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Risk Factors for Readmission of Heart Transplant Recipients: A Retrospective Case-Control Study

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Purpose: The purpose of this study was to identify factors influencing the readmission of heart transplant recipients through survival analysis. **Methods:** We collected data from heart transplant recipients who were discharged after surgery between November 2005 and September 2020 from the electronic medical records of Y University Hospital in Seoul. The Kaplan-Meier estimation was utilized to calculate the survival rate, and Cox's proportional hazards model was employed to determine the factors influencing readmission within 1 year. **Results:** Out of 150 heart transplant recipients, 81 (54.0%) were readmitted within one year. The median time to readmission was 231 days. An increased duration of postoperative days was associated with a higher risk of readmission (p=.016). Groups with abnormal sodium levels (p<.001), those requiring postoperative hemodialysis (p=.013), patients with chronic kidney disease (p=.002), dyslipidemia (p=.040), or diabetes mellitus (p=.045) also faced higher readmission risks. In the final model, sodium levels (hazard ratio [HR]=2.31, p<.001) and chronic kidney disease (HR=1.67, p=.045) were significant risk factors for readmission (x^2=31.90, p<.001). **Conclusion:** Interventions to improve kidney function and a multidisciplinary approach are needed to reduce readmission of heart transplant recipients.

Key Words: Heart transplantation; Patient readmission; Survival analysis

INTRODUCTION

Heart transplantation is an effective treatment for patients with end-stage heart failure that is no longer responsive to drug therapy. The world's first successful heart transplantation was performed in 1967, and the procedure was first attempted in Korea in 1992. Since then, the number of heart transplants in Korea has steadily increased, with 98 transplants in 2011, 127 in 2013, 145 in 2015, 184 in 2017, and 194 in 2019. The one-year survival rate for heart transplant recipients improved from 77.1% in 2017 to 85.2% in 2020, while the 11-year survival rate reached 65.0% [1]. Although heart transplantation surgery improves the survival rate and quality of life for patients with end-stage heart failure, it also carries a heightened risk of complications such as infections due to immunosuppressant drugs, chronic diseases, transplant rejection, and heart-related complications [2-4]. Moreover, proper management of daily activities, including dietary control, medication adherence for infection prevention, and self-care, is essential [5-7]. Incorrect self-care practices and various complications often result in hospital readmissions [2].

Upon examining the readmission rates among patients who underwent heart transplant surgery in Korea between 1992 and 2016, it was observed that 42.1% were readmitted within 1 year [8]. Similarly, among 595 heart transplant recipients in the United States in 2013, 66.5% were readmitted within the same timeframe [9]. Furthermore, international reports indicate that the readmission rates for heart transplant recipients range from 19.3% to 66.0%, which is higher than those for other diseases. These rates vary significantly depending on the volume of transplants performed and the level of surgical expertise [10].

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Readmission may be harmful to patients both physically and psychologically [11]. In particular, readmission following heart transplantation can significantly diminish the quality of life for recipients and impose a substantial financial burden. These consequences can negatively influence the long-term outcomes for heart transplant recipients, who require ongoing treatment and management [12,13]. Although studies on readmission rates post-organ transplantation have varied in their follow-up durations, the majority of research focusing on heart transplant patients has identified the first year post-transplant as a period of high readmission risk. Therefore, these studies have predominantly investigated the 1-year timeframe [8-10]. Given that short-term survival rates are critical benchmarks for transplant recipients, scrutinizing readmission rates within this first year is imperative [14]. Survival analysis is a statistical method that assesses the likelihood of events occurring over a specified time frame. This approach is particularly advantageous for analyzing not only the incidence of readmission but also the duration until such events occur [15]. Utilizing survival analysis to examine the interval between heart transplantation and readmission can provide valuable insights for determining when intensive care is most necessary in the postoperative period. Furthermore, it can assist in the development of tailored care strategies that are specific to the stages at which readmission is most likely to occur for patients who have undergone surgery.

However, existing studies have primarily focused on identifying the reasons for readmission without considering the characteristics mentioned above. Reported causes of readmission include transplant rejection (15.3%), transplant complications (9.4%), acute kidney injury (6.5%), and infections (3.0%). It was found that patients who were readmitted had significantly higher rates of chronic renal failure, longer hospital stays for the transplant, and greater hospitalization costs for surgery [12]. Studies investigating factors influencing readmission have identified that readmission is significantly associated with female gender, pre-existing respiratory diseases or hypertension, and discharge to facilities such as nursing homes. Furthermore, participation in cardiac rehabilitation was associated with a 29.0% reduction in the rate of readmission within one year [9]. Additionally, pre-surgical glomerular filtration rate and the presence of hypertension were significant predictors of readmission [8]. Previous research has typically examined the factors influencing readmission by conducting frequency and regression analyses of the causes. However, these analyses were limited because they only considered the timing of readmission as important. These studies merely treated the occurrence of readmission as a dependent variable, neglecting the characteristics of data that were censored due to readmission. Therefore, to reach a comprehensive understanding, it is necessary to investigate both the timing until readmission and the risk factors for readmission using survival analysis methods, which account for all these factors simultaneously.

