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ORIGINAL ARTICLE

PROGNOSTIC IMPACT OF SNOW SHOVELING FOR PATIENTS WITH ACUTE MYOCARDIAL INFARCTION

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Abstract **Background:** It remains uncertain whether snow shoveling has effects on long-term prognosis in patients with acute myocardial infarction (AMI).

Patients/Methods: Consecutive 355 patients who underwent emergency percutaneous coronary intervention within 24 hours of the AMI onset during the winter months (November to March) between 2008 and 2014 years were retrospectively studied.

Results: Of the 355 patients, 36 (11%) had snow shoveling-related AMI, defined as the AMI onset during or within 6 hours after snow shoveling. These patients suffered fewer adverse cardiovascular events than the non-snow shoveling AMI patients during a median follow-up period of 3.8 years. Notably, snow shoveling did not affect the events for patients with left ventricular ejection fraction (LVEF) <40% at the acute phase, but it was a significant better predictor of events for those with LVEF ≥40%.

Conclusion: Snow shoveling may have important clinical implications for the AMI onset and the prognostic outcome in snowy areas.

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Key words: snow shoveling; acute myocardial infarction; adverse cardiovascular events.

Introduction

Associations have been reported between adverse cardiovascular events and heavy snowfall, cold temperatures, and low atmospheric pressure during the winter months[1, 2]. The Japanese city of Hirosaki is situated at longitude 140°28′ west and latitude 40°36′ north in a region known for its heavy snowfall. During winter months, snow shoveling is a widespread activity for Hirosaki residents, necessary to maintain comfortable living conditions.

Physical exertion (including walking, carrying loads, and snow shoveling) and emotion (such as delight, anger, sorrow, and pleasure) are reported to result in sympathetic activation, catecholamine secretion, and systemic vasoconstriction, and to increase heart rate and systemic blood pressure, thereby modifying myocardial oxygen demand; this can precipitate the rupture of vulnerable atherosclerotic plaque[3-5]. Although previous studies have found a close relationship between snow shoveling and the development of acute cardiovascular events[6-9], no studies have investigated the long-term outcomes for these patients.

The aim of this study was to evaluate whether snow shoveling had an effect on long-term adverse cardiovascular events in patients with acute myocardial infarction (AMI).

Patients and Methods

Patients

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We included in this retrospective study all consecutive patients who underwent emergency percutaneous coronary intervention (PCI) within 24 hours of the onset of AMI during the winter months (November to March) between 2008 and 2014 in Hirosaki University Hospital in Japan. The diagnosis of AMI was made according to the universal definition of myocardial infarction based on clinical symptoms, changes in electrocardiography (ECG) readings, and the elevation of cardiac biomarkers, including cardiac troponin[10]. We defined "snow shoveling-related AMI" as the development of AMI during or within 6 hours after snow shoveling and divided the patients into two groups accordingly: the snow shoveling group (SS) and the non-snow shoveling group (non-SS). Baseline characteristics and outcomes were retrospectively compared between the groups. This study was conducted according to the principles of the Declaration of Helsinki and was approved by the ethics committee of our institution (2018-1064).

All the patients underwent a clinical assessment that included history taking, physical examinations, 12-lead ECG, laboratory tests (including cardiac enzyme values), echocardiography, and coronary angiography. Blood samples for routine tests were collected from each patient at presentation. Left ventricular ejection fraction (LVEF) was assessed by echocardiography or left ventriculography.

Hypertension was defined as systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, or the use of antihypertensive treatment. Dyslipidemia was defined as total cholesterol ≥220 mg/dL, low-density lipoprotein cholesterol ≥140 mg/dL, high-density lipoprotein cholesterol <40 mg/dL, or the use of cholesterol-lowering agents. Diabetes mellitus was recorded if the patient was receiving insulin or oral hypoglycemic agents at the time of AMI onset or had a fasting plasma glucose level ≥126 mg/dL, 2-hour plasma glucose level ≥200 mg/dL by oral glucose tolerance test, classic symptoms with casual plasma glucose level ≥200 mg/dL, or hemoglobin A1c (HbA1c) level ≥6.5% during index hospitalization[11].

