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Factors Related to Percutaneous Coronary Intervention among Older Patients with Heart Disease in Rural Hospitals: A Retrospective Cohort Study

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Abstract: Determining whether emergency catheterization is necessary for treating heart disease in older patients in rural hospitals is important. Their transportation may be affected by ageism. This retrospective cohort study investigated the relationship between patient factors and emergency catheterization in rural hospitals in patients >65 years old who visited the emergency department and were transferred to tertiary hospitals. Factors related to emergency catheterization were analyzed using a logistic regression model. The average age of the exposure and control groups was 77.61 (standard deviation [SD], 13.76) and 74.90 (SD, 16.18) years, respectively. Men accounted for 54.8 and 67.5% of patients in the exposure and control groups, respectively. Factors related to emergency catheterization were Charlson comorbidity index ≥5 (odds ratio [OR], 0.23; 95% confidence interval [CI], 0.06–0.94) and electrocardiogram (ECG) changes (OR, 3.24; 95% CI, 1.00–10.50). In these patients, age, time from onset to transfer, and serum troponin level were not significantly related to emergency catheterization, while ECG changes correlated with the indication for emergency catheterization. Emergency catheterization patients did not confirm that ageism was present. The decision for transfer to tertiary hospitals should consider comorbidities and ECG changes and should not be influenced by age, onset, and troponin level.

Keywords: acute coronary syndrome; catheterization; troponin; comorbidity; electrocardiogram; rural hospital; general medicine

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1. Introduction

It is important to determine whether emergency catheterization is necessary for the treatment of cardiovascular diseases in older patients in rural hospitals. For acute coronary syndrome, timely emergency catheterization can improve the prognoses of patients, including their mortality and morbidity rates [1,2]. The prevalence of coronary vascular disease among older individuals is increasing because aging causes atherosclerosis, which can lead to cardiovascular diseases [3,4]. Proper diagnosis is vital for the effective treatment of acute coronary syndrome [5]. However, older patients often exhibit vague symptoms of coronary artery diseases, making diagnosis difficult [4,6]. In addition, cardiac ischemia may be caused by factors other than one coronary artery obstruction, such as dehydration, sepsis, and other systemic diseases [7]. It is challenging for rural hospitals with many older patients to determine when patients require emergency catheterization and should be transported to tertiary hospitals for the procedure.

With respect to the diagnosis of acute coronary syndrome, measurement of serum troponin level can be useful for determining the presence and extent of cardiac muscle damage. Troponin is a protein found in cardiac muscles; however, it is not typically found in blood, where it appears when heart muscles are pathologically damaged [8]. Serum troponin level can indicate the extent of cardiac muscle damage. Confirming an

increased serum troponin level is helpful for determining the presence of myocardial ischemia. If ST elevation is simultaneously observed on a patient's electrocardiogram (ECG), myocardial infarction caused by the obstruction of specific coronary arteries can be diagnosed, and the patient can be transported to tertiary hospitals in urban areas for emergency catheterization [9]. This process should be smooth for the effective management of acute coronary syndrome caused by coronary artery obstruction.

Indications for emergency catheterization in older people vary because of multimorbidity and aging, which affect the coronary arteries and ideas of healthcare professionals regarding older patients (i.e., ageism). As serum troponin can be elevated by various factors, it is not a decisive indicator for emergency catheterization [10]. For example, tachycardiac arrhythmias, such as atrial fibrillation, cause increased serum troponin without coronary artery obstruction [11]. Additionally, critical diseases, such as dehydration and sepsis, may increase serum troponin due to relative ischemia of the cardiac muscles [7], and systemic inflammation, which can be caused by autoimmune diseases, may also increase troponin level through inflammation of cardiac muscles [12]. The coronary artery calcifies with age, and an increase in troponin is exacerbated by poor hemodynamics caused by dehydration, sepsis, and other shock-related conditions [7]. Further, ageism may affect the decision of the intervention. Both medical professionals and laypeople tend to consider intensive interventions in older patients not meaningful and effective for their quality of life [13,14]. Ageism can affect the decision regarding interventions for older patients with heart disease [13,14]. An aging society may make it difficult to determine indications for emergency catheterization in older patients with increased serum troponin.