To identify the risk factors for readmission, it is important to consider the aforementioned causes. Previous research has indicated that kidney dysfunction is a significant contributor to readmission rates, alongside transplant rejection and infection [12]. Heart transplant recipients are particularly susceptible to kidney function issues due to potential declines in heart function, with blood urea nitrogen and creatinine levels being key indicators of readmission [8,12]. Furthermore, patients who experienced acute kidney failure post-heart transplant were found to have markedly lower survival rates at both 30 days and 1 year [14]. While it is crucial to consider all kidney-related factors in transplant recipients, the majority of research has primarily focused on transplant rejection and the use of immunosuppressants [16]. Therefore, there is a need to investigate a broader spectrum of risk factors associated with readmission. This study aimed to examine the readmission patterns of heart transplant recipients in Korea, including the duration until readmission. Additionally, it sought to identify the risk factors for readmission by comparing the general and clinical characteristics of patients who were not readmitted with those who were.

METHODS

1. Study Design

This retrospective case-control study investigated the risk factors for readmission among patients who underwent heart transplant surgery at Y University Hospital in Seoul. The investigation was carried out by conducting a secondary data analysis of electronic medical records.

2. Participants

This study was conducted with patients who underwent heart transplant surgery at Y University Hospital and were discharged between November 2005 and September 2020. The inclusion criteria were individuals who had heart transplant surgery and were discharged within this timeframe. The exclusion criteria included those aged 18 or younger at the time of surgery, those who received a

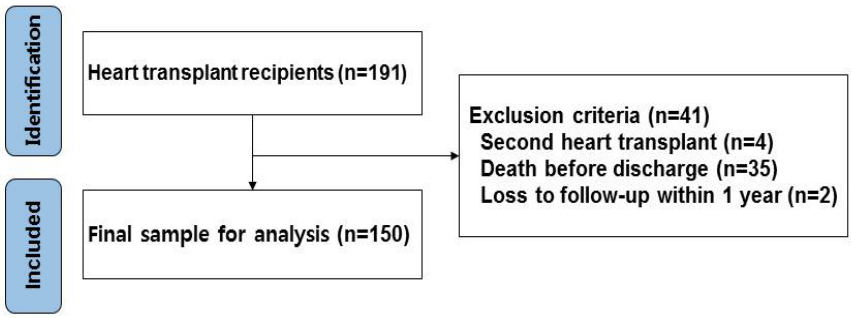

Figure 1. Participants' selection flow in this study.

heart retransplantation, those who died before being discharged following a heart transplant, and those who discontinued treatment within a year after discharge. Out of 191 patients who underwent heart transplants and were discharged during the specified period, 4 cases were excluded due to heart retransplantation, 35 cases were excluded due to death before discharge following a heart transplant, and 2 cases were excluded due to discontinuation of treatment within a year after discharge. Consequently, a total of 150 cases were included in the analysis (Figure 1).

3. Study Tools

Based on a review of the literature, data were collected and categorized into three distinct groups: general characteristics, clinical characteristics, and readmission characteristics.

As general characteristics, data on sex, age, Body Mass Index (BMI), regular exercise, smoking status, drinking status, education level, marital status, and financial difficult were collected. Age was recorded as of the date of surgery. For BMI, measurements taken within a week prior to discharge were used, selecting the value closest to the discharge date. Additional general characteristics, including sex and marital status, were obtained from the nursing information survey completed at the time of hospital admission. The study also investigated whether participants engaged in regular exercise based on their self-report. Smoking and drinking status were evaluated, with individuals categorized as either having smoked or consumed alcohol at least once or not at all. Marital status was classified as either married or unmarried. Economic status was determined by a simple yes or no response to the question, "Do you currently experience financial difficulties?"

