Clinical Relevance of Impaired Consciousness in Accidental Hypothermia: A Japanese Multicenter Retrospective Study

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Abstract

Background: Severe accidental hypothermia (AH) is a life-threatening condition, and early identification can enable transport to an appropriate medical facility. The Swiss staging model has been used to classify patients with AH, but little is known regarding the relationship between the degree of impaired consciousness and core body temperature (BT) in AH. This study aimed to clarify the relationship between the level of consciousness and core BT and determine whether the level of consciousness could be used to predict severe hypothermia and in-hospital mortality among patients with AH.

Methods: We retrospectively investigated the clinical relevance of impaired consciousness in AH. We included adult patients with AH and excluded patients with out-of-hospital cardiac arrest. The patients were identified from the J-point registry, which contains information regarding patients treated for AH between April 1, 2011 and March 31, 2016 in any of the 12 participating institutions in Japan. The primary exposure of interest was the level of consciousness at hospital arrival. Odds ratios were calculated for severe hypothermia and in-hospital mortality.

Results: Overall, 505 of the 572 patients in the registry were included. Compared to mildly impaired consciousness, the adjusted odds ratio for severe hypothermia was 3.3 (95% confidence interval [CI]: 1.7–6.3) for moderately impaired consciousness and 4.7 (95% CI: 2.4–9.1) for severely impaired consciousness. Severely impaired consciousness as a predictor severe hypothermia had a sensitivity of 0.44 (95% CI: 0.34–0.54), specificity of 0.78 (95% CI: 0.74–0.82), positive likelihood ratio of 2.04, and negative likelihood ratio of 0.71. Compared to mildly impaired consciousness, the adjusted odds ratio for in-hospital mortality was 1.7 (95% CI: 0.95–2.9) for moderately impaired consciousness and 2.1 (95% CI: 1.2–3.8) for severely impaired consciousness.

Conclusions: Severely impaired consciousness was a reliable predictor of severe hypothermia and in-hospital mortality in patients with AH. Thus, in an urban out-of-hospital emergency setting, the level of impaired consciousness may be helpful for triaging patients to the appropriate hospital.

Background

Accidental hypothermia (AH) is a serious condition with high rates of morbidity and mortality [1, 2]. In particular, severe hypothermia requires intensive care management, such as extracorporeal rewarming and circulatory support, given the risks of life-threatening arrhythmia and cardiac arrest [3]. The patient's core body temperature (BT) can be used to guide the selection of an appropriate medical facility [1, 4], although emergency services do not have devices that can measure core BT, such as esophageal temperature [5]. Thus, although axillary temperature does not accurately reflect the core BT, this temperature is typically used in an out-of-hospital setting [6]. Therefore, a simple and reliable method is needed for estimating core BT in an out-of-hospital setting.

Traditionally, the Swiss staging model is used. In this model, the degree of impaired consciousness and vital signs are used to estimate the core BT and triage the patient appropriately [1]. However, although the
Swiss staging model is accepted worldwide, there is no high-quality evidence that the level of consciousness is valid for triage application [7]. In addition, little is known regarding appropriate factors for guiding triage in cases of AH.

**Methods**

**Study design and setting**

This multicenter retrospective study aimed to clarify the relationship between the level of consciousness and core BT and to determine whether the level of consciousness could be used to predict severe hypothermia and in-hospital mortality among patients with AH. We used data from the J-point registry database [2, 8], which has been previously described [2, 8-10]. Briefly, the registry includes information regarding patients with BT unknown or \( \leq 35^\circ \text{C} \) who were treated for AH in emergency departments between April 1, 2011 and March 31, 2016. The registry contains data from eight critical care centers and four noncritical care centers in the Osaka, Kyoto, and Shiga Prefectures of Japan. In Japan, a critical care center generally serves a population of 500,000 people and is certified by the Ministry of Health, Labor and Welfare of Japan to provide 24h care to patients with severe trauma, severe shock, stroke, and acute coronary syndrome. A median of 19,651 patients visit the emergency department at each facility (interquartile range [IQR]: 13,281–27,554). Patients were excluded from the J-point registry if they or their family members explicitly refused to be included in the registry.