Effective transfer of older patients with suspected acute coronary syndrome from rural hospitals to tertiary medical institutions, regardless of aging societies and ageism, is important for the sustainability of older people's quality of life. Unnecessary hesitation on emergency transportation of such patients may cause devastating damage to the heart function and worsen their prognoses, which may already be affected by ageism [13,14]. Clarifying the status of transportation of older patients from rural to tertiary hospitals for emergency catheterization can improve their response quality. In addition, clarifying the relationship between the characteristics of older patients transferred and the need for emergency coronary catheterization in tertiary hospitals could be useful for physicians while making treatment decisions in rural hospitals. Therefore, regarding ageism, this study aimed to investigate the relationship between patient factors and emergency catheterization in older patients in rural hospitals.

2. Materials and Methods

This retrospective cohort study enrolled a total of 71 patients >65 years old who visited the emergency department in a rural hospital and were transferred to tertiary hospitals.

2.1. Setting

Unnan City, one of the most rural cities in Japan, is located in the southeastern part of Shimane Prefecture. In 2020, the total population of Unnan was 37,638 (18,145 men and 19,492 women), 39% of whom were over 65. The older proportion of the population is expected to reach 50% by 2025. There are 16 clinics, 12 home care stations, three visiting nurse stations, and one public hospital (Unnan City Hospital) in Unnan City, Japan [15]. At the time of this study, Unnan City Hospital had 281 beds, including 160 acute care beds, 43 comprehensive care beds, 30 rehabilitation beds, and 48 chronic care beds. There are 14 medical specialties in the hospital, and the nurse-to-patient ratio is 1:10 for acute care, 1:13 for comprehensive care, 1:15 for rehabilitation, and 1:25 for chronic care [15]. In the emergency room, physicians with various specialties work individually depending on their availability. Some patients cannot undergo heart ultrasounds for the detection of heart wall motion abnormalities. The duration of emergency transportation for patients from Unnan City Hospital to tertiary hospitals is approximately 30 min [16].

2.2. Participants

All patients older than 65 years who were admitted to Unnan City Hospital between 1 April 2016, and 31 December 2021, were included. Data of patients with suspected acute coronary syndrome who needed emergency catheterization and were transferred to tertiary hospitals were extracted for analysis. The participants were divided into two groups—namely, the exposure group (intervention with catheterization) and the control group (intervention without catheterization).

2.3. Measurements

2.3.1. Primary Outcome

The primary outcome was emergency catheterization performed at a tertiary hospital. We confirmed whether emergency catheterization was performed by checking the response letters from the tertiary hospitals.

2.3.2. Independent Variables

The background data of the participants were collected from the electronic patient records of Unnan City Hospital. The following patient data were collected: age, sex, body mass index for nutritional assessment, serum creatinine level (mg/dL) and estimated glomerular filtration rate (mL/min/1.73 m^2) for renal function assessment, creatinine kinase level (IU/L), creatinine kinase level in the muscle/brain (IU/L), troponin level (ng/mL), dependent conditions (which were based on the Japanese long-term insurance system) [17], and Charlson comorbidity index (CCI) for the assessment of the severity of comorbidities (heart failure, myocardial infarction, asthma, chronic obstructive pulmonary disease, kidney disease, liver disease, diabetes mellitus, brain infarction, brain hemorrhage, hemiplegia, connective tissue diseases, dementia, and cancer) [18]. Regarding symptoms, information on the presence of chest pain was collected. Data on the duration from onset to transfer to tertiary hospitals (hours) were also collected. ST segment changes in any lead were recorded as the presence of ECG changes.