Clinical characteristics such as the length of hospital stay, the postoperative day, the type of hospitalization unit immediately before transplantation (general ward or Intensive Care Unit [ICU]), participation in cardiac rehabilitation, post-transplant hemodialysis, hematologic test results (creatinine, blood urea nitrogen, glomerular filtration rate, and sodium), and comorbidities (hypertension, diabetes, hyperlipidemia, chronic kidney disease, cytomegalovirus, tuberculosis, and cerebrovascular accident) were collected. Hematologic test results from the first outpatient visit after transplant surgery were also gathered. Individuals with a creatinine level between 0.49 mg/dL and 0.91 mg/dL were categorized as the normal group, while those with levels outside this range were considered abnormal. Those with a blood urea nitrogen level within the range of 7.3 mg/dL to 20.5 mg/dL were placed in the normal group, and those with levels outside this range were classified as abnormal. Individuals with a glomerular filtration rate of 60 mL/min or higher were categorized as normal, and those with rates below 60 mL/min were considered abnormal. Sodium levels between 135 mmol/L and 145 mmol/L were deemed normal, with values outside this range classified as abnormal. To identify comorbidities, diagnoses at the time of discharge were reviewed.

The characteristics of readmission examined in this study included whether participants were readmitted within one year following their transplant, the duration between discharge and readmission (in days), the length of the hospital stay (in days), and the cause of readmission. Readmission was specifically defined as any admission for various reasons occurring within the 1-year observation period. Routine checkups and admissions solely for myocardial biopsies were excluded from this definition. In instances of multiple admissions, only the first was considered the initial readmission. Cases without readmission during the observation period were recorded as censored at 1 year. The causes of readmission were investigated by reviewing inpatient records from the admission.

4. Data Collection and Ethical Considerations

After obtaining approval (IRB No. 4-2021-1197) for this study from the IRB of Y University Hospital in Seoul, we requested and obtained data from the Medical Records Team. We used patient information collected up to September 2021 for the secondary data analysis in this study. Prior to being given to the research team, the data were anonymized; the researchers then assigned unique identifiers, analyzed, and stored the data as confidential.

5. Data Analysis

The collected data were analyzed using SPSS for Windows version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including frequency, percentage, mean, standard deviation, median, and quartiles, were calculated to examine the general and clinical characteristics of the participants, as well as the features of readmission. To identify differences in these characteristics between the readmission group and the non-readmission group, we employed the x^2 test, the Fisher exact test, or the Mann-Whitney U test as appropriate. Kaplan-Meier estimation was utilized to assess the readmission rate over 1 year among heart transplant recipients. Additionally, Cox proportional hazard model facilitated a preliminary analysis to identify potential risk factors for readmission. Subsequently, variables that were statistically significant in the initial analysis were incorporated into a multivariate Cox proportional hazard model to further investigate the risk factors for readmission within 1 year post-discharge. To check the proportional hazards assumption, a log-log plot was employed. In the context of this study's survival analysis, an "incident" refers to readmission within 1 year following a heart transplant, while "survival period" denotes the time elapsed until readmission.

RESULTS

1. Readmission Status of Heart Transplant Recipients

In total, 81 (54.0%) out of 150 participants were readmitted. The characteristics of those who were readmitted are presented in Table 1. The average period from discharge to readmission was 83.17±88.19 days, with a median time to readmission of 44 days (Interquartile Range [IQR] 15.00~135.50). The average length of hospital stay during readmission was 18.05±23.24 days, with a median stay of 13 days (IQR, 4.50~20.50). The most common cause of readmission was cytomegalovirus infection (15 cases, 10.0%), followed by gastrointestinal troubles (14 cases, 9.3%), fever (13 cases, 8.7%), pneumonia (8 cases, 5.3%), kidney diseases and inguinal area complications (4 cases each, 2.7%), general weakness, hernia, herpes zoster, pericardial effusion, and transplant rejection (2 cases each, 1.3%), with 14 cases (9.3%) attributed to other causes

Table 1. The Characteristics of Patients Readmitted within 1 Year (*N*=81)

Characteristics	Categories	n (%)	M±SD Median (IQR)
Period from discharge to readmission (days)			83.17±88.19 44.00 (15.00~135.50)
Length of hospital stay during readmission (days)			18.05±23.24 13.00 (4.50~20.50)
Causes of readmission †	Cytomegalovirus infection	15 (10.0)	
	Gastrointestinal troubles ‡	14 (9.3)	
	Fever	13 (8.7)	
	Pneumonia	8 (5.3)	
	Kidney disease	4 (2.7)	
	Inguinal area complication	4 (2.7)	
	General weakness	2 (1.3)	
	Hernia	2 (1.3)	
	Herpes zoster	2 (1.3)	
	Pericardial effusion	2 (1.3)	
	Rejection	2 (1.3)	
	Other§	14 (9.3)	

IQR=interquartile range; M=mean; SD=standard deviation; † Multiple responses; ‡ Constipation, diarrhea, hematochezia, indigestion, nausea, vomiting, poor oral intake; § Anemia, below knee amputation, cough, drowsy mentality, dyspnea, hyperkalemia, left knee pain, oral ulcer, pancytopenia, paracentesis, perm catheter removal, tracheostomy seal up, skin rash, syncope, vocal cord palsy.

