence in Lancashire, and to define its boundaries, we extended the survey to include an additional 17 towns.

Methods

The 17 towns were Aberdeen, Birkenhead, Blackpool, Burnley, Carlisle, Chester, Glasgow, Lancaster, Macclesfield, Middlesbrough, Newcastle upon Tyne, Oldham, Portsmouth, Rochdale, Warrington,

Whitehaven, and Wigan. They were selected to include areas of Britain not studied in the initial survey, and to provide additional data on Lancashire and the towns bordering it. The survey method was identical with that used previously.¹ In each town a sample of abdominal radiographs of people aged 55 and over was taken from the stored films within the radiological department of a general hospital. The selected films showed the entire pelvis and sacrum, the femoral heads, and all lumbar vertebrae—sites that are affected in 95% of patients with Paget's disease.

Wherever possible samples of about 1000 radiographs were drawn for each town, with similar numbers for men and women. In some towns the records systems were such that retrieval of radiographs, of the kind required and for patients of known age, was excessively time-consuming. In these circumstances smaller size samples were used. The films were initially classified by a trained observer (ATC) into three groups: positive (unequivocal signs of Paget's disease), doubtful, and negative. A second observer (PBG, a radiologist) then examined all the positive and doubtful films and a one-in-ten sample of the negative ones. Standardised criteria were used for the diagnosis of Paget's disease. In the previous survey the radiologist's observations were shown to have a high level of repeatability. After completion of the present survey a sample of 109 films from six towns was re-examined to determine whether this level of repeatability had been maintained.

Results

The table shows the prevalence of Paget's disease in the 17 towns, together with those in the 14 towns in the previous survey. The prevalence rates for each sex were directly standardised to allow comparisons corrected for the differing age distributions of the subjects in the various towns. The standardisation procedure used five-year age distributions from 55 to 90 and over. The combined population of the 14 towns was again used as the standard so that results of the two surveys are directly comparable. In the table the towns are listed in descending order of the overall age- and sex-standardised prevalences (final column), which varied from 8.3% in

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