An easy-to-use prehospital indicator for recognition of severity in heat-related illness: An observational study in the Tokyo metropolitan area

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Abstract

**Background:** Quick transportation to the hospital is necessary to decrease mortality risk in patients with heat-related illnesses. This study aimed to establish a rapid, effective, easy-to-use indicator for healthcare providers and laypersons to identify the life-threatening severity of heat-related illness and facilitate quick transport of identified patients in a community setting.

**Methods:** This observational study was conducted using a database from 2016. Information concerning the clinical severity of heat-related illness in patients (n=2528) upon arrival at the hospital was extracted from prehospital transportation records.

**Results:** Patient-related risk factors included age, vital signs, location of the patient, and the severity of the illness. Respiratory rate (adjusted odds ratio [aOR], 3.34; 95% confidence interval [CI], 1.80–6.22), heart rate (aOR, 2.88, 95% CI, 1.57–5.29), axillary body temperature (aOR, 7.79, 95% CI, 4.02–15.1), and consciousness level (aOR, 38.3, 95% CI, 5.22–281.1) were independent factors associated with the severity of heat-related illness. Blood pressure was measured at the scene but was not found to be an independent factor relating to the severity of the patient's condition. A heart rate, respiratory rate, and body temperature of more than 120 beats/min, 24 breaths/min, and 38.6°C, respectively (highest areas under the ROC curves: 0.80, 95% CI 0.75–0.87; 0.73, 95% CI 0.67–0.81; and 0.83, 95% CI 0.77–0.91; respectively) were predictive of life-threatening conditions in patients with heat-related illnesses.

**Conclusions:** Attention should be paid to changes in the vital signs of patients with heat-related illness. Tachycardia and tachypnea are particularly sensitive and easy-to-use indicators for laypersons to facilitate quick identification and transport of patients before they decline to a life-threatening situation.

Background

Due to global warming, high summer temperatures have emerged as an unavoidable cause of heat-related illness, and heat-related deaths have been reported during heat waves [1, 2]. Heat-related illness is defined as a physiological insult to the body that occurs because of exposure to elevated temperatures, which results in the elevation of the core body temperature to levels that surpass the compensatory limits of thermoregulation [3]. Thus, heat-related illness comprises a set of syndromes that evolve along a continuum, ranging from mild illness, such as heat cramps and heat exhaustion, to severe illness, such as fatal multiorgan failure with heatstroke [3, 4].

Projection analysis forecasts higher maximum temperatures, an increased number of hot days, and extreme climatic phenomena for the next 100 years [5]. An increase in health-related damage due to the increase in temperatures, resulting from global warming and the induction of the “heat island phenomenon,” has been predicted [6]. In Japan, there has been a year-on-year increase in the number of patients with heat-related illnesses who are diagnosed by paramedical emergency medical technicians (EMTs) in the community setting and then transported to the hospital in an ambulance. In the Tokyo metropolitan area, which is under the jurisdiction of the Tokyo Fire Department, the number of patients...
with heat-related illness has increased nearly three-fold in a single decade, from 1041 patients in 2006 to 2885 patients in 2016 [7].

In particular, the mortality rate is high among patients with heatstroke who have impaired thermoregulation [8]. The severity of heat-related illness is dependent on factors such as the time until treatment and whether the patient has existing medical conditions or their medical history. In the community setting, it is very important to provide laypersons with the tools to efficiently and effectively identify severe illness that could rapidly progress to a life-threatening status.

Heat-related illness in patients with pathological changes is aggravated by consecutive reactions, which are not clearly demarcated. Therefore, initiating appropriate treatment before the onset of aggravated illness is necessary to improve the clinical outcome. With rapid recognition and diagnosis based on an effective clinical indicator for estimating the severity of heat-related illness, most patients will recover quickly without major complications (e.g., central nervous system disturbances, impaired consciousness) and can be discharged. Many sports competitions are held in hot environments during the summer, such as the 2020 Olympic Games in Tokyo. This necessitates an emergency transport system for quickly identifying and transporting a patient to an appropriate medical facility designated for emergency care. Thus, there is a need to clarify the characteristics and severity of illness in patients with heat-related illness in a community setting. Novel diagnostic criteria are required to recognize the deterioration of a patient’s clinical condition in the prehospitalization stage. Therefore, this study was conducted to clarify the characteristics and severity of heat-related illness, and then to identify a sensitive and easy-to-use indicator for communities. The key objectives of this study were to determine the incidence and severity of heat-related illness in the study population and identify specific criteria that facilitate early diagnosis on the scene.