(Table 1). Survival curves were analyzed to estimate the one-year readmission rate for all heart transplant recipients, revealing that 50.0% were readmitted within 231 days (Figure 2).

2. Differences in General Characteristics between the Non-readmission and Readmission Groups

Table 2 shows the general characteristics of patients in both the non-readmission and readmission groups. The majority of patients in both groups were men, with a proportion of 66.0%. The median age was 53.00 years (IQR, 42.00~60.00 years). Only 17.3% of the individuals participated in regular exercise prior to their heart transplants. The percentage of patients who smoked before undergoing transplant surgery was 44.0%, while 45.3% had consumed alcohol prior to their surgery. In terms of education, university graduates made up 40.0% of the patients. Married individuals represented 69.3% of the sample, and a significant majority, 92.0%, reported no financial difficulties. There were no statistically significant differences in the general characteristics between the non-readmis-

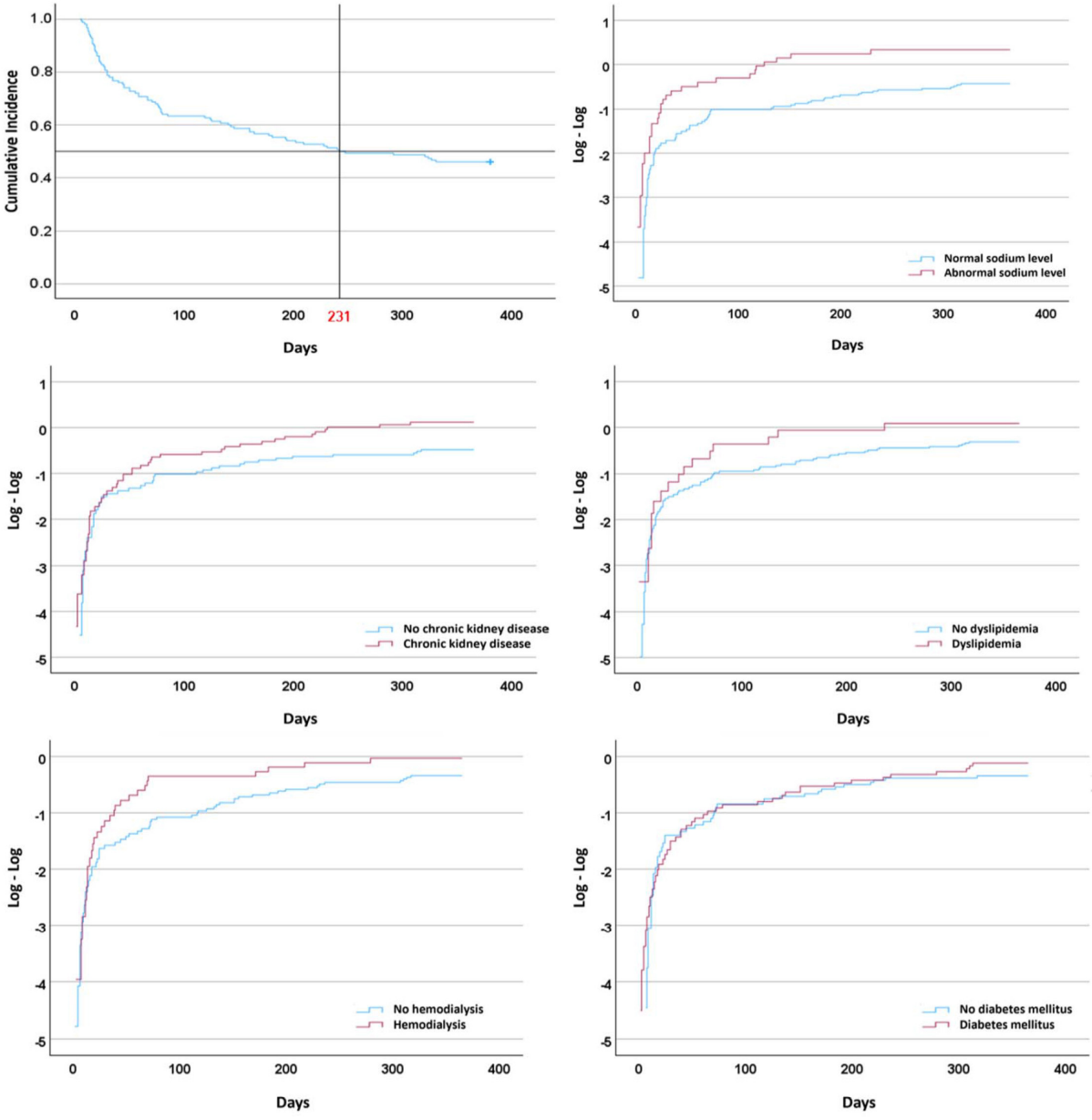

Figure 2. Survival time for readmission and log-log plots.

sion and readmission groups. Similarly, the Cox proportional hazard model revealed no statistically significant differences.

