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Impact of snowfall on emergency medical system and mortality in patients with acute coronary syndrome

Yuki Mori[1,14], Sakae Takenaka[1,14], Toshiyuki Nagai[1]✉, Kohei Saiin[1], Akinori Takahashi[1], Yoshifumi Mizuguchi[1], Takao Konishi[1], Toshihisa Anzai[1], Daisuke Hotta[2], Mitsunori Kamigaki[3], Seiji Yamazaki[4], Tsutomu Fujita[5], Takehiro Yamashita[6], Kandoh Kawahatsu[7], Takashi Suzuki[8], Yoichi Nozaki[9], Taku Sakurada[10], Takashi Takenaka[11], Yasumi Igarashi[12], Takao Makino[13] & Sapporo city Acute Coronary Syndrome Network[15]

Acute coronary syndrome (ACS) requires rapid transportation by the emergency medical system (EMS). In snowy areas, traffic conditions may delay EMS transport times and increase mortality rate of ACS. However, there is a paucity of systemic data showing how snowfall affects the EMS and mortality in patients with ACS. This study aimed to investigate the impact of snowfall on the EMS transport times and in-hospital death in patients with ACS. We examined 2387 consecutive ACS patients who were transported via EMS to hospitals participating in the Sapporo City ACS network between April 2013 and April 2023. The patients were divided into two groups based on their arrival on either a snowy day (n = 612, 26%) or a non-snowy day (n = 1775, 74%), as determined by historical weather records from the Japan Meteorological Agency for the Sapporo area. The median age was 68 years, 1754 (74.6%) patients were male. Patients in the snowy day group had longer median time from an EMS call to hospital than those in the non-snowy day group (33 min [IQR 26–40] vs. 29 min [IQR 24–36], $P < 0.001$). Quantity of snowfall was associated with a delayed time from EMS call to hospital. The proportion of in-hospital death was higher in the snowy day group compared to the non-snowy day group (7.3% vs. 4.6%, $P = 0.011$). Multivariable logistic regression analysis showed that the snowfall was independently associated with higher incidence of in-hospital death (odds ratio 1.57, 95% confidence interval 1.00–2.47, $P = 0.048$). In conclusion, snowfall had a significant impact on the EMS and mortality in patients with ACS in an urban city in Japan.

Keywords Acute coronary syndrome, Emergency medical system, Snowfall

Cardiovascular diseases represent the major cause of morbidity and mortality in the world, being responsible for important medical costs, despite the improvement of prevention and management measures[1,2]. Acute coronary syndrome (ACS) is the clinical manifestation of coronary artery disease and includes acute myocardial infarction (AMI) with and without ST-segment elevation (STEMI and NSTEMI) and unstable angina pectoris (UAP),

[1]Department of Cardiovascular Medicine, Faculty of Medicine and Graduate School of Medicine, Hokkaido University, Kita 15, Nishi 7, Kita-ku, Sapporo, Hokkaido 060-8638, Japan. [2]Department of Cardiovascular Medicine, Hokkaido Cardiovascular Hospital, Sapporo, Japan. [3]Department of Cardiovascular Medicine, KKR Sapporo Medical Center, Sapporo, Japan. [4]Department of Cardiovascular Medicine, Sapporo Higashi Tokusyukai Hospital, Sapporo, Japan. [5]Department of Cardiovascular Medicine, Sapporo Cardiovascular Center, Sapporo, Japan. [6]Department of Cardiovascular Medicine, Sapporo Kojinkai Memorial Hospital, Sapporo, Japan. [7]Department of Cardiovascular Medicine, Teine Keijinnkai Hospital, Sapporo, Japan. [8]Department of Cardiovascular Medicine, Kin-Ikyo Central Hospital, Sapporo, Japan. [9]Department of Cardiovascular Medicine, Hokko Memorial Hospital, Sapporo, Japan. [10]Department of Cardiovascular Surgery, Sapporo Central Hospital, Sapporo, Japan. [11]Department of Cardiovascular Medicine, NHO Hokkaido Medical Center, Sapporo, Japan. [12]Department of Cardiovascular Medicine, Sapporo-Kosei General Hospital, Sapporo, Japan. [13]Department of Cardiovascular Medicine, Sapporo City General Hospital, Kita 11, Nishi 13, Chuo-ku, Sapporo, Hokkaido 060-8604, Japan. [14]Yuki Mori and Sakae Takenaka contributed equally to this work. [15] A list of authors and their affiliations appears at the end of the paper. ✉email: nagai@med.hokudai.ac.jp