**Methods**

This single-center observational study was conducted using prehospitalization data obtained from January 1 to December 31, 2016 from medical records in the database of the Tokyo Fire Department, which covers the Tokyo metropolitan area. Eligible study participants were adult patients older than 20 years who were transferred to the hospital by paramedical EMTs in an ambulance in the Tokyo metropolitan area. The prehospital transportation record had to include heat-related illnesses. In this study, heat-related illness was based on the diagnosis provided for approval of emergency transport of a patient. The diagnosis, which was coded as heat syncope, heat cramps, heat exhaustion, or heatstroke, was obtained from the Tokyo Fire Department database system. Two coauthors with expertise in treating patients with heat-related illnesses reviewed the records in this database and identified 2968 cases during the study period with heat-related illness. Of the 2968 patients, 440 juvenile patients (≤ 19 years old) were excluded because of differences in the standard values of their vital signs compared to those of adults. Finally, this study included 2528 patients considered to have a heat-related illness. Patient-related risk factors, including age, vital signs and level of consciousness measured upon arrival at the site, the
location of the patient, and the severity of the illness stated for approval of the emergency transport, were extracted from the prehospital transportation records.

The certification for emergency transport was issued by a doctor who noted the degree of illness severity (Grades 1–5) of the patient upon arrival at the hospital. The five degrees of illness severity on hospital arrival are as follows: Grade 1, does not require hospitalization; Grade 2, necessitates hospitalization, but is not life-threatening; Grade 3, considered to be life-threatening; Grade 4, critical illness with impending danger of death; and Grade 5, death. The study participants were divided into two groups: the non-severe [non-S] group comprising patients with Grade 1 and 2 severities and the severe [S] group comprising patients with Grade 3 and 4 severities. Grade 5 was not considered, as patients with out-of-hospital cardiopulmonary arrest were excluded. The classification of the level of consciousness was also divided into two categories: alert or not alert. The study did not enroll patients who received medical treatment at the hospital but were not transported by ambulance, or those who did not receive medical treatment at the hospital despite being transported to the hospital in an ambulance. Patients aged 70 years or older were classified as elderly patients in this study, and the study participants were divided into an elderly group and a non-elderly group [9].

**Statistical Analysis**

All analyses were conducted using SPSS (IBM Statistics Version 25, Chicago, IL, USA) and JMP ver. 11.0 (SAS Institute, Cary, NC, USA). Data are presented as the mean (standard deviation) or the number of cases (%). Continuous variables were compared using Student’s t-test or the Mann–Whitney U test, as appropriate. The chi-square test was used to compare categorical variables. The clinical outcome (severe or non-severe) was predicted using multiple logistic regression through a stepwise increase in the variables and calculation of the odds ratios and 95% confidence intervals (CI). The stepwise increase in variables for analysis was applied for the previously described clinical factors that are related to the outcome (severe or non-severe) explanatory variables. All variables with a p-value < 0.2 in the bivariate model were included in the multivariate model and subjected to multiple logistic regression analysis. Using receiver operating characteristic (ROC) curve analysis, we determined the optimal cutoff points at a significance level of 5%.

**Results**

The subgrouping of patients, based on the degree of severity as per the certificate of emergency transport, is shown in Table 1. There were 1484 patients with Grade 1 severity, 984 patients with Grade 2, and 60 patients with Grades 3 and 4. The average age of this study population was 62.8 years and 1433 were regarded as elderly patients (56.7% of the total study population; Tables 1 and 2). Of the total, 1483 cases of heat-related illness occurred indoors (Table 2). The incidence of each severity level and prevalence in each age group are shown in Fig. 1. The incidence of mild illness (Grade 1) was higher in the younger age group than in the elderly. However, the incidence of severe illness, which required inpatient treatment and included all participants besides those with non-mild illness (Grade 2, 3, and 4),
was higher in the older age groups (Fig. 1a). A logistic regression analysis identified a significant decrease in the incidence rate of mild illness by age group (adjusted odds ratio [aOR], 0.976; 95% CI, 0.972–0.980, \( p < 0.001 \)) and revealed that the incidence of heat-related illness was higher in the more advanced age groups (Fig. 1a). Multiple logistic regression analyses were performed to identify the significant predictors of severity in patients with heat-related illness in prehospitalization conditions. These analyses revealed that the respiratory rate (RR; aOR, 0.897; 95% CI, 0.855–0.941, \( p < 0.0001 \)), heart rate (HR; aOR, 0.983; 95% CI, 0.968–0.998, \( p = 0.027 \)), body temperature (BT; aOR, 0.509; 95% CI, 0.405–0.641, \( p < 0.0001 \)), and consciousness level (aOR, 0.030; 95% CI, 0.004–0.225, \( p = 0.0001 \)) at the prehospitalization stage were independently associated with illness severity in patients with heat-related illnesses. The blood pressure measured at the scene was not an independent factor for severity. The level of consciousness was divided into two categories: alert (1481 patients [58.6%]) or not alert (1047 patients [41.4%]). A comparative subgroup analysis of the non-S and S-groups showed a statistically significant intergroup difference in the requirement for hospitalization.

