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Risk Factors with 30-Day Readmission and the Impact of Length of Hospital Stay on It in Patients with Heart Failure: A Retrospective Observational Study Using a Japanese National Database

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Heart failure is a major disease, and its 30-day readmission (readmission within 30-day after discharge) negatively impacts patients and society. Thus, we need to stratify the risk and prevent readmission. We aimed to investigate risk factors associated with 30-day readmission and examine the impact of length of hospital stay (LOS) on 30-day readmission. Using the Diagnosis-Procedure-Combination database from April 2018 to March 2021, we conducted multiple logistic regression to investigate risk factors with 30-day readmission. Also, we conducted subgroup analysis in the short LOS group. To examine the association between LOS and 30-day readmission, we performed propensity score matching between the short and middle LOS groups. As a result, we categorized 10,283 patients and 169,842 patients into the readmission group and the no-readmission group. We identified the following factors as the risk of readmission: short LOS, female, smoking, older age, lower body mass index, lower barthel index, artificial ventilator, beta-blockers, thiazides, tolvaptan, loop diuretics, carperitides, class III antiarrhythmic agents, myocardial infarction, diabetes, renal disease, atrial fibrillation, dilated cardiomyopathy, and discharge to home. As a subgroup analysis in the short LOS group, we revealed that the short LOS group risk factors differed from overall. After propensity score matching in the short LOS group and middle LOS group, 37,199 pairs were matched, and we revealed that shorter LOS increases the risk of readmission. These results demonstrated that shortened LOS increases 30-day readmission, and risk factors are unique to each LOS. We suggest stratifying the readmission risk and being careful with early discharge.

Keywords: Diagnosis-Procedure-Combination; heart failure; length of hospital stay; readmission; risk factor
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Introduction

Heart failure is one of the major diseases, and the number of patients suffering from heart failure is large worldwide (Ambrosy et al. 2014; Ponikowski et al. 2016; Heidenreich et al. 2022). In Japan, the number of patients with heart failure is also expected to increase (Okura et al. 2008). Furthermore, heart failure is a specific disease that experiences cycles of exacerbation and remission, which causes frequent readmission (Murray et al. 2005; Harikrishnan et al. 2017). The high readmission rate for heart failure exacerbations is one of the biggest problems, and early readmission, like 30-day readmission, is considered a significant burden to society (Jencks et al. 2009; Maggioni et al. 2013; Greene et al. 2015; Kwok et al. 2021). 30-day readmission is a readmission within 30-day after discharge. In addition, it has been reported that repeated readmission leads to increased mortality, decreased daily living activities, and prolonged hospital stays (Itoh et al. 2020; Kaneko et al. 2020). Thus, identifying risk factors with 30-day readmission in patients with heart failure is necessary to reduce the burden on society and improve

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patients' quality of life. Although previous studies about risk factors associated with 30-day readmission in patients with heart failure exist, most of them are limited to assessing each factor, and the scale is insignificant. Furthermore, no study in Japan comprehensively examines the association between 30-day readmission and patient characteristics, comorbidities, medication during hospitalization, procedure, and status at index admission discharge.

Also, the length of hospital stay (LOS) in Japan is long even by global standards, and the need to shorten LOS is required to reduce medical costs (Organization for Economic Co-operation and Development 2019; Sundaram et al. 2022). On the other hand, some previous studies have reported that shorter LOS is a risk factor for 30-day readmission (Khan et al. 2015; Sud et al. 2017). 30-day is often used as an indicator to measure the quality of medicine. There is no consensus on the association between LOS and hospital readmission, with other studies that longer LOS increases the risk of readmission (Reynolds et al. 2015; Arundel et al. 2021).

Characteristics of heart failure patients and risk factors, including LOS, have been reported to be heterogeneous by region and race (Afzal et al. 1999; Echols et al. 2006; Vivo et al. 2014). Therefore, there is a need to build evidence unique to Japan on risk factors with 30-day readmission in patients with heart failure and the impact of shortened LOS on readmission to prevent readmission caused by heart failure exacerbation.

This study aims to comprehensively investigate the factors associated with the 30-day readmission of heart failure patients and examine the association between LOS and 30-day readmission.

Materials and Methods

Design and data source

This retrospective observational study used the inpatient data from Diagnosis-Procedure-Combination (DPC) database (Murata et al. 2011, 2012, 2014; Tarasawa et al. 2020). The DPC database includes discharge and administrative claims data for all inpatients discharged from more than 1,000 participating hospitals. It covers 92 % of all tertiary-care emergency hospitals in Japan (Murata et al. 2012; Tarasawa et al. 2020). This database is used widely in medical and health research (Tomioka et al. 2019; Fujimori et al. 2021a, b). The institutional review board approved this study of Tohoku University (No. 2021-1-1082). Because of the anonymous nature of the DPC database, the need for informed consent was waived.