3. Differences in Clinical Characteristics between the Non-readmission and Readmission Groups

Table 2 presents the clinical characteristics of patients in the non-readmission and readmission groups. A comparison of the clinical characteristics between the two groups revealed that a higher percentage of patients in the readmission group had been in the ICU prior to surgery (25.9%) compared to the non-readmission group (13.0%) (x^2=3.87, p=.049). Additionally, a greater proportion of patients in the readmission group required hemodialysis after surgery (33.3%) than those in the non-readmission group (18.8%) (x^2=4.00, p=.045). Following the hematologic test conducted during the first outpatient visit, a higher percentage of patients in the readmission group exhibited abnormal sodium levels (32.1%) than in the non-readmission group (10.1%) (x^2=10.47, p=.001). Regarding comorbidities, the readmission group had a significantly higher proportion of individuals with diabetes (x^2=4.55, p=.033) and chronic kidney disease (x^2=10.60, p=.001), with each of these conditions affecting 50.6% of the readmission group (vs. 33.3% and 24.6% of the non-readmission group, respectively).

The simple analysis conducted using a Cox proportional hazard model based on the clinical characteristics is summarized in Table 2. Among clinical characteristics, a longer postoperative day (p=.016) and the performance of hemodialysis during admission after heart transplant surgery (p=.013) were associated with higher risks of readmission. Moreover, abnormal sodium levels on the first outpatient visit after discharge (p<.001) were correlated with a high risk for readmission. Among comorbidities, the presence of diabetes (p=.045), dyslipidemia (p=.040), and chronic kidney disease (p=.002) were found to correspond to a high risk of readmission.

4. Risk Factors for Readmission

To identify the risk factors for readmission among the participants, we selected variables that showed statistically significant differences in the sample analysis. These included the postoperative day, the performance of hemodialysis after surgery, sodium levels from outpatient tests, diabetes, dyslipidemia, and chronic kidney disease. The results of incorporating these predictor variables into the model are summarized in Table 3. The final model was statistically significant (x^2=31.90, p<.001). The analysis revealed the following risk ratios for time to readmission: the risk of readmission was 2.31 times higher (95% CI= 1.40~3.83) if the sodium level was abnormal (p<.001), and 1.67 times higher (95% CI=1.01~2.77) if the participant had chronic kidney disease (p=.045). Examination of the log-log plot to test the proportional hazards assumption showed no crossover of these variables (Figure 2).

DISCUSSION

This study aimed to assess the readmission status of heart transplant recipients by exploring the time until readmission and identifying risk factors. The ultimate objective was to lower readmission rates and establish a foundation for the care of heart transplant recipients in clinical practice.

An examination of readmission rates in this study showed that 54.0% of heart transplant recipients were readmitted within one year. This figure is higher than the 42.1% readmission rate previously reported in a Korea study [8] but lower than the 66.0% one-year readmission rate in the United States [9], which leads the world in the number of heart transplants performed. The higher readmission rate in this study may be attributed to the fact that only 30.2% of participants in the Korean study had comorbidities [8], compared to 79.3% in the current study, suggesting a greater severity of illness among our participants. Although the U.S. study did not provide a comprehensive percentage of comorbid conditions, it did report that 52.0% of patients had hypertension and 42.0% had kidney disease. These figures are higher than the 37.4% (hypertension) and 38.7% (kidney disease) observed in our study [9]. This disparity could explain the higher readmission rate noted in the U.S. study.