Table 1
Classification of severity (Grades 1–5) from the certificate of emergency transport\(^a\)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Non-elderly</th>
<th>Elderly(^b)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>775</td>
<td>705</td>
<td>1484 (58.7%)</td>
</tr>
<tr>
<td>2</td>
<td>302</td>
<td>682</td>
<td>984 (38.9%)</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>36</td>
<td>49 (1.9%)</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td>11 (0.4%)</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>1095</td>
<td>1433 (56.7%)</td>
<td>2528</td>
</tr>
</tbody>
</table>

\(^a\) The certificate of emergency transport is written by a doctor when the patient arrives at the hospital in an ambulance; the degree of clinical severity upon admission of the patient is documented in this certificate. Grade 1, does not require hospitalization; Grade 2, necessitates hospitalization, but is not life-threatening; Grade 3, considered to be life-threatening; Grade 4, critical illness with impending danger of death, and Grade 5, death or a patient who is in cardiopulmonary arrest on hospital admission.

\(^b\) Patients older than 70 years were classified as elderly patients in this study.
Table 2
Comparison of patient characteristics (prehospital setting) between the two groups using univariate analysis

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All (n = 2528)</th>
<th>Non-S group (n = 2468)</th>
<th>S group (n = 60)</th>
<th>p-value b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62.8 ± 21.7</td>
<td>62.6 ± 0.44</td>
<td>69.9 ± 2.61</td>
<td>0.006</td>
</tr>
<tr>
<td>Sex (M/F) [M/total (%)]</td>
<td>1532:996 [60.6]</td>
<td>1496:972 [60.6]</td>
<td>36:24 [60.0]</td>
<td>0.88</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>126.6 ± 31.6</td>
<td>126.7 ± 25.3</td>
<td>124.4 ± 38.9</td>
<td>0.66</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>71.2 ± 15.2</td>
<td>71.2 ± 15.2</td>
<td>71.2 ± 18.4</td>
<td>0.95</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>95 ± 20.8</td>
<td>94 ± 20.3</td>
<td>120.4 ± 25.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Respiratory rate (bpm)</td>
<td>20 ± 3.92</td>
<td>19.9 ± 3.67</td>
<td>25.4 ± 7.92</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Body temperature (℃)</td>
<td>37.1 ± 1.2</td>
<td>37.1 ± 1.1</td>
<td>39.2 ± 1.62</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Location (indoor: outdoor)</td>
<td>1483:1045 [58.7]</td>
<td>1447:1021 [58.6]</td>
<td>36:24 [60.0]</td>
<td>0.87</td>
</tr>
<tr>
<td>[indoor/total (%)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elderly (elderly: non-elderly)</td>
<td>1433:1095 [56.7]</td>
<td>1391:1077 [56.4]</td>
<td>42:18 [70.0]</td>
<td>0.042</td>
</tr>
<tr>
<td>[elderly/total (%)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consciousness level</td>
<td>1481:1047 [58.6]</td>
<td>1480:988 [60.0]</td>
<td>1:59 [1.67]</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>(alert: not alert)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[alert /total (%)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are shown as the mean ± standard deviation, or n (%)

The study population was divided into two groups based on the classification of illness severity to identify life-threatening or non-life-threatening illness severity. Grades 1 and 2, non-severe [non-S] group; Grades 3 and 4, severe [S] group; Grade 5 was not considered, as we excluded patients with out-of-hospital cardiopulmonary arrest. Axillary body temperatures were measured. Patients older than 70 years were classified as elderly patients in this study. The classification of the level of consciousness was divided into two categories: alert or not alert.