Patient selection

We analyzed inpatient data between April 2018 to March 2021. We included patients whose most resource-consuming diagnosis was heart failure. Based on the International Classification of Diseases, 10th Revision (ICD-10) codes, we identified heart failure as I50.0, I50.1, and I50.9 (World Health Organization 2019). We excluded patients who met following criteria: (1) patients who were under the age of 20, (2) patients who died in hospital at index admission, (3) patients with planned admission, (4) patients who readmitted after 31-day or more from their discharge at index admission, (5) patients who readmitted second or subsequent time to avoid reflecting the characteristics of same patient, defining first readmission in our study period as readmission if same patient readmitted multiple times, (6) patients whose discharge disposition was other hospital or clinic, or death, (7) patients whose readmission-precipitating diagnosis was not heart failure, (8) patients whose index admission was in April 2018 to check the index admission was not 30-day readmission, (9) patients whose index admission was in March 2021 for complete 30-days follow-up, and (10) patients with cancer (ICD10 codes; C00-C26, C30-C34, C37-C41, C43, C45-C58, C60-C76, C81-C85, C88, C90-C97). We also excluded patients with missing these data.

Variables

We determined variables to extract based on the former studies and existing knowledge regarding readmission risk factors and poor prognosis. The baseline data we extracted were age, sex, Body Mass Index (BMI) (Wakabayashi et al. 2019), Barthel Index (BI) at discharge (Nguyen et al. 2021), smoking status (Son and Lee 2020), discharge disposition (Howie-Esquivel and Spicer 2012), relativized LOS (Aizawa et al. 2015), Percutaneous Coronary Intervention (PCI) (Curtis et al. 2009), ablation (Pallisgaard et al. 2020), artificial ventilator (Page et al. 2018), dialysis (Chen et al. 2021), cardiac rehabilitation (Thygesen et al. 2022), beta-blocker (Bhatia et al. 2015), Angiotensin II receptor blockers (ARBs) (Pfeffer et al. 2003), Angiotensin-covering enzyme inhibitors (ACEIs) (Sanam et al. 2016), calcium (Ca) antagonists (Packer et al. 1996), thiazide (Aizawa et al. 2015), tolvaptan (Gheorghiade et al. 2007), loop diuretics (Faselis et al. 2020), carperitide (Matsue et al. 2015), class III antiarrhythmic agents (Doval et al. 1994), and following comorbidities: myocardial infarction (ICD10 codes; I21, I22, I252) (Shiba et al. 2005), dilated cardiomyopathy (ICD10 codes; I420) (Jefferies and Towbin 2010), hypertension (ICD10 codes; I10-I15) (Basnet et al. 2018), valvular disease (ICD10 codes; I05-I08, I091, I34-I38, I390, I391, I392, I393, I394) (Koelling et al. 2002), diabetes (ICD10 codes; E10-E14) (Al-Jarallah et al. 2020), renal disease (ICD10 codes; N18, N19, N052, N053, N054, N055, N056, N057, N250, I120, I131, N032, N033, N034, N035, N036, N037, Z490, Z491, Z492, Z940, Z992) (Blair et al. 2011), atrial fibrillation (ICD10 codes; I48) (Amin et al. 2013), chronic pulmonary disease (ICD10 codes; J40- J47, J60- J67, I278, I279, J684, J701, J703) (Gulea et al. 2019), cerebrovascular disease (ICD10 codes; G45, G46, I60-I69, H340) (Wang et al. 2020). BI is one of the indexes that assess activity of daily living. Tolvaptan is the vasopressin type-2 receptor antagonist. Carperitide is recombinant human atrial natriuretic peptide. Relativized LOS is defined as LOS that is divided by the national average of LOS for each patient group based on the classification of DPC.

BMI was classified as under 18.5 kg/m2, between 18.5 to 30 kg/m2, and over 30 kg/m2, according to the World Health Organization (2000). Also, age was classified as under 64, between 65 to 74, and over 75. Smoking status was classified as smoking and no-smoking. BI at discharge was classified as under 59 and over 60. Age, smoking status, and BI were classified according to previous studies (Shah et al. 1989; Morishita et al. 2020; Kim et al. 2020; Hidaka et al. 2021; Katano et al. 2021). Discharge disposition was classified as home and facilities. Concerning LOS, we classified under the 25 percentile as the short LOS group, between the 25 percentile and the 75 percentile as the middle LOS group, and over the 75 percentile as the long LOS group. We chose a method of LOS classification that included half of the patients in the middle LOS group.

Outcomes

The primary outcome of this study was 30-day readmission. We defined 30-day readmission as admission caused within 30-day from the patient's discharge at index admission, and their readmission-precipitating diagnosis was heart failure.