For the present study, clinical data were retrospectively extracted by emergency physicians using a predefined data extraction sheet.

**Study patients**

This study included patients from the J-point registry who were aged > 18 years and diagnosed with hypothermia. Hypothermia was defined as having a core BT of \( \leq 35^\circ \text{C} \) based on a previous report [1]. Patients were excluded if they had cardiac arrest at hospital arrival or had no record of consciousness level.

**Data collection**

Data on age, sex, activities of daily living (ADLs), medical history, vital signs at hospital arrival, blood test findings, comorbidities, and in-hospital mortality were collected. Age was categorized as 18–64 years, 65–74 years, and \( \geq 75 \) years based on the definition for elderly from the Japanese government standards [11]. The vital signs were categorized based on the Japan Fire and Disaster Management Agency protocol for triage [12]. Patients whose systolic blood pressure was difficult to measure were assigned a value of \( \leq 60 \) mmHg, and patients whose heart rate was difficult to measure were assigned a value of \( \leq 30 \) beats/min. Data regarding respiratory status were not included in the analysis because it is difficult to measure percutaneous arterial oxygen saturation in patients with hypothermia [13] and because many patients had missing data regarding their respiratory rate.
Exposure

The primary exposure of interest was the level of consciousness at hospital arrival. The level of consciousness was evaluated using the Glasgow Coma Scale (GCS), and impaired was classified as mild (GCS of 13–15), moderate (GCS of 9–12), or severe (GCS of 3–8). In Japan, the level of impaired consciousness is also evaluated using the Japan Coma Scale (JCS), which consists of eye-opening to stimuli, similar to the E component of the GCS. The JCS is widely accepted by paramedics and nurses working in the emergency department and is correlated with the GCS [14]. Therefore, when GCS data were missing, we imputed values for mildly impaired consciousness (JCS level 1, 1–3), moderately impaired consciousness (JCS level 2, 10–30), and severely impaired consciousness (JCS level 3, 100–300) based on previous reports [8, 9].

Outcomes

The primary outcome measure was severe hypothermia at hospital arrival. According to the Swiss staging system, hypothermia was classified into stage 1 (BT: 32°C–35.0°C), stage 2 (BT: 28°C–31.9°C), stage 3 (BT: 24°C–27.9°C), and stage 4 (BT: <24°C).[1] For the present study, severe hypothermia was defined as stage 3–4 hypothermia [1]. The secondary outcome measure was all-cause in-hospital mortality.

Statistical analysis

Patient characteristics at hospital arrival were analyzed according to the level of consciousness. Continuous variables are reported as median and IQR, and categorical variables are reported as number (%). The relationship between the level of impaired consciousness and severe hypothermia was evaluated based on the following covariates that are generally available in an out-of-hospital setting: age, sex, ADL, consciousness, systolic blood pressure, and heart rate. Logistic regression analysis was used to evaluate the risk of severe hypothermia (BT: < 28.0°C) according to the level of impaired consciousness. The results were reported as crude odds ratio (COR) or adjusted odds ratio (AOR) with the corresponding 95% confidence interval (CI). The predictive capability of impaired consciousness for severe hypothermia was evaluated according to its sensitivity, specificity, positive likelihood ratio (LR), and negative LR. Logistic regression analysis was also used to evaluate the relationships between the level of impaired consciousness and in-hospital mortality using the same covariates for the primary analysis. All statistical analyses were performed using JMP Pro 14 for Windows software (SAS Institute, Tokyo, Japan).