<u>Weather information</u>

The daily temperatures and amounts of snowfall in Hirosaki city for the winter months (November through March) for the years 2008 to 2014 were obtained from the Japan Meteorological Agency[12]. These data were used to calculate the yearly average winter temperatures and total amounts of snowfall from 2008 through 2014.

<u>Adverse cardiovascular events</u>

Adverse cardiovascular events were defined as a composite of cardiovascular death, non-fatal AMI, non-fatal stroke, and hospitalization due to heart failure. Clinical follow-up data were obtained from outpatient records or telephone contact with the patients or their families. The patients or their families were questioned, using a standard format, about the recurrence of heart disease, the need for hospitalization related to cardiovascular disease, and death since being discharged from the hospital.

<u>Statistical analyses</u>

The statistical analyses were performed using JMP 11 software (SAS, Cary, NC, USA). Continuous variables were expressed as the mean ± standard deviation (SD) or the median [interquartile range], and categorical variables as numbers and percentages. An unpaired *t*-test or chi-square test was used to compare the differences between the two groups. Mann–Whitney's *U* test was used for nonparametric variables. The cumulative probabilities related to the event-free curves were estimated by using the Kaplan–Meier method. Multivariate analysis for the predictors of adverse cardiovascular events was performed using Cox proportional hazards regression, and hazard ratios (HRs) and 95% confidence intervals (CIs) were calculated. A p value <0.05 was considered statistically significant.

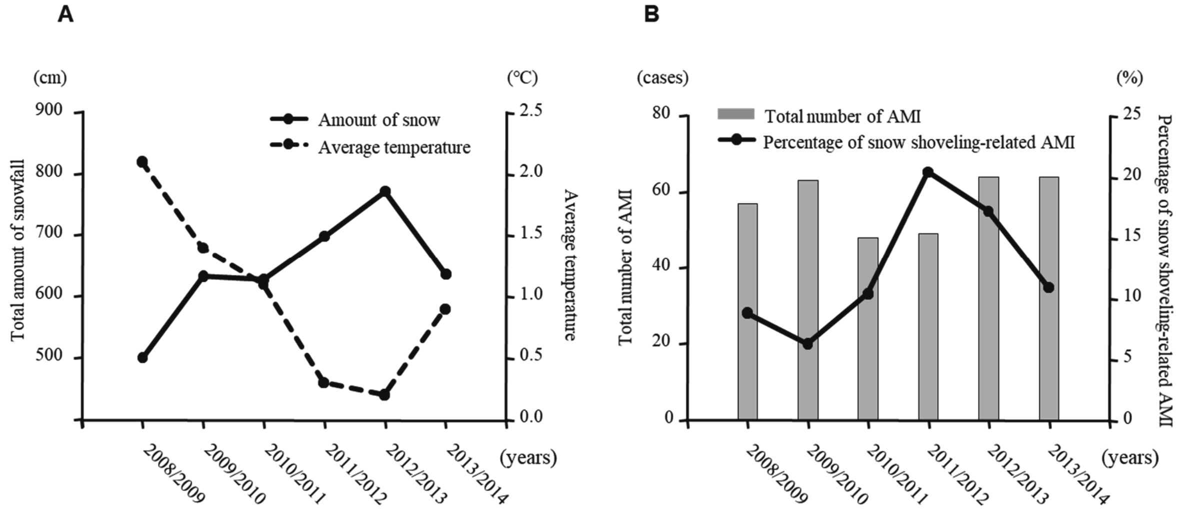

Figure 1. (A) Relationship between average temperatures and the total amounts of snowfall during winter months in Hirosaki city for the years 2008 to 2014. (B) Total number of AMI patients and the percentage of snow shoveling-related AMI to the total AMI patients each year.