Statistical analysis

Categorical variables were presented as numbers and percentages. Using the Chi-square test, we compared categorical variables between the readmission and no-readmission groups. We conducted multiple logistic regression analyses to identify risk factors with 30-day readmission and included all variables described in the part of *Variables* as independent variables in the model. Also, we used the presence of 30-day readmission as a dependent variable. We checked the correlation coefficients between each variable to satisfy the independence of the variables. All the correlation coefficients were under 0.7, and all variables were considered independent. Then, we performed a complete case analysis. As a subgroup analysis, we conducted multiple logistic regression in the short LOS group, including the same variables other than relativized LOS.

We also performed propensity score matching using a 1:1 matching protocol to balance baseline characteristics between the short and middle LOS groups. The caliper was a width equal to 0.2 of the standard difference of the propensity score (Austin 2011). We estimated propensity scores with logistic regression, including the presence of the short or middle LOS groups as a dependent variable. We added the missing group in BI, smoking status, and BMI and included all variables other than relativized LOS as independent variables. For comparing baseline characteristics between the short and middle LOS groups after propensity score matching, we considered absolute standardized difference (ASD) as under 0.1 as balanced (Austin 2011). After matching the propensity score, we compared the 30-day readmission rate between the short and middle-LOS groups.

All p values were two-tailed, and we considered $p < 0.05$ statistically significant. We performed all statistical analyses using SPSS version 28.

Results

As shown in Fig. 1, 180,125 cases were identified as index admission. 169,842 and 10,283 patients were categorized into the no-readmission group and 30-day readmission group, respectively. Relativized LOS 0.6 and 1.4 were 25 percentile and 75 percentile, respectively. Therefore, we categorized relativized LOS as short LOS group (under 0.6), middle LOS group (between 0.6 to 1.4), and long LOS group (over 1.4). Table 1 shows the unadjusted baseline characteristics of patients of each group. The patients in the readmission group were more likely to receive an artificial ventilator, cardiac rehabilitation, and be prescribed beta blockers, thiazides, tolvaptan, loop diuretics, carperitides, and class III antiarrhythmic agents. Also, they are likely to have a myocardial infarction, cerebrovascular disease, diabetes, renal disease, atrial fibrillation, dilated cardiomyopathy, and valvular disease. In the no-readmission group, patients were more likely to be male, smoke, have higher BI, be discharged to home, receive PCI, ablation, dialysis, and be prescribed ARBs, ACEIs, Ca antagonists, and have hypertension. There were significant age differences, BMI, and relativized LOS.

Multiple logistic regression analysis showed that the following factors significantly increase the risk of readmission: short LOS, female, higher age, smoking, lower BI, lower BMI, artificial ventilator, beta-blockers, thiazide, tolvaptan, loop diuretics, carperitides, class III antiarrhythmic agents, myocardial infarction, diabetes, renal disease, atrial fibrillation, dilated cardiomyopathy, and discharge to home (Table 2). Conversely, factors in decreasing readmission risk were PCI, ablation, dialysis, ARBs, ACEIs, Ca antagonist, and hypertension (Table 2).

Table 3 shows the results of subgroup analysis in the short LOS group. It revealed that the following factors were associated with increasing 30-day readmission: higher age, lower BMI, artificial ventilator, beta-blockers, tolvaptan, loop diuretics, class III antiarrhythmic agents, diabetes, and renal disease. Conversely, ablation, ARBs, ACIEs, and Ca antagonists were significantly associated with decreasing 30-day readmission risk.

Table 4 shows the baseline characteristics of patients in the short LOS group and middle LOS group before and after propensity score matching. After propensity score matching of the short LOS group and middle LOS group, 37,199 pairs were matched, and characteristics between the groups were well balanced, with all ASD under 0.1. The C-statistic was 0.661 (95% confidence interval 0.658 to 0.664) and demonstrated it was confirmed in the propensity score model. As a result of Chi-square tests, the readmission rates in the short LOS group were significantly higher