and extremely serious disease that requires rapid transportation by the emergency medical system (EMS) and immediate treatment including percutaneous coronary intervention (PCI).

Besides the well-known risk factors for atherosclerosis such as advanced age, smoking, dyslipidaemia, and diabetes, several studies have showed that climate variations could affect the development of ACS. A study from the United States reported a 53% increase in AMI cases in the winter months[3]. Data from studies performed in European countries also reported an increase in the morbidity and mortality of coronary heart disease in the winter months[4,5]. Notably, snowfall could affect the risk of ACS, given the evidence that snow-related exertion, including shoveling, can excessively strain the cardiovascular system in susceptible individuals[6,7]. A previous report indicated that snowfall was more important in triggering deaths from heart disease than air temperature[8]. Moreover, in snowy areas, traffic conditions due to snowfall may delay EMS transport times and increase mortality rate of ACS. However, there is a paucity of systemic data showing how snowfall affects the EMS and mortality in patients with ACS.

Accordingly, this study aimed to assess the impact of snowfall on the number of patients transported via the EMS, the time from an EMS call to hospital arrival, treatment strategies, and in-hospital death in patients with ACS in a snowy urban area of Japan.

Methods

Study design and population

The study was performed using data from the Sapporo City ACS network database collected between April 2013 and April 2023. Only the data from patients with ACS were selected and retrospectively analysed. The diagnostic and therapeutic strategies for ACS were applied by cardiologists in each hospital according to the Japanese Circulation Society guidelines for the treatment of ACS[9]. ACS included AMI and UAP.

The Sapporo City ACS network database is an ongoing multicentre registry launched in 2013 that prospectively collects information regarding emergency admissions suspected of cardiovascular emergencies to 29 acute cardiac care facilities via the EMS in Sapporo city, Japan (Supplementary Fig. S1). The Sapporo City ACS network was originally established in 2010 and jointly run by the Sapporo City Fire Department and Sapporo City Medical Association, with the goal of treating patients with emergency cardiovascular events as promptly as possible. This network covers most patients admitted via the EMS who have ACS within the area of Sapporo city, serving a population of approximately 2 million (the fifth largest population among Japanese cities). In our network system, when a patient with chest pain occurs in an area of Sapporo city, the EMS team first contacts an ACS network hospital in that district. The on-duty hospital is able to receive the patient promptly. After transport, a cardiologist, not a general physician, provides the initial response, allowing for rapid treatment of patients who need revascularisation[10].

In this study, 10,308 consecutive patients registered in the Sapporo City ACS network database were identified. Of these, 7,921 patients without ACS were excluded from the analysis. Ultimately, 2,387 patients were included in this study. We divided our study population into two groups according to arrival at snowy or non-snowy day (Fig. 1). Sapporo city has the most quantity of snowfall in winter; mean total quantity of snowfall in one year was 440 cm (standard deviation [SD]: 86.6) from 2013 to 2023, and monthly quantity of snowfall was over 100 cm at mean in December, January and February from 2013 to 2023 (Fig. 2).