Results

<u>Association between weather conditions and the incidence of AMI</u>

Figure 1A shows the average temperatures and the total amounts of snowfall in Hirosaki city during the winter months for each year during the study period. There was a significant negative correlation between the average temperatures and the total amounts of snowfall ($r = -0.6$, $p < 0.05$), indicating that snow shoveling was more likely to be necessary when the temperature was low. Figure 1B shows the total numbers of patients with AMI admitted to Hirosaki University Hospital in the years 2008 to 2014 and the percentages of those patients in the SS group. The percentage of SS group patients was high for the 2011/2012 and 2012/2013 seasons, which both had high total amounts of snowfall (Figure 1A).

<u>Baseline characteristics of the patients</u>

A total of 325 patients with AMI were included in the study. The mean age was 67 ± 13 years and 248 (76%) were male. Of the 325 patients, 36 (11%) were considered to have developed snow shoveling-related AMI and were included in the SS group. Table 1 summarizes the baseline characteristics and details such as the weather conditions at the time of AMI onset and the time course of the patients. There were no differences in medical history or coronary risk factors, including hypertension, diabetes mellitus, dyslipidemia, and smoking habits, between the SS and non-SS groups. On the day of AMI onset, the average temperature was significantly lower and the amount of snowfall was greater in the SS group compared with the non-SS group. The time between AMI onset and hospital presentation tended to be shorter in the SS group than in the non-SS group ($p = 0.07$). Although there was no difference between the groups in door-to-balloon time, the SS group showed a significantly shorter interval between symptom onset and reperfusion (the onset-to-balloon time) compared with the non-SS group (4.9 ± 2.7 vs. 7.0 ± 6.8 hours, $p < 0.05$). Mean body mass index (BMI) was significantly lower for the SS group than for the non-SS group. There were no significant differences in Killip

Table 1. Baseline characteristics

	SS group (n=36)	Non-SS group (n=289)	p value
Age, years	66 ± 11	67 ± 13	0.99
Male gender, n (%)	29 (78)	219 (76)	0.72
BMI, kg/m^2	23.2 ± 2.9	24.3 ± 3.5	<0.05
Coronary risk factors			
Hypertension, n (%)	26 (70)	222 (77)	0.39
Dyslipidemia, n (%)	30 (81)	226 (78)	0.68
Diabetes Mellitus, n (%)	17 (46)	129 (45)	0.88
Smoking, n (%)	25 (68)	179 (62)	0.51
Previous MI, n (%)	4 (11)	27 (9)	0.77
Previous CABG, n (%)	0 (0)	3 (1)	0.53
Weather conditions on the day of AMI onset			
Average temperature, °C	-1.7 ± 2.5	1.2 ± 4.4	<0.05
Amount of snowfall, cm	5 [3-12.5]	2 [0-6]	<0.05
Onset to presentation time, hour	4.0 ± 2.8	5.8 ± 6.6	0.07
Onset to balloon time, hour	4.9 ± 2.7	7.0 ± 6.8	<0.05
Door to balloon time, min	54 ± 26	72 ± 70	0.13
Killip classification, n (%)			0.13
I	33 (89)	228 (79)	
II	2 (5)	24 (8)	
III	0 (0)	20 (7)	
IV	2 (5)	17 (6)	
Culprit lesion, n (%)			0.60
LMT	0 (0)	9 (3.1)	
RCA	15 (41)	96 (33)	
LAD	16 (43)	139 (48)	
LCX	6 (16)	45 (16)	
Multi-vessel or LMT, n (%)	19 (51)	156 (54)	0.76
PCI procedure			
Stent replacement, n (%)	34 (94)	265 (92)	0.55
Plain old balloon angioplasty, n (%)	2 (6)	24 (8)	0.57
LVEF %	47.2 ± 11	46.0 ±11	0.51

Data are shown as mean ± standard deviation (SD) or median [25th–75th percentiles].
SS group indicates snow shoveling-related acute myocardial infarction (AMI) group, Non-SS group; non-snow shoveling AMI group. BMI indicates body mass index, MI; myocardial infarction, CABG; coronary artery bypass grafting, LMT; left main trunk, RCA; right coronary artery, LAD; left anterior descending artery, LCX; left circumflex artery, LVEF; left ventricular ejection fraction, PCI; percutaneous coronary intervention.

classification, culprit lesion of AMI, or LVEF at the acute phase. Plasma levels of brain natriuretic peptide (BNP) were significantly lower in the SS group than in the non-SS group (Table 2); apart from that, the laboratory data, including maximum creatine phosphokinase levels, did not differ between the groups.