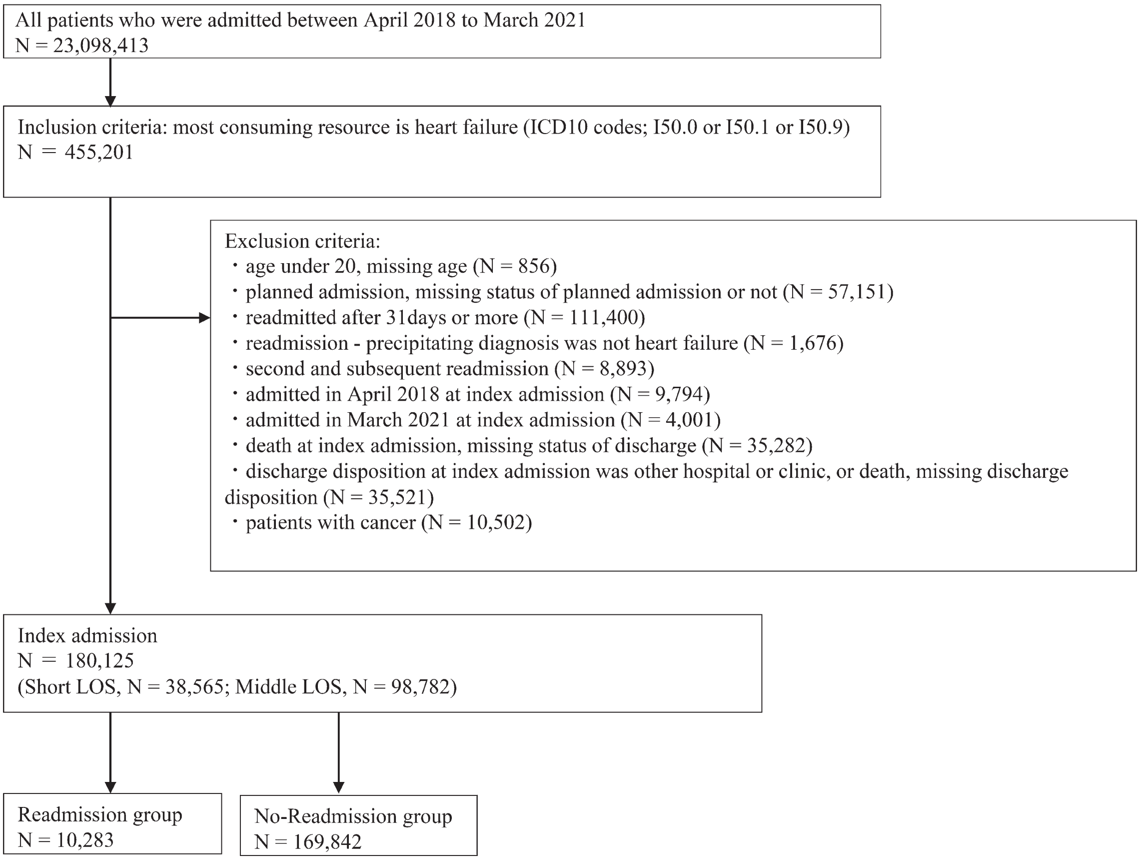

Fig. 1. Patient selection flow.
Short LOS group defined as relativized LOS under 0.6. Middle LOS group defined as relativized LOS between 0.6 to 1.4.
LOS, Length of hospital stay; N, the number of patients; ICD10, the International Classification of Diseases, 10th Revision.

than middle LOS group (short LOS 5.49%; middle LOS 5.05 %; p = 0.008).

Discussion

In our study, 180,125 heart failure patients throughout Japan were investigated using big data, namely DPC data. This study is the first in Japan to comprehensively investigate the risk factor associated with 30-day readmission, focusing on patients' characteristics and medications in hospitalization, procedures, comorbidities, and status at the discharge of index admission. The key results of this study are (1) short LOS increased 30-day readmission, (2) discharge disposition was associated with 30-day readmission, (3) other risk factors with 30-day readmission were comprehensively identified, and (4) it had a possibility that the risk factors in short LOS group were different from those in overall.

First, the association between LOS and 30-day readmission was examined using multivariate analysis and propensity score matching. Both results showed that short LOS increases the risk of 30-day readmission. One of the earlier studies in Japan has shown the same results, although that study has not shown cut-off points regarding LOS (Aizawa et al. 2015). This result suggests that the shorter LOS may provide insufficient medical care. Therefore, we need to be careful with the early discharge of heart failure patients in the Japanese medical system context. In addition, there is no study to use an index named "relativized LOS" that divides LOS by the national average of LOS for each patient's group based on the classification of DPC. In Japan, a DPC system classifies patients into groups based on the combination of their diagnoses and medical procedures. Therefore, each group has its national average of LOS according to the combination of diagnoses and medical procedures. In this study, we selected heart failure patients by ICD10 codes, but patients classified into various groups were mixed. So, the national average of LOS differed by each patient. Therefore, we divided LOS by the national average of LOS for each patient's group to make it possible to compare LOS across groups. This process is a manipulation that improves the comparability of patients' LOS. Most previous studies have not reported the rationale for grouping LOS, and variations existed in their cut-off points. So, clinicians were not sure how early discharge increases the risk of readmission. Using this index, we could compare patients in different conditions and settings and show how early discharge increases each patient's readmission risk.

Table 1. Patients' characteristics.

