ORIGINAL RESEARCH

The electrocardiogram in hypothermia

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Objective.—Hypothermia is known to adversely affect the electrocardiogram (ECG) in many cases. This study set out to determine the incidence of defined cardiac dysrhythmias, J waves, and conduction abnormalities in urban hypothermia.

Methods.—A prospective, multicenter study was carried out to determine the incidence of defined cardiac rhythms in patients suffering from accidental urban hypothermia. The ECGs were independently analyzed by 2 of the authors and placed into 1 of 6 rhythm categories.

Results.—Seventy-three ECGs were analyzed. Normal sinus rhythm was the most common rhythm (41%). Overall mortality was 36% (26/73). J waves occurred in 36% of survivors and 38% of nonsurvivors and were, therefore, not prognostic. Shivering artifact was present in 66% of survivors and 38% of nonsurvivors. Although there was no statistically significant association between J waves and survival ($P = .21$), the presence of shivering artifact was associated with survival in severe hypothermia ($P = .047$). Atrial fibrillation and junctional bradycardia were both associated with high mortality.

Conclusions.—This study confirms that the ECG is abnormal in the majority of patients suffering from accidental hypothermia. J waves do not appear to be independently prognostic in hypothermia. The results suggest that the inability to mount a shivering response may be associated with a poorer outcome; this finding requires further study.

Key words: accidental hypothermia, electrocardiogram, J waves, shivering, dysrhythmia

Introduction

Hypothermia (defined as a core body temperature less than 35°C) is well known to adversely affect cardiac rhythm, which has deleterious effects on cardiac output.^{1–4} Some changes in the electrocardiogram (ECG) are said to be characteristic of hypothermia, the best known being the “J wave” (Figure), as originally described by Osborne.^{5,6} The spectrum of defined cardiac rhythms in hypothermia has not been well documented in the past. We performed a prospective study to analyze the ECG rhythm disturbances and the abnormalities in cardiac conduction associated with hypothermia in an urban setting.

Methods

This was a prospective, multicenter observational study. All patients presenting to 8 accident and emergency de-

partments in Glasgow, Paisley, and Airdrie (all in the west of Scotland) with a rectal temperature less than 35°C were prospectively studied between December 1, 1993, and March 31, 1994.⁷ An admission ECG was taken for each patient in the accident and emergency department, and data were collected on the patients' demographics, core temperatures, and outcomes. The ECGs were subsequently categorized independently into 6 categories by 2 of the authors, and agreement was made collectively in all cases.

Outcome was recorded in terms of survival or death, but no attempt was made to relate any specific cause of death to the episode of hypothermia.

Mild hypothermia was defined as a core (rectal) temperature of 32.0°C to 34.9°C. Severe hypothermia was defined as a core (rectal) temperature of less than 32.0°C. Rectal temperature was measured using a low-reading rectal thermometer. Statistical analysis was evaluated by means of the χ^2 test, and significance was defined as $P < .05$.

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Electrocardiogram showing sinus bradycardia with J waves (arrows).

Results

Seventy-three ECGs were available for analysis from a total of 93 patients who entered the study. It was not possible to locate the remaining 20 ECGs. The ECGs were from 47 survivors and 26 nonsurvivors. The mean age for survivors was 70 years (range 13–97 years) and the male-female ratio was 1:1. For nonsurvivors, mean age was 77 years (range 49–92 years) and the male-female ratio was 1:1.4. Nine of the 26 nonsurvivors were known to be taking cardiac drugs (eg, digoxin, furosemide, atenolol), compared to 12 of 47 survivors. Sixty-

four ECGs were classified into 6 categories (Table 1). Nine could not be accurately classified owing to baseline shivering artifact. These 9 patients had a mean core temperature of 31.8°C (range 27.2°C–34.6°C).

Mean PR and QRS durations were within normal limits, but the mean QTc interval was prolonged at 481 ms (upper limit of normal 440 ms). ST segment abnormalities were present in 17% (8/47) of survivors and 31% (8/26) of nonsurvivors. This factor was not statistically significant ($\chi^2 = 1.849$, $P = .17$, $df = 1$). These abnormalities consisted of 3 ECGs with ST segment elevation (2 sur-

Table 1. Electrocardiographic (ECG) rhythms

ECG rhythm	No. of ECGs	Percentage of ECGs	No. of ECGs with J waves	Mean core temperature, °C (range)	No. of deaths	Percentage of deaths
Normal sinus rhythm	30	41	12	34.3 (27.5–34.9)	8	31
Sinus bradycardia	9	12	4	32.3 (27.7–34.7)	1	4
Sinus tachycardia	5	7	1	33.0 (28.0–34.9)	2	8
Atrial fibrillation	15	21	5	31.0 (25.0–33.9)	9	35
Junctional bradycardia	4	5	3	30.5 (27.2–34.2)	3	12
Paced rhythm	1	1	0	33.2 (33.2)	1	4
Unclassified rhythm	9	12	2	31.8 (27.2–34.6)	2	8
Total	73		27		26	