2.4. Statistical Analysis

Student's *t*-test was used to analyze parametric data, whereas the Mann–Whitney U test was used to analyze nonparametric data. Numerical variables were dichotomized as follows based on the information provided by previous studies and the average of the variables: age, ≥80 years and <80 years; CCI, ≥5 and <5 [18]; time from onset to transfer, ≥24 h and <24 h [19]; and troponin level, ≥0.05 ng/mL and <0.05 ng/mL [20]. A univariate regression model was used to determine whether catheterization was associated with the independent variables. Based on the information from previous studies, variables related to the decision to perform emergency catheterization were further analyzed using a logistic regression model [5,18–20]. The presence of chest pain was not included in the logistic regression model because of the vagueness of symptoms in older people [6]. Patients with missing data were excluded. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation, Vienna, Austria) [21].

2.5. Ethical Considerations

The hospital was assured of the anonymity and confidentiality of the patient information used in this study. Information related to this study was posted on the hospital website without disclosing any patient details. The contact information of the hospital representative was also listed on the website to ensure that any questions regarding this study were addressed. All participants were informed of the purpose of this study and provided informed consent. The clinical ethics committee of our institution approved this study (approval code: 20210025).

3. Results

3.1. Demographic Characteristics of the Participants

Of 30,040 patients who visited the emergency department of a rural community hospital during the study period, 13,710 were older than 65 years. After excluding 13,639 patients with other diagnoses, 71 were evaluated. The patient inclusion flowchart is shown in Figure 1.

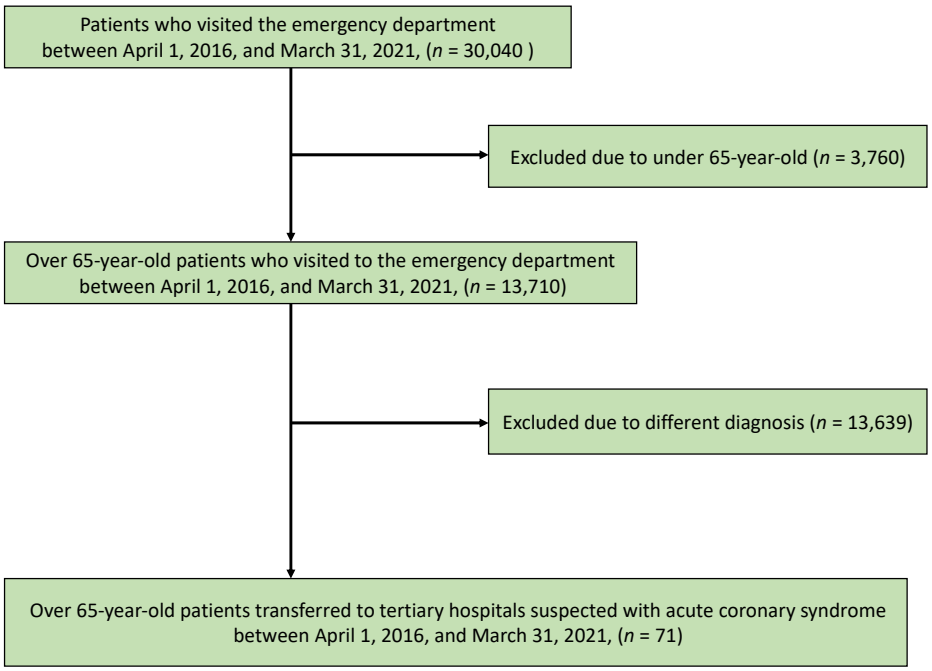

Figure 1. Flow chart of patient selection.

The average age of the exposure and control groups was 77.61 (standard deviation [SD], 13.76) and 74.90 (SD, 16.18) years, respectively. Men accounted for 54.8% and 67.5% of patients in the exposure and control groups, respectively. No independent variable significantly differed between the two groups (Table 1).

Table 1. Demographic characteristics of the participants.