In this study, because patient information was anonymised and de-identified prior to analysis, written informed consent was not obtained from each patient. Due to the retrospective nature of study, Ethical Review Board for Life Science and Medical Research, Hokkaido University Hospital waived the need of obtaining informed consent. Nevertheless, we posted a summary of the protocol (with an easily understood description) at each site; the notice clearly informed the patients of their right to refuse enrolment. These procedures for

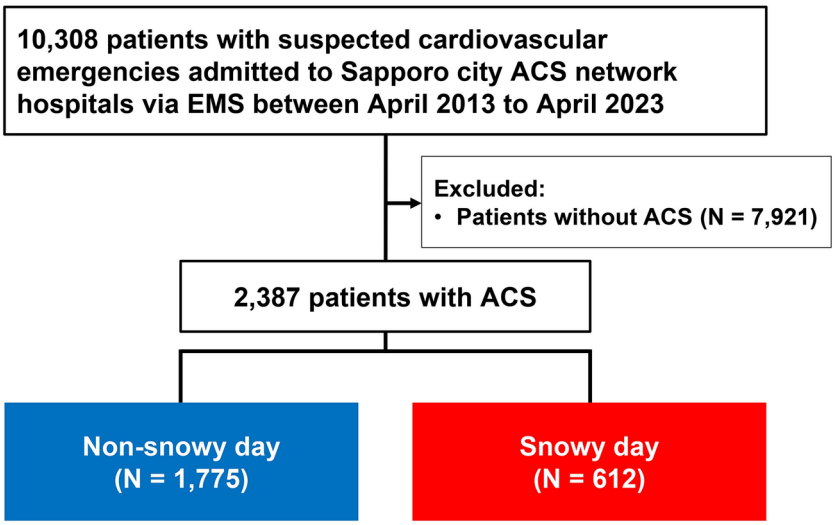

Fig. 1. Flow diagram of the present study. *ACS* Acute coronary syndrome, *EMS* Emergency medical system.

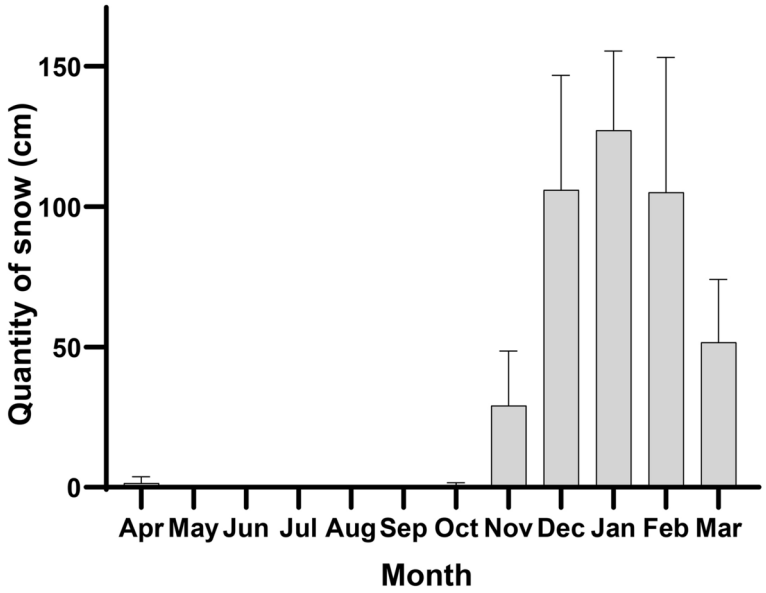

Fig. 2. Mean quantity of snow each month during April 2013 and April 2023.

informed consent and enrolment were in accordance with the detailed regulations regarding informed consent described in the guidelines, and this study, including the procedure for enrolment, has been approved by the Ethical Review Board for Life Science and Medical Research, Hokkaido University Hospital and the Ethics Committee of each participating hospital (Supplementary appendix 1 and 2) and was registered under the Japanese UMIN Clinical Trials registration (UMIN000045251). This study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Data collection and outcome measures