The most common reason for readmission was cytomegalovirus infection, followed by gastrointestinal troubles, fever, pneumonia, kidney diseases, and inguinal area complications. Infections accounted for a significant proportion of readmissions, a finding consistent with previous studies. International research has also indicated a high rate of readmission and mortality due to infections following heart transplants [10,17]. Infections are particularly dangerous for heart transplant recipients because they require high doses of immunosuppressants [2]. Therefore, comprehensive and systematic education upon discharge, along with nursing interventions, is essential for patients after heart transplants [18]. Gastrointestinal troubles were the second most common cause of readmission, accounting for 9.3% of cases. These issues are known side

Table 2. Comparisons of Characteristics between the Non-Readmission and Readmission Groups (*N*=150)

Variables	Categories	Total (n=150)	Non readmission (n=69)	Readmission (n=81)	x^2 or Z	*p*	HR (95% CI)	*p*
		n (%) or M (IQR)	n (%) or M (IQR)	n (%) or M (IQR)				
Sex	Male	99 (66.0)	47 (68.1)	52 (64.2)	0.25	.614	1.10 (0.70~1.74)	.676
	Female	51 (34.0)	22 (31.9)	29 (35.8)				
Age (year)		53.00 (42.00~60.00)	50.00 (38.50~59.00)	55.00 (44.00~61.00)	-1.66	.667	1.01 (0.10~1.03)	.084
BMI (kg/m²)		22.40 (20.60~25.58)	22.30 (20.60~25.25)	22.70 (20.60~26.15)	-0.43	.097	1.01 (0.96~1.07)	.729
Regular exercise	No	124 (82.7)	54 (78.3)	70 (86.4)	1.73	.188	0.70 (0.37~1.33)	.279
	Yes	26 (17.3)	15 (21.7)	11 (13.6)				
Smoking	No	84 (56.0)	34 (49.3)	50 (61.7)	2.35	.126	0.74 (0.47~1.16)	.184
	Yes	66 (44.0)	35 (50.7)	31 (38.3)				
Drinking	No	82 (54.7)	37 (53.6)	45 (55.6)	0.06	.813	0.93 (0.60~1.46)	.731
	Yes	68 (45.3)	32 (46.4)	36 (44.4)				
Education level (ref=≤middle)	≤Middle school	31 (10.7)	18 (26.1)	13 (16.0)	2.30	.317		
	High school	59 (39.3)	25 (36.2)	34 (42.0)			1.56 (0.82~2.96)	.173
	≥University	60 (40.0)	26 (37.7)	34 (42.0)			1.49 (0.79~2.83)	.220
Marital status	Unmarried	46 (30.7)	26 (37.7)	20 (24.7)	2.96	.086	1.45 (0.87~2.40)	.152
	Married	104 (69.3)	43 (62.3)	61 (75.3)				
Financial difficult	No	138 (92.0)	65 (94.2)	73 (90.1)	0.84	.359	1.45 (0.70~3.00)	.321
	Yes	12 (8.0)	4 (5.8)	8 (9.9)				
HOD		73.50 (52.75~110.50)	76.00 (58.00~107.00)	72.00 (52.00~128.00)	-0.13	.896	1.00 (1.00~1.00)	.438
POD		29.00 (23.00~46.00)	28.00 (22.00~42.50)	30.00 (23.50~51.00)	-1.32	.187	1.01 (1.00~1.01)	.016
Preoperative unit	ICU	30 (20.0)	9 (13.0)	21 (25.9)	3.87	.049	0.61 (0.37~1.01)	.055
	GW	120 (80.0)	60 (87.0)	60 (74.1)			0.69 (0.44~1.07)	.097
Cardiac rehabilitation	No	81 (54.0)	33 (47.8)	48 (59.3)	1.96	.161		
	Yes	69 (46.0)	36 (31.7)	33 (40.7)				
HD (post)	No	110 (73.3)	56 (81.2)	54 (66.7)	4.00	.045	1.81 (1.14~2.88)	.013
	Yes	40 (26.7)	13 (18.8)	27 (33.3)				
Creatinine (mg/dL)	Normal	76 (50.7)	40 (58.0)	36 (44.4)	2.73	.099	1.48 (0.96~2.30)	.078
	Abnormal	74 (49.3)	29 (42.0)	45 (55.6)				
BUN (mg/dL)	Normal	48 (32.0)	23 (33.3)	25 (30.9)	0.10	.747	1.14 (0.71~1.83)	.589
	Abnormal	102 (68.0)	46 (66.7)	56 (69.1)				
eGFR (mL/min)	Normal	123 (82.0)	61 (88.4)	62 (76.5)	3.55	.059	1.40 (0.90~2.16)	.136
	Abnormal	27 (18.0)	8 (11.6)	19 (23.5)				
Sodium (mmol/L)	Normal	117 (78.0)	62 (89.9)	55 (67.9)	10.47	.001	2.61 (1.63~4.19)	<.001
	Abnormal	33 (22.0)	7 (10.1)	26 (32.1)				
Co-morbidity	No	31 (20.7)	17 (24.6)	14 (17.3)	1.23	.268	1.39 (0.78~2.47)	.265
	Yes	119 (79.3)	52 (75.4)	67 (82.7)				
HTN	No	94 (62.7)	44 (63.8)	50 (61.7)	0.07	.797	1.15 (0.73~1.79)	.553
	Yes	56 (37.3)	25 (36.2)	31 (38.3)				
DM	No	86 (57.3)	46 (66.7)	40 (49.4)	4.55	.033	1.56 (1.01~2.41)	.045
	Yes	64 (42.7)	23 (33.3)	41 (50.6)				
Dys-lipidemia	No	129 (86.0)	63 (91.3)	66 (81.5)	2.99	.084	1.80 (1.03~3.17)	.040
	Yes	21 (14.0)	6 (8.7)	15 (18.5)				
CKD	No	92 (61.3)	52 (75.4)	40 (49.4)	10.60	.001	2.03 (1.31~3.14)	.002
	Yes	58 (38.7)	17 (24.6)	41 (50.6)				
CMV	No	138 (92.0)	63 (91.3)	75 (92.6)	0.08	.772	0.89 (0.39~2.04)	.775
	Yes	12 (8.0)	6 (8.7)	6 (7.4)				
TB	No	147 (98.0)	69 (100.0)	78 (96.3)		.250†	2.99 (0.94~9.55)	.064
	Yes	3 (2.0)	0 (0.0)	3 (3.7)				
CVA	No	142 (94.7)	64 (92.8)	78 (96.3)		.471†	0.62 (0.20~1.96)	.416
	Yes	8 (5.3)	5 (7.2)	3 (3.7)				