Adverse cardiovascular events

The median follow-up period was 3.8 [2.1–5.7] years. During the follow-up period, adverse cardiovascular events were suffered by 3 (8%) of the 36 patients in the SS group and by 73 (25%)

Table 2. Laboratory data at admission

	SS group (n=36)	Non-SS group (n=289)	p value
Total cholesterol, mg/dL	194 [168-24]	193 [168-223]	0.97
LDL cholesterol, mg/dL	123 [102-150]	120 [98-143]	0.82
HDL cholesterol, mg/dL	45 [39-58]	45 [37-54]	0.41
Triglyceride, mg/dL	92 [62-133]	118 [73-168]	0.09
Glucose, mg/dL	146 [113-188]	150 [121-210]	0.65
HbA1c, %	5.6 [5.2-6.1]	5.7 [5.3-6.5]	0.24
BNP, pg/mL	39 [16-60]	62 [23-188]	<0.05
Creatinine, mg/dL	0.8 [0.7-0.9]	0.8 [0.7-1.0]	0.14
max CPK, IU/L	2656 [1252-4945]	2560 [1208-5314]	0.51
max CPK-MB, IU/L	289 [131-511]	259 [115-474]	0.26

Data are shown as median [25th–75th percentiles]. SS group indicates snow shoveling-related acute myocardial infarction (AMI) group, Non-SS group; non-snow shoveling AMI group. LDL indicates low-density lipoprotein, HDL; high-density lipoprotein, BNP; brain natriuretic peptide, CPK; creatine phosphokinase.