		No-readmission		Readmission		
		Rate	Number	Rate	Number	p value
Number			169,842		10,283	
Relativized LOS						< 0.001
	Short	21.5%	36,457	20.5%	2,108	
	Middle	55.0%	93,369	52.6%	5,413	
	Long	23.6%	40,016	26.9%	2,762	
Age						< 0.001
	≦ 64	13.2%	22,347	7.4%	764	
	≧ 65 to ≦ 74	16.0%	27,124	14.0%	1,441	
	≧ 75	70.9%	120,371	78.6%	8,078	
Sex (male)		51.9%	88,132	49.1%	5,050	< 0.001
Barthel index at discharge						< 0.001
	≦ 59	24.3%	37,344	28.0%	2,572	
	≧ 60	75.7%	116,282	72.0%	6,627	
Smoking status						0.013
	No-smoking	67.4%	101,504	68.7%	6,363	
	Smoking	32.6%	49,069	31.3%	2,904	
Body mass index						< 0.001
	< 18.5	14.2%	22,306	17.0%	1,637	
	≧ 18.5 to < 30	78.0%	122,686	77.9%	7,514	
	≧ 30	7.9%	12,372	5.1%	491	
Discharge disposition						0.045
	Home	87.6%	148,743	86.9%	8,936	
	Facility	12.4%	21,099	13.1%	1,347	
Percutaneous coronary intervention		3.9%	6,637	2.7%	275	< 0.001
Ablation		0.7%	1,158	0.3%	29	< 0.001
Artificial ventilator		15.7%	26,659	16.7%	1,719	0.006
Dialysis		5.3%	8,950	4.5%	461	< 0.001
Cardiac rehabilitation		53.5%	90,843	54.5%	5,608	0.039
Beta-blockers		62.8%	106,631	64.8%	6,660	< 0.001
Angiotensin II receptor blockers		36.2%	61,441	31.8%	3,269	< 0.001
Angiotensin-covering enzyme inhibitors		27.0%	45,874	23.2%	2,385	< 0.001
Calcium antagonists		47.4%	80,571	43.5%	4,469	< 0.001
Thiazide		6.7%	11,310	8.4%	867	< 0.001
Tolvaptans		33.3%	56,593	45.8%	4,704	< 0.001
Loop diuretics		90.3%	153,300	92.6%	9,524	< 0.001
Carperitides		22.8%	38,771	24.9%	2,561	< 0.001
Class III antiarrhythmics		6.6%	11,222	8.8%	900	< 0.001
Myocardial infarction		8.0%	13,523	9.6%	986	< 0.001
Dilated cardiomyopathy		1.6%	2,778	2.2%	226	< 0.001
Valvular disease		12.2%	20,665	14.0%	1,439	< 0.001
Hypertension		58.3%	99,027	55.6%	5,719	< 0.001
Cerebrovascular disease		8.2%	13,853	9.2%	947	< 0.001
Chronic pulmonary disease		7.7%	13,124	8.3%	848	0.057
Diabetes		27.6%	46,890	29.7%	3,049	< 0.001
Renal disease		16.5%	28,064	21.7%	2,231	< 0.001
Atrial fibrillation		33.8%	57,391	37.2%	3,821	< 0.001

LOS, Length of hospital stay. Calculated using Chi-square test.

Table 2. Multiple logistic regression.

		Odds rate	95 % CI	p value
Relativized LOS				
	Short	1.075	1.011-1.143	0.021
	Middle	reference		
	Long	1.033	0.976-1.093	0.260
Age				
	≦ 64	reference		
	≧ 65 to ≦ 74	1.431	1.292-1.586	< 0.001
	≧ 75	1.835	1.673-2.013	< 0.001
Sex (reference: male)		1.110	1.051-1.172	< 0.001
Barthel index: ≧ 60 (reference: ≦ 59)		0.909	0.856-0.966	0.002
Smoking		1.066	1.006-1.129	0.031
Body mass index				< 0.001
	< 18.5	reference		
	≧ 18.5 to < 30	0.879	0.825-0.937	< 0.001
	≧ 30	0.654	0.579-0.739	< 0.001
Discharge to home (Reference: Facility)		1.094	1.011-1.183	0.026
Percutaneous coronary intervention		0.718	0.625-0.824	< 0.001
Ablation		0.382	0.250-0.585	< 0.001
Artificial ventilator		1.157	1.085-1.235	< 0.001
Dialysis		0.871	0.768-0.987	0.031
Cardiac rehabilitation		0.978	0.932-1.027	0.373
Beta-blockers		1.114	1.058-1.173	< 0.001
Angiotensin II receptor blockers		0.812	0.769-0.857	< 0.001
Angiotensin-covering enzyme inhibitors		0.754	0.710-0.800	< 0.001
Calcium antagonists		0.842	0.802-0.884	< 0.001
Thiazides		1.181	1.086-1.284	< 0.001
Tolvaptan		1.567	1.493-1.645	< 0.001
Loop diuretics		1.161	1.058-1.275	0.002
Carperitides		1.084	1.027-1.145	0.004
Class III antiarrhythmic agents		1.335	1.228-1.452	< 0.001
Myocardial infarction		1.184	1.092-1.283	< 0.001
Dilated cardiomyopathy		1.426	1.216-1.671	< 0.001
Valvular disease		1.049	0.981-1.123	0.160
Hypertension		0.950	0.905-0.996	0.035
Cerebrovascular disease		1.078	0.994-1.168	0.070
Chronic pulmonary disease		1.071	0.984-1.166	0.113
Diabetes		1.167	1.108-1.229	< 0.001
Renal disease		1.414	1.332-1.502	< 0.001
Atrial fibrillation		1.085	1.033-1.140	< 0.001

CI, Confidence interval; LOS, Length of hospital stay.