BMI=body mass index; BUN=blood urea nitrogen; CI=confidence interval; CKD=chronic kidney disease; CMV=cytomegalovirus; CVA=cerebrovascular accident; DM=diabetes mellitus; eGFR=estimated glomerular filtration rate; GW=general ward; HD=hemodialysis; HOD=hospital day; HR=hazard ratio; HTN=hypertension; ICU=intensive care unit; IQR=interquartile range; M=median; POD=postoperative day; SD=standard deviation; TB=tuberculosis; †Fisher's exact test.

Table 3. Risk Factors for Readmission (Cox Proportional Hazard Regression)

Variables	Categories	B	Adjusted HR	95% CI	*p*
Sodium (mmol/L)	Abnormal	.84	2.31	1.40~3.83	< .001
Chronic kidney disease	Yes	.52	1.67	1.01~2.77	.045
Dyslipidemia	Yes	.42	1.53	0.84~2.78	.164
Hemodialysis	Yes	.36	1.43	0.791~2.58	.238
Diabetes mellitus	Yes	.14	1.15	0.72~1.84	.557
Postoperative day		.00	1.00	0.99~1.01	.842
			x^2=31.90, p < .001		

CI=confidence interval; HR=hazard ratio.

effects of immunosuppressants and steroids [19]. Since a previous study reported that 2.8% of patients were readmitted due to gastrointestinal diseases [8], further investigations and interventions are necessary to address gastrointestinal problems in these patients. Although transplant rejection is often cited as a leading cause of readmission in existing literature [10,12,17], it was not a major factor in this study, representing only 1.3% of cases. This discrepancy may be due to transplant rejection being asymptomatic or presenting with various symptoms, leading to underreporting. Additionally, early diagnosis and treatment of transplant rejection through myocardial biopsy post-transplantation may have contributed to the lower readmission rates observed [2].

In this study, the survival analysis revealed that the median time to readmission for half of the heart transplant recipients was 231 days. This duration exceeds the 126-day survival period reported for heart transplant recipients who received discharge education from nurses in prior research. The difference in survival periods may be due to the previous study's primary focus on patients who were readmitted. Furthermore, the current study found that the median time to readmission for those who were readmitted was 44 days, closely aligning with the 43-day survival period for heart transplant recipients who underwent routine treatment, as reported in earlier literature [20]. Since an earlier study indicated that individuals who consistently received education from nurses after heart transplants had a longer time to readmission [20], the data from this study could serve as a basis for developing stage-specific care strategies for transplant surgery patients. Research on outcomes following solid organ transplants has demonstrated that the introduction of an interdisciplinary program, which provides continuous post-discharge care from the time of discharge, significantly enhances patients' self-management skills and knowledge regarding self-care, medications, diet, and physical activity [21]. Consequently, informed by the success of such programs in other solid organ transplant populations, strategies should be formulated to improve post-transplant self-care and reduce readmission rates among heart transplant recipients. These strategies should be tailored based on the critical period for intensive management identified in this study.