Factor	Intervention		*p*-Value
	+ (Exposure)	− (Control)	
n	31	40	
Age, mean (SD)	77.61 (13.76)	74.90 (16.18)	0.458
Age ≥80 years (%)	17 (54.8)	21 (52.5)	1
Male patients (%)	17 (54.8)	27 (67.5)	0.329
BMI, mean (SD)	22.77 (4.56)	24.21 (4.88)	0.319
Creatinine level (SD)	1.28 (0.80)	1.12 (0.58)	0.341
eGFR (SD)	64.48 (20.87)	64.16 (19.79)	0.935
Troponin level, median (IQR)	0.24 (0, 1519)	0.21 (0, 4242)	0.981
Troponin level ≥0.05 (%)	20 (66.7)	27 (67.5)	1
Creatinine kinase level, median (IQR)	191 (24, 2936)	179 (55, 2247)	0.5
CK-MB, median (IQR)	16 (2, 146)	16 (0, 197)	0.881
Presence of chest pain	9 (30.0)	8 (20.0)	0.404
Hours from onset to transfer, median (IQR)	6 (1, 168)	6 (1, 240)	0.617
Time from onset to transfer <24 h (%)	10 (32.3)	10 (25.0)	0.598
ECG changes	19 (63.3)	32 (80.0)	0.175

Table 1. *Cont.*

Factor	Intervention		*p*-Value
	+ (Exposure)	− (Control)	
CCI ≥5 (%)	22 (73.3)	22 (55.0)	0.139
CCI (%)			
1	1 (3.3)	4 (10.0)	0.813
2	2 (6.7)	3 (7.5)	
3	2 (6.7)	5 (12.5)	
4	3 (10.0)	6 (15.0)	
5	8 (26.7)	8 (20.0)	
6	5 (16.7)	8 (20.0)	
7	3 (10.0)	1 (2.5)	
8	3 (10.0)	4 (10.0)	
9	1 (3.3)	1 (2.5)	
15	1 (3.3)	0 (0.0)	
17	1 (3.3)	0 (0.0)	
Heart failure (%)	10 (33.3)	8 (20.0)	0.272
Myocardial infarction (%)	16 (53.3)	30 (75.0)	0.077
Asthma (%)	1 (3.3)	0 (0.0)	0.429
Peptic ulcer (%)	2 (6.7)	1 (2.5)	0.387
Kidney disease (%)	8 (26.7)	8 (20.0)	0.573
Liver disease (%)	3 (10.0)	1 (2.5)	0.307
Diabetes mellitus (%)	9 (30.0)	11 (27.5)	1
Brain infarction (%)	6 (20.0)	2 (5.0)	0.066
Brain hemorrhage (%)	1 (3.3)	0 (0.0)	0.429
Hemiplegia (%)	2 (6.7)	0 (0.0)	0.18
Connective tissue disease (%)	0 (0.0)	2 (5.0)	0.503
Dementia (%)	3 (10.0)	3 (7.5)	1
Cancer (%)	4 (13.3)	3 (7.5)	0.452
Dependent condition (%)	9 (30.0)	8 (20.0)	0.404

Abbreviations: BMI, body mass index; eGFR, estimated glomerular filtration rate; FIM, functional independence measure; CCI, Charlson comorbidity index; CK-MB, creatine kinase in the muscle/brain; ECG, electrocardiogram; SD, standard deviation; IQR, interquartile range.

3.2. Relationship between the Intervention and Demographic Factors

The logistic regression model showed that the factors statistically related to emergency catheterization were CCI ≥5 (odds ratio [OR], 0.23; 95% confidence interval [CI], 0.06–0.94) and ECG changes (OR, 3.24; 95% CI, 1.00–10.50). Age, time from onset to transfer, and serum troponin level were not statistically related to emergency catheterization (Table 2).

Table 2. Results of the logistic regression model.

Factor	OR	95% CI	*p*-Value
Age ≥80 years (reference: age <80 years)	1.77	0.49–6.41	0.39
CCI ≥5 (reference: CCI <5)	0.23	0.06–0.94	0.041
Time from onset to transfer <24 h (reference: time ≥24 h)	0.56	0.18–1.70	0.3
ECG changes (reference: no ECG change)	3.24	1.00–10.50	0.049
Troponin level ≥0.05 ng/mL (reference: troponin level <0.05 ng/mL)	1.42	0.48–4.25	0.53

OR, odds ratio; CI, confidence interval; CCI, Charlson comorbidity index; ECG, electrocardiogram.