Results

Patient characteristics

Of the 572 patients included in the registry, we excluded 68 patients who were aged < 18 years (N = 8), whose BT could not be measured or was not recorded (N = 19), whose recorded BT was > 35 °C (N = 11), who were in cardiac arrest at the hospital arrival (N = 11), and with no data regarding the level of
consciousness (N = 9). Thus, 505 patients with a median age of 79 years (IQR: 68–87 years) were included in the analysis (Fig. 1).

The patient characteristics are shown in Tables 1 and 2. The median BT was 30.8 °C (IQR: 28.4 °C–32.6 °C). Figure 2 shows the relationships between the level of impaired consciousness and BT. The in-hospital mortality rate was 22.4% (N = 113). Among the patients who died, 31 patients had moderately impaired consciousness (14.6%), 41 patients had mildly impaired consciousness (25.5%), and 41 patients had severely impaired consciousness (31.1%) (Fig. 3).
Table 1
Patient characteristics in the overall cohort and by degree of impaired consciousness.

<table>
<thead>
<tr>
<th>Parameters, n (%)</th>
<th>All patients (N = 505)</th>
<th>Degree of impaired consciousness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>255 (50.5%)</td>
<td>110 (51.9%)</td>
<td>67 (41.6%)</td>
</tr>
<tr>
<td>Age, years</td>
<td>79 [68–87]</td>
<td>78 [67–87]</td>
<td>82 [70–88]</td>
</tr>
<tr>
<td>18–64</td>
<td>99 (19.6%)</td>
<td>42 (19.8%)</td>
<td>25 (15.5%)</td>
</tr>
<tr>
<td>65–74</td>
<td>83 (16.4%)</td>
<td>38 (17.9%)</td>
<td>23 (14.3%)</td>
</tr>
<tr>
<td>≥ 75</td>
<td>323 (64.0%)</td>
<td>132 (62.3%)</td>
<td>113 (70.2%)</td>
</tr>
<tr>
<td>ADL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent</td>
<td>350 (69.3%)</td>
<td>150 (70.8%)</td>
<td>104 (64.6%)</td>
</tr>
<tr>
<td>Modified dependence</td>
<td>123 (24.4%)</td>
<td>48 (22.6%)</td>
<td>49 (30.4%)</td>
</tr>
<tr>
<td>Complete dependence</td>
<td>30 (5.9%)</td>
<td>12 (5.7%)</td>
<td>8 (5.0%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>2 (0.4%)</td>
<td>2 (0.9%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Medical history</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>226 (44.8%)</td>
<td>95 (44.8%)</td>
<td>78 (48.4%)</td>
</tr>
<tr>
<td>Neurological</td>
<td>90 (17.8%)</td>
<td>37 (17.5%)</td>
<td>28 (17.4%)</td>
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<tr>
<td>Endocrine</td>
<td>128 (25.3%)</td>
<td>53 (25.0%)</td>
<td>35 (21.7%)</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>110 (21.8%)</td>
<td>41 (19.3%)</td>
<td>35 (21.7%)</td>
</tr>
<tr>
<td>Malignant</td>
<td>16 (3.2%)</td>
<td>7 (3.3%)</td>
<td>4 (2.5%)</td>
</tr>
<tr>
<td>Dementia</td>
<td>104 (20.6%)</td>
<td>48 (22.6%)</td>
<td>38 (23.6%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>7 (1.4%)</td>
<td>3 (1.4%)</td>
<td>3 (1.9%)</td>
</tr>
</tbody>
</table>

Data are shown as number (%) or median [IQR].