Individual clinical information was collected using a medical questionnaire. When an EMS team transported a Sapporo City ACS network-eligible patient, they issued a medical questionnaire that included information on the vital signs, the situation at the onset, chief complaint, and past history and passed it to a cardiologist who received the patient. After treatment, the cardiologist completed the remaining questionnaire items, including treatment details, diagnosis, and in-hospital clinical outcomes. The completed questionnaire was mailed from each hospital to the core data centre of the network at the Hokkaido University. In this study, we extracted information on demographics, medical history, clinical data, clinical course, and the use of therapeutic interventions, such as PCI, surgery, and mechanical circulatory support. The study outcomes included the following: (1) time from an EMS call to hospital arrival, (2) the association between time from an EMS call to hospital and quantity of snow, (3) the proportion of patients receiving coronary angiography (CAG) and emergency PCI, and (4) in-hospital death. Detailed data on weather conditions, including daily snowfalls were obtained from the Japan Meteorological Agency website (https://www.jma.go.jp. Accessed on 29 September 2023)[11]. We reviewed historical weather conditions in the Sapporo area using Japan Meteorological Agency records and defined snowy and non-snowy days based on the presence or absence of observed snowfall.

Statistical analyses

Continuous variables are presented as mean ± standard deviation (SD) when normally distributed and as medians and interquartile ranges (IQR) when non-normally distributed. Comparisons of differences between two groups were performed by an unpaired t-test or a Mann–Whitney U test for continuous variables and by a chi-squared test or Fisher's exact test for dichotomous variables, when appropriate. Kolmogorov–Smirnov test was used to determine whether the distribution was normal or non-normal. A multivariable logistic regression analysis was performed based on the variables achieving P value < 0.10 in a univariable logistic regression analysis, to explore the independently associated with in hospital death. Selected variables were age, male sex, systolic blood pressure, Killip classification, Japan coma scale, history of heart failure, and cardiac care unit (CCU) admission, as previously reported[12]. A two-sided P value < 0.05 was considered statistically significant. All data were analysed using the Stata MP64 software (version 16; StataCorp, College Station, TX, USA).

Results

Baseline demographics and clinical characteristics

The baseline patient characteristics are presented in Table 1. The numbers of patients admitted hospital on non-snowy and snowy days were 1,775 and 612, respectively. The rates of ACS presentations were comparable between the groups (non-snowy day: 1.40 cases/day vs. snowy day: 1.37 cases/day; $P = 0.32$). The median age was 68 years (IQR 59–78), 74.6% were men, and 34.9%, 70.1%, and 69.2% had diabetes mellitus, hypertension, and dyslipidaemia, respectively. There were no significant differences in gender, body mass index (BMI), past

Variable	All patients (N = 2387)	Non-snowy day (N = 1775)	Snowy day (N = 612)	*P* value
Age (years)	68 (59–78)	68 (59–78)	69 (58–78)	0.718
Male, n (%)	1,754 (74.6)	1,301 (74.4)	453 (75.4)	0.631
Body mass index (kg/m^2)	24.1 (21.8–26.6)	24.0 (21.8–26.6)	24.5 (22.1–27.0)	0.127
Medical history				
Diabetes, n (%)	736 (34.9)	549 (35.2)	187 (34.1)	0.633
Hypertension, n (%)	1,626 (70.1)	1.207 (69.6)	419 (71.5)	0.377
Dyslipidemia, n (%)	1,512 (69.2)	1,124 (68.9)	388 (69.9)	0.661
Killip classification				
Class I, n (%)	1,485 (79.6)	1,124 (80.3)	361 (77.5)	0.081
Class II, n (%)	206 (11.0)	155 (11.1)	51 (10.9)	
Class III, n (%)	91 (4.9)	68 (4.9)	23 (4.9)	
Class IV, n (%)	84 (4.5)	53 (3.8)	31 (6.7)	
SBP (mmHg)	134 (110–159)	134 (110–158)	134 (110–160)	0.723
HR (beats/min)	73 (60–87)	74 (60–87)	73 (62–87)	0.544
Laboratory findings				
Haemoglobin (g/dL)	14.2 (12.7–15.5)	14.1 (12.6–15.4)	14.4 (12.8–15.5)	0.094
Serum creatinine (mg/dL)	0.87 (0.73–1.07)	0.87 (0.73–1.06)	0.88 (0.74–1.09)	0.269
Maximum CPK (U/L)	776 (138–2651)	778 (134–2603)	774 (150–2796)	0.362
Maximum CK-MB (U/L)	59.0 (10.8–240.0)	58.0 (10.0–233.1)	61.5 (12.6–262.5)	0.260
Time from Symptom onset to EMS call (min)	41 (14–117)	41 (14–117)	41 (13–119)	0.981
Time from EMS call to arrival (min)	7 (5–9)	7 (5–8)	8 (6–10)	< 0.001
Time from EMS call to hospital (min)	30 (25–37)	29 (24–36)	33 (26–40)	< 0.001