M/F: male/female, BP: blood pressure

To assess the ability of the parameters HR, RR, and BT to predict clinical severity, the diagnostic performances (sensitivity, specificity, and negative and positive predictive values) of each variable were calculated. An ROC curve was constructed, and the corresponding area under the ROC curve (AUROC) was calculated. ROC curve analysis showed that the values for HR, RR, and BT that distinguished the
non-S and S groups of patients were 120/min, 24/min, and 38.6°C, respectively. Additionally, ROC curves for the prediction of life-threatening severity of heat-related illness were constructed. The highest AUROCs were observed for RR > 24/min (AUROC, 0.73; 95% CI, 0.67–0.81), HR > 120/min (AUROC, 0.80; 95% CI, 0.75–0.87), and BT > 38.6°C (AUROC, 0.83; 95% CI, 0.77–0.91) (Fig. 2). The respective hazard ratios for the severity based on RR, HR, and BT values as prehospital triage criteria, which were dichotomized to ≥ 120/min, ≥ 24/min, and ≥ 38.6°C, respectively, were estimated with a Cox proportional hazards model after adjustment for the measured confounders. The model fit was assessed by calculating the concordance probability, which is defined as the probability of the predictions and outcomes being concordant (Table 3).

### Table 3
Multivariate logistic regression analysis of factors associated with the severity of heat-related illness (prehospitalization setting)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Correlation coefficient</th>
<th>SE</th>
<th>p-value</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR over 24/min</td>
<td>1.207</td>
<td>0.317</td>
<td>&lt; 0.0001</td>
<td>3.34</td>
<td>1.80–6.22</td>
</tr>
<tr>
<td>HR over 120/min</td>
<td>1.057</td>
<td>0.310</td>
<td>0.001</td>
<td>2.88</td>
<td>1.57–5.29</td>
</tr>
<tr>
<td>BT over 38.6°C</td>
<td>2.053</td>
<td>0.338</td>
<td>&lt; 0.0001</td>
<td>7.79</td>
<td>4.02–15.1</td>
</tr>
<tr>
<td>Alert or not</td>
<td>3.646</td>
<td>1.017</td>
<td>&lt; 0.0001</td>
<td>38.3</td>
<td>5.22–281.1</td>
</tr>
</tbody>
</table>

Explanatory variables: elderly, respiratory rate, heart rate, temperature, and consciousness level

BT: body temperature (axillary temperature); CI: confidence interval; HR: heart rate; RR: respiratory rate; SE: standard error

Multivariate logistic regression analyses (stepwise increase in the number of variables) were conducted.

**Discussion**

This study was conducted to firstly identify factors related to the clinical severity of patients with heat-related illness in the prehospital setting, and secondly, to identify an easy-to-use prehospital indicator of the clinical severity of patients with heat-related illness. This indicator must be easy to use by ordinary citizens to facilitate early recognition of the severity of heat-related illness. This severity indicator is also of use to caregivers because the elderly group in this study were at a greater risk for more severe heat-related illness. Data analysis showed that the optimal cutoff points for HR, RR, and BT were 120 beats/min, 24 breaths/min, and 38.6°C, respectively, for use as a prehospital indicator to assess the severity of illness in patients with heat-related illness. Interestingly, BP did not indicate the severity of illness in the prehospital setting. Easier indicators for recognition of severity in patients with heat-related illness for caregivers in community settings would be preferable. Thus, these factors can be utilized to develop triage criteria, focusing not only on the high BT but also tachypnea and tachycardia in patients
with heat-related illness, to prioritize the transportation of patients to designated emergency care centers based on their condition.

Higher temperatures in summer due to global warming create an increase in heat-related illnesses [1, 2]. In an observational study, Hausfater et al. [10] aimed to determine independent mortality factors for heatstroke in a study population of 1456 patients. The patients suffered from heat-related illnesses and core temperatures of > 38.5°C were measured upon arrival in the emergency room at 16 medical facilities. Similarly, Davido et al. [11] undertook a single-center study to identify early-phase independent predictive factors of mortality risk in 165 patients with heat-related illness, core temperatures of > 38.0°C, as well as dehydration. In addition, Misset et al. [2] considered independent risk factors associated with higher mortality risk in 345 patients with heat-related illness from 80 study centers. The findings from these abovementioned three studies suggested that the patient’s vital signs upon hospital arrival were related to poor outcomes of heat-related illness.

An international classification for the severity of heat-related illness was applied in this study, which includes heat cramps and syncope, heat exhaustion, and heatstroke, and has been used globally to assess the severity of heatstroke based on the patient’s symptoms and pathophysiology [8, 11]. The abovementioned international classification has a wide application due to its ease of use and sensitivity in the identification of patients with heat-related illnesses who are at risk of fatal multiorgan failure. This international classification characterizes severe heat-related illness using elevated core temperature and central nervous abnormalities as definitive criteria [8].