Abbreviations: GCS, Glasgow Coma Scale; ADL, activities of daily living
Table 2
Patient data in the overall cohort and by degree of impaired consciousness.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>All patients (N = 505)</th>
<th>Degree of impaired consciousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td>30.8 [28.4–32.6]</td>
<td>31.8 [30.1–33.1]</td>
</tr>
<tr>
<td>34.9–32</td>
<td>180 (35.6%)</td>
<td>102 (48.1%)</td>
</tr>
<tr>
<td>31.9–28</td>
<td>223 (44.2%)</td>
<td>93 (43.9%)</td>
</tr>
<tr>
<td>27.9–24</td>
<td>88 (17.4%)</td>
<td>16 (7.5%)</td>
</tr>
<tr>
<td>≤ 23.9</td>
<td>14 (2.8%)</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 50 beats/min</td>
<td>379 (75.1%)</td>
<td>173 (81.6%)</td>
</tr>
<tr>
<td>31–49 beats/min</td>
<td>107 (21.2%)</td>
<td>36 (17.0%)</td>
</tr>
<tr>
<td>≤ 30 beats/min</td>
<td>15 (3.0%)</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Unmeasurable</td>
<td>4 (0.8%)</td>
<td>2 (0.9%)</td>
</tr>
<tr>
<td>Systolic blood pressure, mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 90</td>
<td>370 (73.3%)</td>
<td>178 (84.0%)</td>
</tr>
<tr>
<td>61–89</td>
<td>85 (16.8%)</td>
<td>28 (13.2%)</td>
</tr>
<tr>
<td>≤ 60</td>
<td>17 (3.4%)</td>
<td>3 (1.4%)</td>
</tr>
<tr>
<td>Unmeasurable</td>
<td>33 (6.5%)</td>
<td>3 (1.4%)</td>
</tr>
<tr>
<td>Laboratory findings</td>
<td></td>
<td></td>
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<tr>
<td>Lactate (mmol/L)</td>
<td>2.7 [1.3–5.85]</td>
<td>2.4 [1.3–4.6]</td>
</tr>
</tbody>
</table>

Data are shown as number (%) or median [IQR].

Abbreviations: GCS, Glasgow Coma Scale; ADL, activities of daily living
### Primary Analysis

Compared to mildly impaired consciousness, the COR value for severe hypothermia was 3.8 (95% CI: 2.1–7.0) for moderately impaired consciousness and 5.9 (95% CI: 3.2–11.0) for severely impaired consciousness. Compared to mildly impaired consciousness, the AOR value was 3.3 (95% CI: 1.7–6.3) for severe hypothermia and 4.7 (95% CI: 2.4–9.1) for severely impaired consciousness (Fig. 4). Severely impaired consciousness had a sensitivity of 0.44 (95% CI: 0.34–0.54), specificity of 0.78 (95% CI: 0.74–0.82), positive LR of 2.04, and negative LR of 0.71 for predicting severe hypothermia. Meanwhile, the combination of moderately or severely impaired consciousness provided a sensitivity of 0.83 (95% CI: 0.76–0.91), specificity of 0.48 (95% CI: 0.44–0.53), positive LR of 1.61, and negative LR of 0.34.

### Secondary Analysis

Compared to mildly impaired consciousness, the COR value for in-hospital mortality was 2.0 (95% CI: 1.2–3.3) for moderately impaired consciousness and 2.6 (95% CI: 1.5–4.5) for severely impaired consciousness. Compared to mildly impaired consciousness, the AOR value for in-hospital mortality was
1.7 (95% CI: 0.95–2.9) for moderately impaired consciousness and 2.1 (95% CI: 1.2–3.8) for severely impaired consciousness (Fig. 4).

Discussion

Data on the appropriate factors for guiding triage in AH are limited, and the association of the level of consciousness with severe hypothermia and in-hospital mortality in these patients is yet to be clarified. In this study, we have shown that the degree of impaired consciousness in patients with AH may be related to severe hypothermia and prognosis.

We believe that our study has two important strengths relative to previous studies. First, we performed a multicenter study with a large sample of patients, whereas most previous studies examined a small sample of patients at a single center. Moreover, although some reports have addressed the validity of the Swiss staging model [7, 15], no study has directly analyzed the relationship between the level of impaired consciousness and core BT among patients with AH. Second, we evaluated patients who developed AH in urban areas, whereas previous studies typically evaluated AH occurring in cold climates, such as the Alps [16, 17]. By contrast, we evaluated a predominantly urban sample that included a large number of elderly people with underlying diseases, thus suggesting that our results may be generalizable to urban areas with aging populations.