Table 1. Baseline characteristics. Continuous variables are presented as mean ± standard deviation if normally distributed, and median (interquartile range) if not normally distributed. Categorial variables are presented as number of patients (%). *CK-MB* Creatine kinase and its MB isoenzyme, *CPK* Creatine phosphokinase, *EMS* Emergency medical system, *HR* Heart rate, *SBP* Systolic blood pressure.

Variable	All patients (N = 2387)	Non-Snowy day (N = 1775)	Snowy day (N = 612)	*P* value
Emergency CAG, n (%)	2,108 (88.4)	1,573 (88.7)	535 (87.6)	0.440
Treatments				
Emergency PCI, n (%)	1,973 (84.8)	1,472 (85.1)	501 (84.1)	0.547
TIMI grade 3 flow post PCI, n (%)	1,461 (89.9)	1,091 (89.6)	370 (89.6)	0.993
Door to balloon time (min)	77 (60–106)	76 (60–106)	79 (62–105)	0.281
Door to balloon time under 90 min, n (%)	1,078 (63.7)	809 (64.3)	269 (62.0)	0.385
CABG, n (%)	110 (4.8)	85 (5.0)	25 (4.4)	0.578
IABP, n (%)	229 (10.1)	167 (9.8)	62 (11.0)	0.411
VA-ECMO, n (%)	45 (2.0)	24 (1.4)	21 (3.7)	0.001

Table 2. Angiographic findings and invasive procedures. Continuous variables are presented as median (interquartile range). Categorial variables are presented as number of patients (%). *CABG* coronary artery bypass grafting, *CAG* Coronary angiography, *IABP* Intra-aortic balloon pumping, *PCI* Percutaneous coronary intervention, *TIMI* Thrombolysis in myocardial infarction, *VA-ECMO* Venoarterial extra-corporeal membrane oxygenation.

history, Killip classification, blood pressure, heart rate, or laboratory findings between the groups. Patients in the snowy day group had longer time from EMS call to arrival, and longer time from EMS call to hospital than those in the non-snowy day group (8 min [IQR 6–10] vs. 7 min [IQR 5–8], $P < 0.001$, 33 min [IQR 26–40] vs. 29 min [IQR 24–36], $P < 0.001$, respectively). The proportion of time from EMS call to hospital arrival longer than 60 min was higher in the snowy day group compared to that in the non-snowy day group (2.6% vs. 0.8%, $P < 0.001$).

Procedural characteristics

Procedural variables are presented in Table 2. The proportions of patients with ACS receiving emergent CAG and PCI on the day of admission were comparable between the groups. The median door-to-balloon time was 77 min (IQR 60–106). Compared to the non-snowy day group, door-to-balloon time was similar in the snowy day group. There were no significant differences in proportions of patients with ACS receiving coronary artery bypass grafting (CABG) and the use of intra-aortic balloon pumping between the groups. The proportion of the