Second, we revealed that discharge to home increase the risk of 30-day readmission. In a prior study, patients discharged to nursing facilities had low readmission rates (Howie-Esquivel and Spicer 2012). Furthermore, other studies have shown that patients with social support in their region were less likely to readmit (Tomita et al. 2010; Takabayashi et al. 2020). These studies imply that readmission risk may be decreased with social or medical support. Unfortunately, as our research showed, most people discharge home, and receiving such support in a home is more challenging than in other facilities. Thus, we must facilitate regional cooperation to support heart failure patients in their homes after discharge.

Third, other risk factors were identified. Factors including higher age, smoking, lower BMI, and lower BI agree with prior studies (Fernandez-Gasso et al. 2017; Wakabayashi et al. 2019; Son and Lee 2020; Nguyen et al. 2021). We also identified that female is a risk factor for

Table 3. Subgroup analysis in short LOS group.

	Odds rate	95 % CI	p value
Age			
≦ 64	reference		
≧ 65 to ≦ 74	1.286	1.058-1.563	0.012
≧ 75	1.597	1.337-1.907	< 0.001
Sex (reference: male)	1.044	0.925-1.178	0.484
Barthel index: ≧ 60 (reference: ≦ 59)	0.913	0.791-1.052	0.207
Smoking	1.086	0.961-1.227	0.185
Body mass index			
< 18.5	reference		
≧ 18.5 to < 30	0.865	0.743-1.007	0.061
≧ 30	0.770	0.591-1.002	0.052
Discharge to home (Reference: Facility)	0.895	0.720-1.113	0.319
Percutaneous coronary intervention	0.802	0.612-1.050	0.109
Ablation	0.275	0.087-0.866	0.027
Artificial ventilator	1.175	1.016-1.358	0.029
Dialysis	1.134	0.911-1.411	0.261
Cardiac rehabilitation	0.909	0.815-1.014	0.087
Beta-blockers	1.153	1.031-1.289	0.013
Angiotensin II receptor blockers	0.720	0.637-0.813	< 0.001
Angiotensin-covering enzyme inhibitors	0.796	0.694-0.912	0.001
Calcium antagonists	0.814	0.730-0.909	< 0.001
Thiazides	1.100	0.889-1.362	0.379
Tolvaptan	1.579	1.409-1.768	< 0.001
Loop diuretics	1.440	1.220-1.701	< 0.001
Carperitides	1.103	0.967-1.258	0.146
Class III antiarrhythmic agents	1.447	1.181-1.773	< 0.001
Myocardial infarction	1.156	0.975-1.372	0.096
Dilated cardiomyopathy	1.044	0.693-1.573	0.836
Valvular disease	1.060	0.902-1.247	0.477
Hypertension	0.960	0.863-1.067	0.449
Cerebrovascular disease	1.181	0.974-1.431	0.091
Chronic pulmonary disease	1.197	0.989-1.449	0.065
Diabetes	1.218	1.087-1.366	< 0.001
Renal disease	1.390	1.208-1.600	< 0.001
Atrial fibrillation	0.944	0.841-1.060	0.329

LOS, Length of hospital stay; CI, Confidence interval.

readmission. Studies on sex differences in patients with heart failure have been conducted, but their results may not be consistent (Hoang-Kim et al. 2020; López-Vilella et al. 2021). At least in Japanese tertiary-care emergency hospitals, females may be at risk for readmission because the DPC database has high representativeness in the setting.

Regarding comorbidities, this study found that diabetes, renal disease, and atrial fibrillation increased the risk of readmission as well as earlier studies (Kim et al. 2009; Blair et al. 2011; Amin et al. 2013; Yamauchi et al. 2017; Thomas 2018; Al-Jarallah et al. 2020). Also, myocardial infarction, hypertension, dilated cardiomyopathy, and valvular disease are known to be primary causative diseases of heart failure (Tsutsui et al. 2019). Regarding myocardial infarction and dilated cardiomyopathy, the results of this study are in line with former studies reporting an association with poor prognosis (Shiba et al. 2005; Jefferies and Towbin 2010). As for valvular disease, we found valvular disease has no association with readmission. Against our findings, previous studies have reported that valvular disease is a risk factor for 30-day readmission, but these studies were conducted outside of Japan and targeted only patients with heart failure with preserved ejection fraction or performed in a single center (Harmon et al. 2020; Tantarattanapong and Keeratipongpun 2021). Therefore, it may be reasonable not to think there is an association between valvular disease and 30-day readmission in overall heart failure patients in Japan. Although hypertension is

Table 4. Patients' characteristics before-after PS matching.