Table 2. J waves

	<i>Mild hypothermia</i>	<i>Severe hypothermia</i>	<i>Total</i>
Survivors	31% (11/35)	50% (6/12)	36% (17/47)
Mean core temperature, °C (range)	33.8 (32.4–34.9)	29.1 (27.2–31.0)	32.1 (27.2–34.9)
Nonsurvivors	33% (4/12)	43% (6/14)	38% (10/26)
Mean core temperature, °C (range)	33.8 (32.7–34.2)	30.0 (27.7–31.3)	31.5 (27.7–34.2)
Total	32% (15/47)	46% (12/26)	37% (27/73)

vivors) and 13 ECGs with ST segment depression (6 survivors). J waves were more common in patients with severe hypothermia (12/26, 46%) than in those with mild hypothermia (15/47, 32%) (Table 2), although this factor was not statistically significant ($\chi^2 = 1.556$, $P = .21$, $df = 1$). Overall, shivering artifact was present on 56% of ECGs (Table 3). A higher proportion of survivors had shivering artifact on the ECG, and this factor was statistically significant ($\chi^2 = 3.931$, $P = .047$, $df = 1$).

Discussion

This prospective observational study has demonstrated that the ECG is rarely normal in patients suffering from hypothermia. Sinus rhythm was frequently seen (41%), whereas sinus bradycardia (12.3%) and sinus tachycardia (6.8%) were less common. Atrial fibrillation was common (20.5%) and was associated with a poor prognosis (60% mortality). Although junctional bradycardia was rare (5.5%), 3 of the 4 patients with this rhythm died.

Overall mortality for all causes for the patients in the study was 35.6% (26/73). The difference in mortality was not necessarily due to cardiac dysrhythmias or other cardiovascular mortality. Confounding factors included advanced age, premorbid pathology, precipitating illnesses, etc. Various factors, including alcohol, confusion, and immobility, have been implicated in the causes of urban hypothermia,⁷ and these pathologies often cannot be separated from the hypothermic process itself.

J waves occurred in 36% of survivors and 38% of nonsurvivors, and therefore were not prognostic. Shivering artifact was present in 66% of survivors and 38%

of nonsurvivors. Of the severe hypothermia group, 4 survivors (33%) failed to mount a shivering response, whereas 8 patients who died (57% of the severe hypothermia deaths) failed to mount a shivering response.

The inability to mount a shivering response to hypothermia may be associated with a poorer outcome. Although these results reached statistical significance, larger studies are required to confirm these results and to further explore the link between shivering and death from hypothermia.

Mean PR and QRS durations were within normal limits, but the mean QTc interval was prolonged at 481 ms. The data suggested a link between increasing QTc and poorer outcome, but no convincing relationship could be proven.

Overall, atrial fibrillation and junctional bradycardia were associated with a poor outcome. These rhythms probably reflect a progressive decline in myocardial function as hypothermia worsens rather than being malignant dysrhythmias. J waves were found to be nondiscriminatory for survival, and the presence of shivering artifact may be a favorable prognostic indicator.

Acknowledgments

We thank all the following consultants in Accident and Emergency Medicine at the participating hospitals for permission to study their patients: I. J. Swann, R. Crawford, R. G. Simpson (Glasgow Royal Infirmary); P. T. Grant, W. M. Tullett (Western Infirmary, Glasgow); I. W. R. Anderson, D. A. W. Ritchie (Victoria Infirmary,

Table 3. Shivering artifact

	<i>Mild hypothermia</i>	<i>Severe hypothermia</i>	<i>Total</i>
Survivors	66% (23/35)	67% (8/12)	66% (31/47)
Mean core temperature, °C (range)	33.8 (32.0–34.8)	29.3 (27.2–31.6)	32.6 (27.2–34.8)
Nonsurvivors	33% (4/12)	43% (6/14)	38% (10/26)
Mean core temperature, °C (range)	33.8 (33.4–34.2)	30.3 (28.5–31.3)	31.7 (28.5–34.2)
Total	57% (27/47)	54% (14/26)	56% (41/73)

Glasgow); M. W. G. Gordon (Southern General Hospital, Glasgow); C. A. Allister, J. Finlay (Royal Alexandra Hospital, Paisley); N. V. Doraiswamy (Royal Hospital for Sick Children, Glasgow); Dr I. McLaren, Dr M. Brookes (Monklands District General Hospital, Airdrie); and M. H. Calvert (Stobhill General Hospital, Glasgow).

Our thanks also go to the members of the former West of Scotland Accident and Emergency Trainees Research Group, without whom the data could not have been collected. These members were Mr A. J. Ireland, Dr L. M. Laughton, Dr L. J. Hislop, Dr T. H. Rainer, and Dr G. Olverman.

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