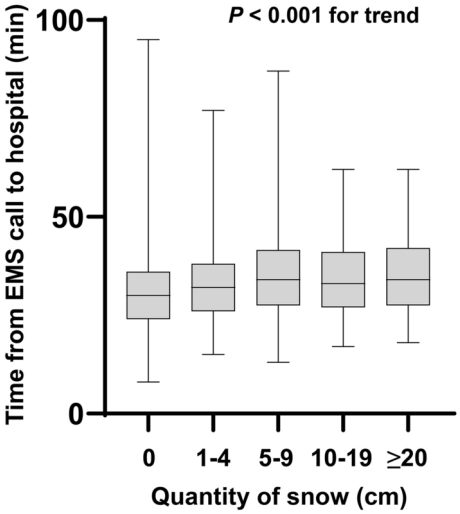

Fig. 3. Correlation between quantity of snow and time from EMS call to hospital. EMS, emergency medical system.

	Univariable		Multivariable	
Variable	OR	*P* value	OR	*P* value
Age	1.08 (1.04–1.10)	< 0.001	1.06 (1.04–1.08)	< 0.001
Male sex	2.26 (1.57–3.29)	< 0.001	1.05 (0.66–1.66)	0.845
SBP	0.97 (0.97–0.98)	< 0.001	0.98 (0.97–0.99)	< 0.001
Killip 4	13.3 (8.19–21.8)	< 0.001	3.50 (1.86–6.57)	< 0.001
JCS ≥ 1	8.54 (5.87–12.4)	< 0.001	3.58 (2.31–5.56)	< 0.001
History of heart failure	3.45 (1.66–7.20)	0.001	2.80 (1.16–6.75)	0.022
CCU admission	1.67 (1.05–2.65)	0.029	1.42 (0.84–2.40)	0.193
Snowfall	1.63 (1.11–2.38)	0.012	1.57 (1.00–2.47)	0.048

Table 3. Logistic regression analyses for in-hospital death. *CCU* Cardiac care unit, *JCS* Japan coma scale, *OR* Odds ratio, *SBP* Systolic blood pressure.

extra-corporeal membrane oxygenation was higher in the snowy day group compared to that in the non-snowy day group (Table 2).

Association between quantity of snowfall and time from EMS call to hospital

Quantity of snowfall was significantly associated with a delayed time from EMS call to hospital. The median time from EMS call to hospital with 0 cm of snowfall was 29 min (IQR 24–36), while that with more than 20 cm of snowfall was 34 min (IQR 29–37) (Fig. 3).

In-hospital death

Overall, in-hospital death occurred in 125 patients (5.3%). The proportion of in-hospital death was higher in the snowy day group compared to that in the non-snowy day group (7.3% vs. 4.6%, $P = 0.011$). Multivariable logistic regression analysis showed that the snowfall was independently associated with higher incidence of in-hospital (Table 3).

Discussion

This study showed that the snowfall affected clinical characteristics, management strategies, and outcomes of patients with ACS admitted via the EMS in an urban city of Japan. The major findings were as follows: 1) in snowy day, time from EMS call to hospital was longer and in-hospital death was higher compared to non-snowy day, although there were no significant differences in the proportion of emergency PCI and door to balloon time between the groups, 2) the time from EMS call to hospital arrival was longer with increasing the quantity of snowfall.

Generally, the association between the season and the type of atherosclerotic plaque have reported that cold weather was a risk factor for atheroma destabilisation. In winter, ACS due to rupture of the atheroma plaque are more likely to occur, compared to summer[13]. The main mechanical trigger for plaque rupture is considered to be high blood pressure, and it is more frequently found in STEMI, resulting in large infarction size of myocardium[14]. It has been reported that a decrease in atmospheric temperature causes an increase in the activity

of the sympathetic nervous system, resulting in an increase in blood pressure and heart rate[15]. Other factor, such as snow shoveling, increases blood pressure and heart rate. Sheldahl et al. reported that myocardial function might be compromised during snow shoveling because of increased myocardial afterload, coronary vasospasm or circulating catecholamines with static effort[7]. The highest prevalence of infections, including influenza also promote systemic inflammation that may enhance plaque destabilisation during winter season[16].