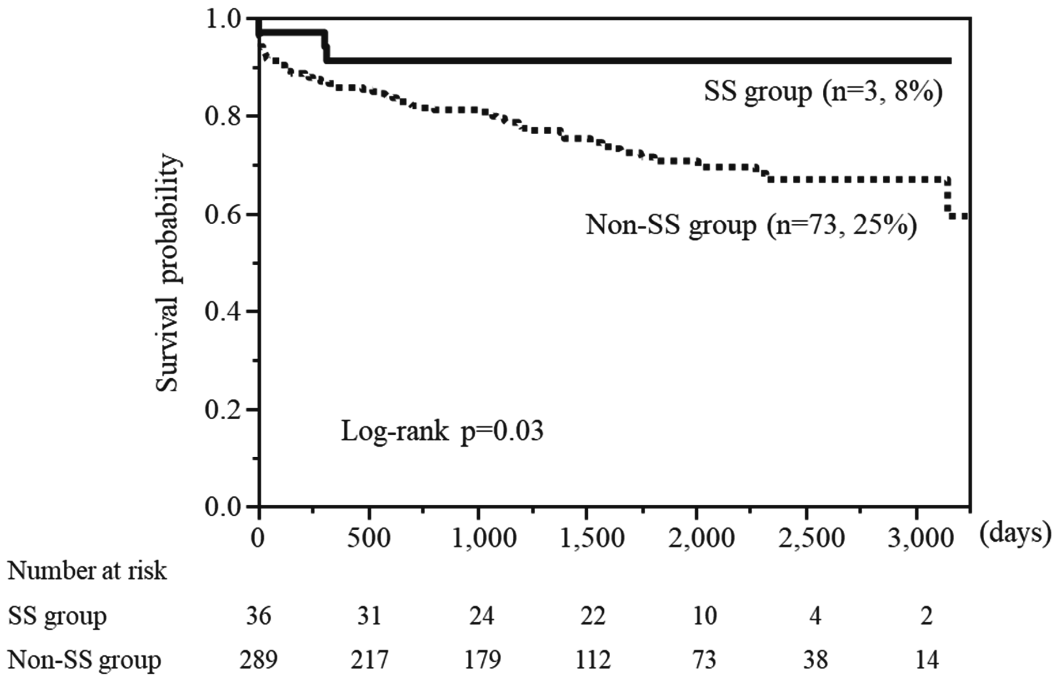

Figure 2. Kaplan-Meier curves of the adverse cardiovascular events evaluated by log-rank test in snow shoveling-related AMI (SS) group (n=289) and in non-snow shoveling AMI (non-SS) group (n=36). The number of events was 3 cases (8%) in the SS group and 73 cases (25%) in the non-SS group.

of the 289 patients in the non-SS group. The patients, who were in cardiopulmonary arrest on arrival and underwent PCI but died in the acute phase, were 1 case (2.7%) in the SS group and 9 cases (3.1%) in the non-SS group. Kaplan–Meier curves showed significantly lower adverse cardiovascular events in the SS group than in non-SS group ($p < 0.05$ by the log-rank test; Figure 2). Table 3 presents the details of the adverse cardiovascular events. Fatal or non-fatal

Table 3. Details of the adverse cardiovascular events

	SS group (n=36)	Non-SS group (n=289)
Number of total events, n (%)	4 (11)	73 (25)
Cardiovascular death, n (%)	3 (8)	28 (10)
AMI	3 (8)	7 (2)
Heart failure	0 (0)	10 (3)
Sudden cardiac death	0 (0)	4 (1)
Cardiac rupture	0 (0)	2 (1)
Arrhythmia	0 (0)	4 (1)
Unknown	0 (0)	1 (1)
Non-fatal AMI, n (%)	0 (0)	18 (6)
Non-fatal stroke, n (%)	0 (0)	12 (4)
Hospitalization for heart failure, n (%)	1 (3)	15 (5)

SS group indicates snow shoveling-related AMI group, Non-SS group; non-snow shoveling AMI group. AMI indicates acute myocardial infarction.

Table 4. Multivariate analyses for the predictors of the adverse cardiovascular events

	Model 1			Model 2		
Covariates	HR	95% CI	p value	HR	95% CI	p value
Age (per year)	1.04	1.01-1.06	<0.05	1.03	1.01-1.06	<0.05
Gender (male)	0.97	0.52-1.79	0.91	0.65	0.48-1.38	0.80
Snow shoveling	0.29	0.08-0.97	<0.05	0.39	0.09-1.05	0.06
Onset to balloon time (hour)	1.00	0.99-1.00	0.30	1.00	0.99-1.00	0.53
LVEF (per 1 % increase)	-	-	-	0.95	0.93-0.97	<0.05

Model 1 included age, male gender, and snow shoveling.
Model 2 included age, male gender, snow shoveling, and LVEF at the acute phase.
HR indicates hazard ratio, CI; confidence interval, LVEF; left ventricular ejection fraction.

AMI and heart failure were the most common events in both groups.

Impact of snow shoveling

Multivariate analysis for the predictors of adverse cardiovascular events was performed using Cox proportional hazards regression (Table 4). Age, gender, and snow shoveling were used as covariates in Model 1, which identified age and snow shoveling as independent predictors of the adverse cardiovascular events. Model 2 included the LVEF at the acute phase in addition to the covariates used in Model 1. This model identified age and LVEF were identified as independent predictors, but no snow shoveling. Because LVEF was an important prognostic factor, we further evaluated the adverse cardiovascular events by dividing the patients into two groups, with LVEF ≥40% and LVEF <40%. The Kaplan–Meier analysis for adverse cardiovascular events showed no difference between the SS and non-SS groups for the patients with LVEF <40% (p = 0.93 by log-rank test; Figure 3A) but a significant difference for the patients with LVEF ≥40% (p = 0.02 by log-rank test; Figure 3B). Multivariate analysis revealed that age and snow shoveling were independent predictors for adverse cardiovascular events for patients with LVEF ≥40%, whereas snow shoveling was not an independent