This study reported that extended postoperative day, postoperative hemodialysis, abnormal sodium levels at the first outpatient visit, chronic kidney disease, dyslipidemia, and diabetes were associated with an increased risk of readmission. Survival analysis based on these findings indicated that the highest risk of readmission was associated with abnormal sodium levels and chronic kidney disease. Similarly, previous research has shown that patients with deteriorated kidney function have a high rate of readmission. When examining the 30-day readmission status of heart transplant recipients, a high proportion of those readmitted had chronic kidney disease [12]. Another study investigating the readmission rate within one year post-transplant found that glomerular filtration rates, along with creatinine levels, significantly influenced readmission rates [8]. McCartney et al. [22] reported that 68.0% of patients experienced chronic kidney dysfunction within 10 years following heart transplant surgery, with 6.2% requiring dialysis and 3.7% undergoing kidney transplants. The high incidence of chronic kidney disease among heart transplant recipients within a decade post-surgery is attributed to pre-existing cardiac output issues affecting kidney function [22]. Additionally, the use of immunosuppressants can lead to chronic renal toxicity [23], resulting in many heart transplant recipients being admitted for acute kidney disease post-transplant [12]. The importance of kidney function management in heart transplant recipients has been underscored by both previous literature and this study. However, existing research on post-transplant nursing interventions has primarily focused on survival,

with an emphasis on managing infections and preventing transplant rejection, rather than extensively addressing kidney function management, including fluid balance and body fluid management [21,24-27]. With the improved survival rates and longer post-transplant survival periods for heart transplant recipients [1], there is a need to prioritize consistent health management that considers the comorbidities of these patients [28,29]. Moreover, the risk of infection and complications increases when heart transplant recipients require dialysis [30], which is directly related to their readmission and mortality rates. Therefore, it is important to develop nursing intervention plans for heart transplant recipients that focus on kidney function management. These plans should include dietary restrictions, such as limiting high-fat and high-carbohydrate foods and maintaining a low-sodium diet [2], to preserve kidney function and manage electrolyte levels post-surgery. Additionally, monitoring high-risk indicators that significantly impact readmission in clinical practice where various types of data, including vital signs, hematologic test results, and imaging test results, are continuously observed can greatly assist in various tasks [31]. By screening and monitoring high-risk patients through these indicators, healthcare providers can assess patients' health status and prevent readmission.

Cardiac rehabilitation, which was reported as a significant risk factor for readmission in a previous study [9], was not identified as a significant variable in this study. This discrepancy may be due to the fact that many heart transplant recipients, particularly those who underwent surgery before health insurance coverage was extended in February 2017, did not participate in rehabilitation programs [32]. Furthermore, the analysis did not differentiate between patients who participated in rehabilitation before surgery and those who did so afterward, owing to the nature of the secondary data collection. Additionally, while left ventricular assist devices are recognized as significantly impacting the prognosis of heart transplant patients [33], the number of patients at this institution who received heart transplants following left ventricular assist device surgery was too low to be included in the analysis. As the frequency of left ventricular assist device surgery is anticipated to increase, future research should consider left ventricular assist devices as an additional variable and include a larger cohort of patients.

This study has the following limitations. First, as the research was carried out at a single institution, the findings may be influenced by the specific characteristics of that institution. Consequently, there are limitations to applying these results to the broader population of heart transplant recipients in Korea. Second, the study was based on a secondary data analysis, which did not include the psychological and social aspects of the recipients. The analysis was therefore conducted with a restricted dataset. Given that heart transplant recipients have been reported to experience psychological and social instability [34], and that depression developing within the first year can impact their survival rate [35], future studies should incorporate these variables. Despite these limitations, the study is significant as it investigates the risk factors for readmission and the timing of readmission among heart transplant recipients in Korea. It also suggests directions for subsequent research and the development of interventions for this patient group. Moving forward, it is imperative to conduct repeated studies with heart transplant recipients from multiple centers across Korea, including psychological and social variables, to broaden the applicability of the findings and to formulate theories related to the self-care of heart transplant recipients.

CONCLUSION

Through this study, we explored the readmission status of the subjects, the time until readmission, and the risk factors for readmission. The findings can inform the development of practical clinical guidelines for the care of heart transplant recipients. Additionally, they can provide a foundation for creating educational materials and interventions for these patients in the future. By identifying individuals at high risk for readmission, we may be able to decrease the costs associated with readmission and use this information as a performance indicator for readmission reduction efforts. Early identification of high-risk individuals, based on our research, followed by appropriate nursing interventions, could help lower the readmission rate. This, in turn, could enhance the survival rates of the participants and ultimately improve their health-related quality of life.

CONFLICTS OF INTEREST

The authors declared no conflict of interest.

AUTHORSHIP

Study conception and design acquisition - JDE & JYS; Data collection - JDE; Analysis and interpretation of the data - JDE; Drafting and critical revision of the manuscript - JDE & JYS.

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