Several studies have assessed that the incidence of ACS was significantly higher in winter than in other seasons, as well as on heavy snowy days. A study from North America, an increase in cardiovascular and cerebrovascular mortality was observed among elderly patients during the winter season[17]. In European country, the number of AMI deaths were seasonal, with the maximum mortality recoded in winter and the minimum in summer[18]. In New Zealand, there was also a higher incidence of STEMI during winter compared with summer[19]. In addition, Auger et al. focused on winter snowfall and reported that quantity and duration of snowfall was significantly associated with an increased likelihood of hospital admission or death due to myocardial infarction[20]. Another study examined whether winter temperature or snowfall had a greater impact on cardiovascular events and concluded that snowfall played a more significant role in increasing cardiovascular mortality[8]. The mechanisms underlying these findings might include the stress and anxiety associated with snowfall, and the physical exertion associated with snow shoveling[21]. However, these studies have not demonstrated that how snowfall affects the EMS transport times and clinical outcome for patients with ACS.

In the present study, we showed that time from EMS call to hospital was longer and in-hospital death was higher in snowy day, compared to non-snowy day. Moreover, the time from EMS call to hospital arrival was longer with increasing the quantity of snowfall. These findings indicate that heavy snowfall may affect road traffic in urban area, resulting in delays in EMS transport time. In snowy areas, traffic congestion during heavy snowfall is a major problem. Hong et al. investigated the effects weather conditions and snow removal operations on travel speed to determine the causes of traffic congestion in the winter in Sapporo city. They found that operations to remove fresh snow were more effective at increasing the travel speed for locations where the traffic volume was low, whereas road widening was more effective at increasing the road capacity for roads where the traffic volume was high[22]. Given these findings, delays in EMS transport times have been also caused by the quantity of snowfall in one day and the width of roadside snow. In our study, the same factors were expected to have delayed the EMS transport time, resulting in increasing in-hospital death. A previous study reported that the time from first medical contact to primary PCI was a strong predictor of adverse outcomes with every 10-min delay associated with increased mortality in patients presenting with STEMI. This study concluded nearly liner relationship between the time from first medical contact to primary PCI and mortality in patients with STEMI[23]. In fact, there were no significant differences in door to balloon time and the proportion of patients with ACS receiving CAG and PCI on the day of admission between the groups. It showed that the cardiologists on duty were able to promptly perform emergency PCI for ACS patients in Sapporo City ACS network. Nevertheless, in urban areas, heavy snowfall may cause significant delays in transport times, and it is considered necessary to predict traffic conditions based on weather data and to improve the system in the future.

The present study has some limitations. First, this study was limited by its retrospective design, which expected to lead to missing data although the median monthly collection rate of the questionnaire was 91% (IQR 87–94). Unfortunately, our registry data did not classify STEMI and NSTEMI in the medical questionnaire before 2018, and therefore, the overall sample size of patients with STEMI from 2018 to 2023 was small (n = 732), which limits the statistical power for performing the subanalysis. Second, the diagnosis and treatment of ACS were handled by each hospital, leading to significant bias. Third, we analysed only patients with ACS transported by the EMS; therefore, the studied patients did not always reflect all patients with ACS in Sapporo city. Fourth, the number of patients receiving emergency CABG was small in this study. In Sapporo city, patients with ventricular fibrillation or cardiopulmonary arrest are generally transported to advanced emergency medical hospitals, not ACS network hospitals, which may have resulted in fewer cases with complex coronary lesions such as a left main trunk lesion and multivessel disease.

Conclusions

Snowfall had a significant impact on the EMS and the management of patients with ACS in an urban city in Japan. Our findings showed that the time from EMS call to hospital was longer and in-hospital mortality was higher in snowy day, compared to non-snowy day. Further research is needed to investigate how to reduce emergency transport times according to snowfall conditions.

Data availability

The data on weather condition, including daily snowfalls are available at https://www.jma.go.jp. The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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Correspondence and requests for materials should be addressed to T.N.

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Sapporo city Acute Coronary Syndrome Network

Takao Makino[13]