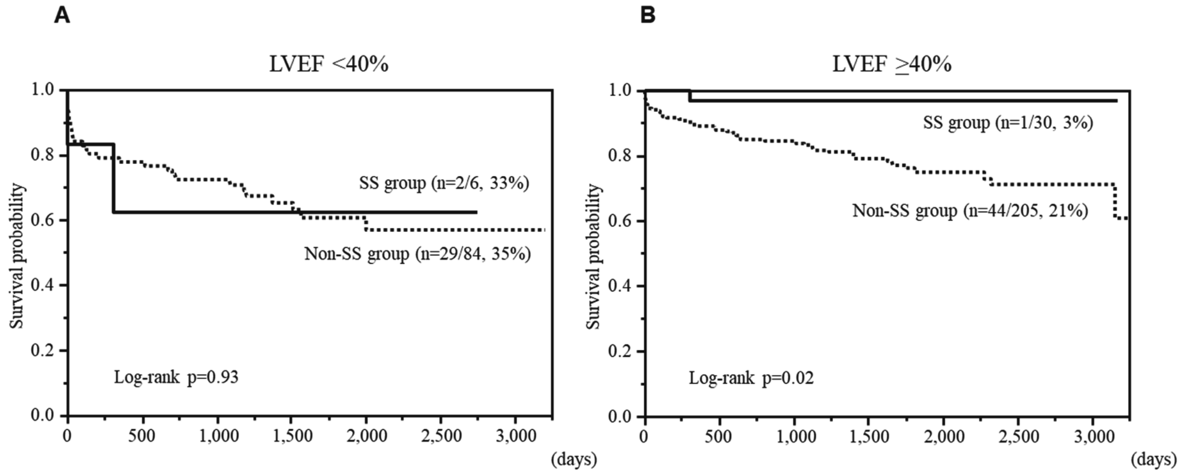

Figure 3. Kaplan-Meier curves of the adverse cardiovascular events evaluated by log-rank test in snow shoveling-related AMI (SS) group and in non-snow shoveling AMI (non-SS) group. (A) Curves in AMI patients with left ventricular ejection fraction (LVEF) <40% at the acute phase (n=6 in SS group and n=84 in non-SS group). The number of events was 2 cases (33%) in the SS group and 29 cases (35%) in the non-SS group. (B) Curves in AMI patients with LVEF ≥40% at the acute phase (n=30 in SS group and n=205 in non-SS group). The number of events was 1 case (3%) in the SS group and 44 cases (21%) in the non-SS group.

Table 5. Multivariate analyses for the predictors of the adverse cardiovascular events divided by the LVEF at the acute phase

	LVEF <40%			LVEF ≥40%		
Covariates	HR	95% CI	p value	HR	95% CI	p value
Age (per year)	1.05	1.00-1.09	<0.05	1.03	1.01-1.06	<0.05
Gender (male)	0.94	0.31-1.86	0.92	0.90	0.42-1.91	0.77
Snow shoveling	1.06	0.17-6.51	0.95	0.13	0.02-0.98	<0.05
Onset to balloon time (hour)	1.00	0.99-1.00	0.77	1.00	0.99-1.00	0.37

HR indicates hazard ratio, CI; confidence interval, LVEF; left ventricular ejection fraction.

predictor for those with LVEF <40% (Table 5). These results suggest that patients with LVEF <40% at the acute phase of AMI had poor outcomes regardless of whether they had been shoveling snow, whereas there may have been a relationship between snow shoveling and better outcomes in those with LVEF ≥40%.