Impaired consciousness and high axillary temperature were also independent factors of heat-related illness severity in our study. However, an axillary temperature reading might be more susceptible to changes in response to external factors before the patients are transferred to the hospital than other measures of core temperature (rectal or tympanic). In the prehospital or community setting, only paramedics or other medical staff may obtain an accurate core temperature measurement. Therefore, it might be difficult for medical staff to precisely determine the clinical severity of the patient using only the international classification. The novel indicators of the severity of heat-related illness in prehospital settings described in this study may improve the outcome of patients as they do not rely on measurement of the core body temperature. This could decrease the likelihood of severe cases being underestimated by medical staff, paramedics, or even the general public, including caregivers. The indicators should be focused on early recognition of heat-related illness. Overestimated triage regarding the recognition of heat-related illness is permissible since it will initiate rapid treatment to improve the prognosis of heat-related illness. Thus, there is a need for the proposed more sensitive indicators to enable recognition of any deterioration of the clinical status of patients with heat-related illnesses in prehospitalization settings. Well-designed prospective studies are needed to clarify the cutoff points for abnormalities in physical signs, such as consciousness or vital signs, to avoid progressive worsening of the patient’s clinical condition.
Previous reports have suggested that changed vital signs upon admission are related to poor patient outcomes [2, 11]. However, blood pressure was not related to the patient's severity in our study. The differences in our results compared to those of previous reports might be attributed to compensatory mechanisms affecting the heart rate. In addition, the patient's temperature was determined to be a dependent prehospital triage criterion, as other variables often influence it in the prehospital setting. For this reason, there is a need for greater attention to changes in vital signs, especially regarding tachycardia and tachypnea, to prevent accelerated worsening of the clinical condition in prehospitalization settings. As abnormal RR and HR values are easily recognizable by both healthcare providers and laypersons, these criteria can be useful to recognize early signs of illness severity in patients with heat-related illnesses before it evolves into a life-threatening condition.

Limitations

This study has several limitations. First, the retrospective observational study design and the use of a patient database limited the number of predetermined factors available for analysis. Second, the clinical characteristics of patients with heat-related illnesses in the Tokyo metropolitan area could not be captured comprehensively because the study population did not include patients who received medical treatment in an ambulance and those who did not receive medical treatment at the hospital despite being transported in an ambulance. Third, the characteristics of non-heat-related illness were not investigated at the same time and in the same area. Finally, any misclassification of the severity of the disease in the records could not be accounted for. Other factors such as chronic diseases, which might alter vital signs in conditions of heat-related illness, were not assessed in this study.

Conclusions

Impaired consciousness, tachycardia, tachypnea, and higher BT, but not BP, in the prehospital phase are potentially sensitive indicators for the severity of heat-related illness. Thus, additional attention should be focused on changes in vital signs, especially tachycardia and tachypnea, in the prehospitalization stage. Both healthcare providers and laypersons can easily determine these two parameters. This easy-to-use indicator that incorporates the HR and RR can facilitate early recognition of the clinical severity of heat-related illness in patients before their progression to a life-threatening situation.

Abbreviations

AUROC, Area under the ROC curve
aOR, Adjusted odds ratio
BT, Body temperature
CI, Confidence interval
Declarations

Ethics approval and consent to participate

This study was approved by the Clinical Research Review Committee of Nihon University School of Medicine (RK-180612-14). The need for informed consent of the study was waived by the approving authority.

Consent for publication

Not applicable.

Availability of data and materials

The data generated and analyzed during the current study are not publicly available because only officers of the Tokyo Fire Department can access the database. Minami Takeyama, who is our co-author, accessed the database and extracted these data for our research. Our research has been permitted by the Tokyo Fire Department.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JY contributed to the conceptualization, methodology, formal analysis, writing of the original draft, and approval of the final manuscript. KK contributed to validation, supervision, and review and editing of the manuscript. MT curated the data.

Acknowledgements:
References


Figures
Incidence of heat-related illness, degree of illness severity and number of cases by age group.

a) Incidence of heat-related illness by degree of illness severity in each age group.

A logistic regression analysis identified a significant decrease in the incidence rate of mild illness by age group (adjusted odds ratio [aOR], 0.976; 95% confidence interval [CI], 0.972–0.980, p<0.001).

b) Incidence (number of cases) of heat-related illness in each age group.

Receiver operating characteristic curves for severity in patients with heat-related illness in the prehospitalization setting.

The receiver operating characteristic (ROC) curve analysis showed that the optimal cutoff values for heart rate, respiratory rate, and body temperature were 120/min, 24/min, and 38.6°C, respectively. The highest
areas under the ROC curve (AUROC) were for RR >24/min (AUROC, 0.73; 95% CI, 0.67–0.81), HR >120/min (AUROC, 0.80; 95% CI, 0.75–0.87), and BT >38.6°C (AUROC, 0.83; 95% CI, 0.77–0.91).

RR: respiratory rate; HR, heart rate; BT, body temperature (axillary temperature).