The results of this study could be attributed to the following mechanisms. First, we suggest that a decrease in core BT might reduce brain activity and lead to a decreased level of consciousness. Previous studies in mice have shown that a decrease in BT causes a decrease in the permeability of the blood–brain barrier that in turn reduces the delivery of energy sources to the brain cells [18]. Furthermore, studies of humans under surgical anesthesia with hypothermic circulatory arrest revealed reduced brain oxygen consumption [19] and suppressed electroencephalography that was correlated with a decrease in core BT [20]. Thus, it seems reasonable to assume that the level of impaired consciousness in severe hypothermia is caused by a decrease in brain activity that is related to a decreased core BT.

Our study findings have clinical implications. First, it may facilitate the prediction of severe hypothermia for patients with suspected AH in an out-of-hospital setting, where esophageal or rectal measures of core BT are unrealistic. This prediction could guide the transportation of patients to an appropriate medical facility where they can undergo invasive rewarming via extracorporeal membrane oxygenation. Furthermore, it may be useful to treat these patients carefully during transport to avoid ventricular fibrillation. Second, the level of impaired consciousness may be useful for prognostication and guiding decision-making regarding whether to administer or withdraw intensive treatment. Therefore, our findings may be useful in both out-of-hospital and emergency care settings.

The present study has some limitations. First, we excluded patients without information regarding the level of impaired consciousness, which might be a source of selection bias. Second, the retrospective design suggests that there was variability in the measurement site and timing of the core BT measurement. Third, the evaluation of level of consciousness requires skill and experience [21, 22].
Although we believe that the medical staff at the participating emergency departments were well-trained, the validity of the assessments is also unclear, and there is a risk of measurement bias. Fourth, we did not obtain detailed information regarding the causes of AH, which may suggest that there was unmeasured confounding. Further research is needed to validate our results and address these issues.

**Conclusions**

The level of impaired consciousness might be useful for predicting severe hypothermia and in-hospital mortality in AH patients. Therefore, in an urban out-of-hospital emergency setting, the level of impaired consciousness may be helpful for triaging patients to an appropriate hospital.

**List Of Abbreviations**

AH: accidental hypothermia

BT: body temperature

CI: confidence interval

IQR: interquartile range

ADL: activities of daily living

GCS: Glasgow Coma Scale

JCS: Japan Coma Scale

COR: crude odds ratio

AOR: adjusted odds ratio

**Declarations**

**Ethics approval and consent to participate**

This study was approved by the ethics committee of Saiseikai Shiga Hospital (approval ID: 244) and of each registry hospital. Neither patients nor the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

**Consent for publication**

Not applicable.

**Availability of data and materials**
The datasets generated and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

Not applicable.

**Authors' contributions**

TM and TK conceived and designed the study. MN, YO, SM, NE, NM, TJ, YS, NO, MW, AT, YF, YO, and TM recruited the participating centers, collected the data, managed the data, and performed quality control. MF drafted the manuscript. MF and YO analyzed the data and interpreted the results. All authors read and approved the final manuscript.

**Acknowledgements**

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**References**


Figures

Figure 1

Patient inclusion flowchart BT, body temperature; OHCA, out-of-hospital cardiac arrest
Figure 1

Patient inclusion flowchart BT, body temperature; OHCA, out-of-hospital cardiac arrest
Figure 2

Relationship between the degree of impaired consciousness and body temperature
Figure 2

Relationship between the degree of impaired consciousness and body temperature
Figure 3

In-hospital mortality according to the degree of impaired consciousness
Figure 3

In-hospital mortality according to the degree of impaired consciousness
Figure 4

Risk of severe hypothermia and in-hospital mortality according to the degree of impaired consciousness
Figure 4

Risk of severe hypothermia and in-hospital mortality according to the degree of impaired consciousness.