4. Discussion

In this study, we analyzed the correlation between indications for emergency catheterization in tertiary hospitals and the conditions of older patients with suspected acute coronary syndrome who were transferred from rural community hospitals to tertiary hos-

pitals. The results of the analysis showed that comorbidity level and ECG changes were related to the need for emergency catheterization. Age, time from onset to transfer to tertiary hospitals, and troponin level did not correlate with the intervention. In aging societies, the decision to transfer older patients to tertiary hospitals should be considered after reviewing the presence of multimorbidity and ECG changes and should not be strongly influenced by age, onset, and troponin level.

The level and nature of comorbidities should be considered to ensure the effective transfer of older patients to tertiary hospitals for emergency catheterization. The level of comorbidities is related to mortality during admission for various diseases, including heart failure, as well as pneumonia, and other infectious diseases [22–25]. As the present study showed, CCI is associated with a lower tendency for emergency catheterization in tertiary hospitals. This may be related to the elevated mortality risk among older people with multiple comorbidities who undergo emergency catheterization. Because many older patients suffer from multiple diseases, their high mortality risk should be considered prior to the initiation of transfer to tertiary hospitals for emergency catheterization [26,27]. In addition, as this study shows, higher rate of the presence of myocardial infarction in past medical history has a trend of non-performance of catheterization and high rate of brain stroke with performance of catheterization. This trend could be explained by the contents of information possessed by physicians in tertial hospitals. The physicians might know the prior history of coronary arterial catheterization among the patients with previous myocardial infarction and consider that patients with brain stroke might have higher risk of acute coronary syndrome. Furthermore, the poor cognitive function in elderly may affect the decision to transfer them to tertiary hospitals, as the staff of tertiary hospitals may not be familiar with their care requirements. [28]. Therefore, various risks associated with mortality and cognitive impairment should be considered prior to the transfer of older patients with multiple comorbidities.

Analysis of ECG changes, facilitated by precise comparison with previous ECGs using artificial intelligence (AI), should be performed before deciding whether older patients should be transferred for emergency catheterization. ECG changes, especially ST segment changes, can reveal evidence of cardiac ischemia [9]. Even among older people, ST-T segment changes in ECGs can indicate acute coronary syndrome and facilitate timely emergency transportation to tertiary hospitals [4]. ECG changes were associated with the need for emergency catheterization in tertiary hospitals, a finding that is similar to those of previous studies. To detect cardiac ischemic abnormalities, ECG, unlike echocardiography, can be easily performed without using specialized equipment. The interpretation of ECG changes among older people can be difficult because chronic cardiac ischemia and cardiac electrical blockage occurring with age can alter the ST-T segment [29]. Comparing present and past ECGs could be vital for the detection of new ECG changes [30]. In addition, AI can analyze ECG based on their algorism, and the results may facilitate the interpretation of ECG results for accurate diagnosis of acute coronary syndromes [31,32]. Moreover, telemedicine should be developed in rural contexts. Direct consultation with a cardiologist regarding any ECG change in an older cardiac patient with accompanying symptoms could drive effective transfer of the patient to a general hospital [31,32]. To rationalize and improve the transfer effectiveness of older patients for emergency catheterization, the interpretation of ECGs and telemedicine should be improved by comparing previous and present ECGs using AI.

The troponin level should not be strongly considered when determining whether to transfer for emergency catheterization because although high troponin can reflect cardiac ischemia and be used as supportive information for acute coronary syndrome diagnosis [20], the troponin level can be elevated for reasons other than coronary artery obstruction [12]. Sepsis and simple tachycardia can cause relative ischemia, leading to troponin level elevation [11]. In the present study, the troponin level was not associated with the need for emergency catheterization. Older people experience various anatomical changes in blood vessels, which can lead to arteriosclerosis [5]. In older people, arteriosclerosis tends to cause

relative cardiac ischemia with tachycardia, which may not occur in younger people [4]. General physicians should not initiate the transfer of older patients to tertiary hospitals only based on elevated troponin without considering other factors related to acute coronary artery diseases.