	Before matching					After matching				
	Short LOS		Middle LOS			Short LOS		Middle LOS		
	Rate	Number	Rate	Number	ASD	Rate	Number	Rate	Number	ASD
Number		38,565		98,782			37,199		37,199	
Age										
≦ 64	15.3%	5,891	13.4%	13,194	0.055	14.9%	5,552	15.2%	5,666	0.008
≧ 65 to ≦ 74	18.7%	7,202	16.7%	16,488	0.052	18.2%	6,774	18.3%	6,789	0.001
≧ 75	66.1%	25,472	70.0%	69,100	0.084	66.9%	24,873	66.5%	24,744	0.007
Sex (male)	56.8%	21,910	52.8%	52,124	0.081	56.4%	20,965	55.9%	20,796	0.009
Barthel index										
Missing	8.8%	3,390	9.2%	9,046	0.013	8.9%	3,293	8.9%	3,294	0.000
≦ 59	16.5%	6,368	19.1%	18,859	0.067	16.7%	6,207	17.3%	6,447	0.017
≧ 60	74.7%	28,807	71.8%	70,877	0.067	74.5%	27,699	73.8%	27,458	0.015
Smoking status										
Missing	11.6%	4,487	11.3%	11,171	0.010	11.6%	4,319	11.7%	4,368	0.004
No-smoking	55.4%	21,375	58.7%	58,028	0.067	55.7%	20,734	56.8%	21,123	0.021
Smoking	32.9%	12,703	30.0%	29,583	0.064	32.7%	12,146	31.5%	11,708	0.025
Body mass index										
Missing	7.6%	2,943	6.9%	6,819	0.028	7.6%	2,820	7.9%	2,954	0.013
< 18.5	11.1%	4,294	12.5%	12,320	0.042	11.1%	4,137	11.9%	4,423	0.024
≧ 18.5 to < 30	74.4%	28,676	73.2%	72,299	0.027	74.4%	27,665	72.5%	26,963	0.043
≧ 30	6.9%	2,652	7.4%	7,344	0.021	6.9%	2,577	7.7%	2,859	0.029
Discharge disposition										
Home	93.5%	36,046	89.8%	88,672	0.134	93.2%	34,686	92.4%	34,381	0.032
Facility	6.5%	2,519	10.2%	10,110	0.134	6.8%	2,513	7.6%	2,818	0.032
Percutaneous coronary intervention	4.4%	1,702	4.2%	4,100	0.013	4.4%	1,648	4.3%	1,614	0.004
Ablation	0.6%	241	0.7%	708	0.012	0.7%	240	0.6%	227	0.005
Artificial ventilator	15.3%	5,910	16.9%	16,655	0.042	15.2%	5,644	16.5%	6,123	0.035
Dialysis	10.6%	4,079	4.1%	4,021	0.252	8.5%	3,161	7.8%	2,893	0.026
Cardiac rehabilitation	39.6%	15,266	59.3%	58,589	0.402	41.0%	15,262	44.5%	16,550	0.070
Beta-blockers	57.7%	22,242	66.2%	65,376	0.176	58.7%	21,831	62.2%	23,140	0.072
Angiotensin II receptor blockers	35.4%	13,631	36.8%	36,366	0.030	35.8%	13,302	36.8%	13,685	0.021
Angiotensin-covering enzyme inhibitors	21.9%	8,447	29.0%	28,659	0.164	22.7%	8,426	24.8%	9,228	0.051
Calcium antagonists	46.4%	17,897	47.7%	47,071	0.025	46.5%	17,295	46.7%	17,380	0.005
Thiazides	5.3%	2,026	6.5%	6,382	0.052	5.4%	2,020	5.6%	2,064	0.005
Tolvaptan	22.5%	8,678	33.7%	33,297	0.251	23.3%	8,676	27.3%	10,166	0.092
Loop diuretics	81.3%	31,339	92.5%	91,367	0.337	84.2%	31,321	85.6%	31,836	0.039
Carperitides	17.6%	6,780	24.2%	23,905	0.163	18.2%	6,767	20.7%	7,683	0.062
Class III antiarrhythmic agents	5.2%	1,992	6.8%	6,749	0.070	5.3%	1,973	6.5%	2,399	0.049
Myocardial infarction	8.6%	3,315	8.3%	8,159	0.012	8.7%	3,226	8.7%	3,244	0.002
Dilated cardiomyopathy	1.5%	563	1.7%	1,712	0.022	1.5%	559	1.7%	618	0.013
Valvular disease	10.2%	3,944	12.8%	12,617	0.080	10.5%	3,908	12.1%	4,500	0.050
Hypertension	57.4%	22,120	60.6%	59,857	0.066	58.0%	21,578	60.6%	22,555	0.053
Cerebrovascular disease	6.5%	2,517	7.8%	7,668	0.048	6.6%	2,467	7.0%	2,591	0.014
Chronic pulmonary disease	6.8%	2,639	7.8%	7,691	0.036	7.1%	2,624	7.3%	2,721	0.010
Diabetes	27.3%	10,543	28.5%	28,158	0.026	27.3%	10,159	28.3%	10,533	0.023
Renal disease	19.5%	7,519	15.7%	15,475	0.101	18.0%	6,700	17.8%	6,619	0.006
Atrial fibrillation	30.5%	11,767	35.4%	34,934	0.103	31.3%	11,652	33.7%	12,550	0.052