Discussion

In this study, 11% of the patients who suffered AMI during the winter months experienced the onset of symptoms within 6 hours after snow shoveling and were considered to have snow shoveling-related AMI. The number of such patients in each winter season was associated with the total amount of snowfall, with especially high levels of snow and snow shoveling-related AMI in the 2011/2012 and 2012/2013 seasons. The snow shoveling-related AMI patients suffered fewer subsequent adverse cardiovascular events in comparison to the non-snow shoveling AMI patients, and age and LVEF were independent predictors for the adverse cardiovascular events. Notably, snow shoveling did not affect the number of cardiovascular events in patients with LVEF <40%, but it was a significant predictor of events in those with LVEF ≥40%. These findings suggest that snow shoveling has important clinical implications for the onset and prognostic outcome of AMI.

Temperature changes and seasonal variations have been associated with increases in the incidence of myocardial infarction and sudden death[13-16]. A study reported that cold temperatures and heavy snowfall were implicated in the onset of AMI during the winter seasons[13]. Cold temperature induces an increase in cardiac workload through peripheral vasoconstriction and increasing blood viscosity[17]. Furthermore, vigorous exercise in cold weather conditions, such as snow shoveling, induces increases in systolic blood pressure, heart rate, and cardiac demand, which are all associated with the incidence of cardiovascular events[5, 18]. A scientific statement from the American Heart Association based on expert consensus listed snow shoveling as a high-risk activity for the development of cardiovascular disease and recommended that it should be undertaken with caution by high-risk patients[19]. However, snow shoveling is a necessary activity for most people living in regions with heavy snowfall. A study of vital statistics data from five Minneapolis–St. Paul winters indicated that mortality was influenced by cold temperatures and the amount of snowfall[20]. Mortality from cardiovascular diseases has been reported to show seasonal variation, with an increase in deaths in the winter season by one-third or more compared with the number during the summer season[21, 22]. In the present study, we observed a negative correlation between the average temperature and the total amount of snowfall during winter months. Of the patients who were treated for AMI during these months, 11% experienced the onset after shoveling snow, with the individual proportion for each year showing a close relationship with the total amount of snowfall. These findings are consistent with those of previous studies and suggest clinical implications that may be useful for clinical practice.

There were no differences in age, sex, and complications of coronary risk factors between the SS and non-SS groups in baseline characteristics as shown in Table 1, but mean BMI was lower in the SS group. Snow shoveling is classified as moderate intensity exercise (about 6 METs), so the exercise intensity at the onset of AMI was probably greater for the patients in the SS group than for those in the non-SS group. These results suggest that the SS group may include patients with high activity levels in everyday life. However, this was a retrospective study; a further prospective study is warranted.

The average temperature on the day of AMI onset was significantly lower, and the amount of snowfall greater, for the SS group than for the non-SS group, but the SS group experienced fewer subsequent adverse cardiovascular events. Widely accepted prognostic factors for AMI patients include age, complications of coronary risk factors (including diabetes mellitus), a higher Killip classification, and poorer left ventricular function at admission. However, in this study, there were no significant differences between the two groups for these risk factors. Furthermore, the time from onset to reperfusion was significantly shorter for the SS group than for the non-SS group. Consistent with this, a previous study demonstrated that 1-year mortality was affected by every minute of delay in reperfusion for ST-elevation myocardial infarction patients[23].

This study has several limitations. First, it was not a prospective study. Since the study targeted the patients with AMI who underwent PCI, the patients who were dead on arrival without undergoing PCI were excluded. Therefore, we cannot directly apply our results to the general population. Second, it was a single-center study with a relatively small number of study patients, again limiting the generalizability of the results. A study including a larger number of patients is needed to confirm our results. Finally, our database lacked relevant details such as the type of snow shovel and the duration of snow shoveling. We cannot completely exclude the possible effects of these on the results.

Conclusion

The onset of AMI was associated with snow shoveling in 11% of the total number of patients with AMI who underwent PCI during the winter months, and those patients experienced fewer subsequent adverse cardiovascular events than the other AMI patients. Notably, snow shoveling was a significantly better predictor of adverse cardiovascular events for patients with LVEF ≥40% at the acute phase. Our findings indicate that snow shoveling may have important clinical implications for the onset of AMI and the prognostic outcome in snowy areas.

Conflicts of interest

All authors have no conflicts of interest directly relevant to the content of this article.

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