This study revealed that age was not an indication for emergency catheterization in older patients. Chronological age may be unrelated to health conditions [33]. Thus, age may not be a strong indicator for emergency catheterization in aged societies. When patients are older, difficulty in executing activities of daily living can be high and they may require intensive treatment to improve their conditions [33,34]. However, ageism may exist in developed countries, and medical professionals may have a prejudice that older people do not need intensive treatment [35]. Moreover, older patients and their families are usually hesitant in providing consent for intensive treatments [36,37]. Nevertheless, intensive treatment for older patients should not be avoided as many older people are biologically healthy. Many developed countries, including Japan has many older people living longer, and medical professionals and lay people might have realized that mortality may not be decided only by age [36,37]. So, the results of the present study show that ageism may not affect the administration of cardiac interventions in tertiary hospitals. However, the influence of ageism in rural hospitals should be investigated in future studies.

The duration from onset to transfer to tertiary hospitals may be unclear and may not be considered when deciding whether a patient should be transferred for emergency catheterization. Generally, a duration of 24 h from the onset of acute coronary syndrome may be the optimal cutoff for emergency catheterization [19]. However, as this study showed, the optimal duration from the onset of acute coronary syndrome is unrelated to emergency catheterization. Several reasons may explain why the duration from the onset of acute coronary syndrome to the presentation at the clinic did not affect the indications for emergency catheterization among older patients in the present study. First, older people often show vague symptoms. In addition, they tend to have various symptoms due to multimorbidity and polypharmacy [38–40]. Furthermore, older patients with acute coronary syndrome may not show typical symptoms, such as chest pain and cold sweats [4]. The vagueness of symptoms and variations from the typical clinical course of acute coronary syndrome make determining the duration from symptom onset challenging. Second, older patients often have triggers for acute coronary syndrome. Acute coronary syndrome in older people can be caused by various diseases due to the vulnerability of their blood vessels to arteriosclerosis. In addition, viral infections can cause acute coronary syndrome [41,42]. Older people tend to be susceptible to the common cold because of their weak immunity, showing symptoms such as fatigue, chest pain, and cough [43]. Thus, differentiating between symptoms of the common cold and acute coronary syndrome in older patients is difficult. Considering the two above-mentioned factors, defining the onset of acute coronary syndrome is difficult. Therefore, physicians should not decide the onset of acute coronary syndrome based on the symptoms of older patients, and the decision to transfer to tertiary hospitals should be made based on patients' ECG changes and comorbidities and after discussions with the patients, their families, and specialists in tertiary hospitals.

This study had some limitations. First, only patients from one hospital in a rural Japanese setting were included. To elucidate geographical variations in rural contexts, we collected data for a prolonged period and for all admitted older patients. Future studies should include more hospitals in different prefectures and in other countries. Because Japan is a leading country in terms of aging societies, these findings can be applied to countries preparing for issues related to an aging population. Second, the retrospective cohort design prevented the identification of a cause-and-effect relationship. Future longitudinal studies are needed to clarify this relationship. Finally, data on the primary outcomes were based on response letters from the tertiary hospitals. This could have affected the validity of the findings because the response letters did not include the timing of emergency catheterization and the physicians' judgment for catheterization. Future studies should

focus on clarifying the conditions under which emergency catheterization is considered among older patients transferred from rural hospitals.

5. Conclusions

We identified a relationship between indications for emergency catheterization in tertiary hospitals and the conditions of older patients with suspected acute coronary syndrome who were transferred from rural community hospitals to tertiary hospitals. Our results indicated that the level of comorbidities and ECG changes might be related to emergency catheterization in tertiary hospitals. Conversely, age, time from onset to transfer to tertiary hospitals, and troponin level might be unrelated to the intervention. In aging societies, the decision to transfer older people to tertiary hospitals should be made only after reviewing the presence of multimorbidity and ECG changes, and discussing this with patients, their families, and specialists. Such a decision should not be strongly affected by age, onset, and troponin level.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analyzed during this study may be obtained from the corresponding author upon reasonable request.

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