PS, Propensity score; LOS, Length of hospital stay; ASD, Absolute standardized difference. Short LOS group defined as relativized LOS under 0.6. Middle LOS group defined as relativized LOS between 0.6 to 1.4.

considered a risk factor for mortality in patients with heart failure, our study found that it decreases the risk of readmission. This finding is consistent with one previous study (Basnet et al. 2018). This result may be because hypertension, a disease commonly considered to lead to a poor prognosis, makes its management more careful. These results may suggest that differences in causative disease affect the risk of readmission. Therefore, we should pay particular attention to patients with myocardial infarction and dilated cardiomyopathy as causative diseases to control the risk of readmission.

As for medications, our results showed beta-blockers and class III antiarrhythmic agents increased the risk for readmission, and ARBs, ACEIs, and Ca antagonists decreased the risk of readmission. The results regarding beta-blockers, ARBs, ACEIs, and Ca antagonists concord with earlier studies (Packer et al. 1996; Pfeffer et al. 2003; Bhatia et al. 2015; Sanam et al. 2016). Concerning class III antiarrhythmic agents, there are few studies to examine the association between their use and short-term readmission, although there are studies about the long-term prognosis and mortality (Singh et al. 1992; Doval et al. 1994). Thus, this study adds a new finding that using class III antiarrhythmic increases the risk of short-term readmission. Other risk factors of medication were kinds of diuretics, and the same results that diuretics are the risk for readmission have been shown in earlier studies (Domanski et al. 2003; Ahmed et al. 2006; Gheorghiade et al. 2007; Tsutsui et al. 2019).

As for procedures, the result that artificial ventilator increase readmission risk is consistent with a prior study (Page et al. 2018). This result seems reasonable because patients on life support procedures are more severe cases. The results show that ablation decreases the readmission risk and agrees with earlier studies (Pallisgaard et al. 2020). Ablation is a treatment for arrhythmia, and there is a possibility that such treatments for significant comorbidities of heart failure reduce the risk of readmission. Also, we identified PCI as a factor that decreases the risk of readmission. There is a study about the impact of PCI on all-cause readmission (Curtis et al. 2009). However, not enough study has been conducted on readmission by heart failure exacerbation. Because PCI is a treatment for underlying disease of heart failure, it may contribute to decreased risk of readmission by exacerbation of heart failure. In addition, we identified that dialysis decreases readmission risk. This result disagrees with the earlier study conducted in China (Chen et al. 2021). The difference in setting may make the difference in results. As our study showed, renal failure is one of the risk factors of 30-day readmission and this result suggests efficacy of the treatment for comorbidity as well as PCI and ablation. Few studies assess the effect of medical procedures adjusted for LOS. Moreover, the results suggest that we could stratify the readmission risk by types of procedures; life support procedures such as artificial ventilators increase the risk of readmission, and treatment for essential comorbidities may reduce the risk of heart failure readmission.

Fourth, this is the first study to investigate risk factors with 30-days readmission in the short LOS group, even as a subgroup analysis. We found that there were differences in risk factors between the overall and short LOS groups. It suggests the possibility that there are specific readmission-related factors in each LOS.

There are some limitations in this study. First, we could not track patients transferred to other hospitals. Even if we eliminated the risk of bias caused by this limitation as much as possible by excluding patients whose discharge disposition was other hospitals or clinics, it should be noted that the bias was not eliminated. Second, the lack of outpatient data limited our observation of outpatients' medical care after discharge. The status of disease management in outpatient after discharge may be associated with the risk of readmission. Third, the DPC database does not have laboratory data like ejection fraction and nutritional status. Several earlier pieces of research have reported that these laboratory data were also predictors for readmission and prognosis (Cohn et al. 1984; Yoshimura et al. 1993; Shah et al. 2017: Ramiro-Ortega et al. 2018). Fourth, because of the nature of the DPC database, we could not get information about lifestyle after discharge. Some studies show that readmission rates increase depending on family composition and lifestyle, such as adherence to medication and diet management after hospital discharge (Toback and Clark 2017; Wray et al. 2021).

In conclusion, we revealed that short LOS increases the risk of readmission using an index named relativized LOS, a novel method. Therefore, we suggest that we should be careful about too early discharge.

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Author Contributions

All authors have contributed significantly to this work, and all authors agree with the manuscript's content.

Conflict of Interest

The author declares no conflict of interest.

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