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Correlation Between the Distance From Donors and Ischemic Time in Heart Transplantation of Korea and Its Clinical Impact

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ABSTRACT

Background: The heart donor allocation system in South Korea is divided into three regions, with priority given to recipients within the same region over those in other regions of the same tier. It is commonly believed that heart transplantation (HT) within the same region can reduce ischemic time (IT), although its clinical impact remains unclear. The purpose of this study is to compare the characteristics and outcomes of intra-region HT and inter-region HT.
Methods: From 2014 to 2022, a total of 115 adult patients underwent isolated HT at a tertiary hospital. Of these, 58 recipients (54.5 ± 10.3 years, female, 36.2%) underwent intra-region HT and 57 recipients (53.9 ± 14.1 years, female, 31.6%) underwent inter-region HT. Extracorporeal membrane oxygenation-bridged HTs accounted for 50.0% and 54.4% of cases, respectively ($P = 0.638$). There were no differences in preoperative characteristics between the two groups.
Results: The median inter-hospital distance (38.0 [32.0–112.0] km vs. 351.0 [300.0–390.5] km, $P < 0.001$) and total IT (153 [123–170] minute vs. 265 [243–298] minute, $P < 0.001$) were longer in the inter-region group than intra-region group. Despite these differences, both groups showed similar clinical outcomes. The 30-day mortality rates were 5.2% and 5.3% ($P < 0.99$), respectively. There were no differences in postoperative cardiac index, early adverse outcomes, or long-term survival between the two groups. The inter-hospital distance and cold IT showed a strong positive correlation (time [minute] = 39.462 + 0.410 × distance [km]).
Conclusion: Despite the difference in IT, there was no difference in postoperative outcomes between the two groups. Based on these findings, the effect of donor location on the outcomes of HT in South Korea is not considered significant.

Keywords: Heart Transplantation; Transplant Donor Site; Ischemic Time; Korea

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INTRODUCTION

The heart is a sensitive organ to ischemic time (IT) compared to other transplant organs, and it is known to be important to reduce IT to secure a good prognosis for heart transplantation (HT).[1] The International Society for Heart and Lung Transplantation (ISHLT) has reported that cold IT exceeding 4 hours or total IT exceeding 6 hours increases adverse events in HT.[2] In addition, several studies have reported that an increase in IT is associated with an increase in primary graft dysfunction (PGD) occurrence rate and mortality rate.[3-5] Based on these results, several studies have defined donors with cold IT of over 4 hours as marginal donors.[6-8]

The increase in distance between the donor and the recipient is inevitably associated with an increase in IT.[9,10] Recently, in order to overcome this issue, new equipment (Organ Care System; TransMedics, Andover, MA, USA) has been introduced,[11] but their use is difficult in many countries due to high costs and regulatory issues. The use of specialized transportation such as airplanes or helicopters can help reduce transport time, but resource availability varies by country, and there are limitations due to factors such as weather and terrain. Some countries have implemented a system of dividing transplantation areas into specific regions, with the aim of reducing IT by allocating organs within a certain geographic radius.[12,13]

In 2018, the donor heart allocation system was revised in South Korea. Although there were no changes to the regional boundaries compared to before, several details in priority allocation were revised. Under the previous criteria, the classification based on distance was more detailed (e.g., same hospital, same city), but with the revised criteria, the classification was simplified into only three regions, thereby increasing the influence within the same region. According to the revised criteria, within the same tier, priority for allocation is given to recipients in the same region as the donor over those in other regions. Although such a system appears reasonable in South Korea, there are several underlying issues that need to be addressed. Firstly, there is a potential mismatch in the occurrence of donors and recipients based on geographical regions, which can result in certain regions facing disadvantages in donor allocation. Additionally, in specific cases, it is possible for recipients in geographically distant areas to be given priority.

Actually, HT in South Korea has several distinct characteristics that set it apart from other countries. Firstly, a significant number of medical infrastructure and facilities are concentrated in the Seoul metropolitan area, resulting in over 50% of donors originating from this capital region. Additionally, nearly 70% of HT were performed within the metropolitan area. Secondly, the application of Left Ventricular Assist Device (LVAD) is limited to patients who have undergone at least two months of advanced heart failure treatment, leading to Extracorporeal membrane oxygenation-bridged (ECMO) bridged HT accounting for over 40% of whole HT. Due to the challenges in obtaining LVAD approval for many unrecoverable acute heart failure patients, HT becomes the crucial or sole treatment option in practical terms. In such circumstances, HT becomes highly important or even the only treatment option for acute heart failure patients in non-metropolitan areas, highlighting the increased significance of an efficient donor allocation system.

We conducted this study as the transplantation center located furthest away the Seoul metropolitan area, aiming to investigate the impact of distance between the recipient and donor hospitals on IT, and to understand the clinical implications of such differences.

METHODS

Study design and subjects

This retrospective observational study included patients (n = 137) who underwent HT at a single tertiary center between June 2014 and July 2022. Patients under the age of 18 (n = 13) and those who received multiple organ transplantations (n = 9) were excluded from the study. Ultimately, 115 patients were included in the final analysis. Of these, 58 patients (intra-regional HT, 50.4%) received a donor heart from the same region, while 57 patients (inter-regional HT, 49.6%) were transplanted with donor hearts transported from different regions (**Fig. 1**).

The primary endpoints were mortality and PGD, with PGD defined as any instance of moderate or higher left or right ventricular dysfunction occurring within the first 24 hours, in accordance with the guidelines established by the ISHLT during their 2014 meeting.[3] The distance was not measured as the straight-line distance between hospitals, but as the actual travel distance by ambulance. The measurement was conducted using two commercial navigation programs, and the shortest possible route was reflected.

Transportation strategy of donor heart and implantation technique

Following the revision of the allocation system in 2018, South Korea has been divided into three regions for the allocation of donor hearts. The urgency of cases is categorized into four levels, and to minimize transportation time, priority is given to recipients in the same region as the donor among patients of the same priority. The use of private jets or planes for transportation is exceedingly rare in South Korea's infrastructure. Most transports are conducted via ground routes using high-speed trains or ambulances, depending on the distance. In this study, excluding donor hearts originating from within the same hospital, 100% of intra-regional HT were transported by ambulance. For inter-regional HT, the modes of transportation were distributed as follows: trains (40.4%), planes (22.8%), helicopters (1.8%), and ambulances (35.1%). or train and plane transports, ambulances were used to move to and from stations and airports, respectively, while helicopters directly transported to the hospital's landing site. Despite longer distances, ambulances were utilized when planes or trains were not available due to timing constraints. During transport, iceboxes containing

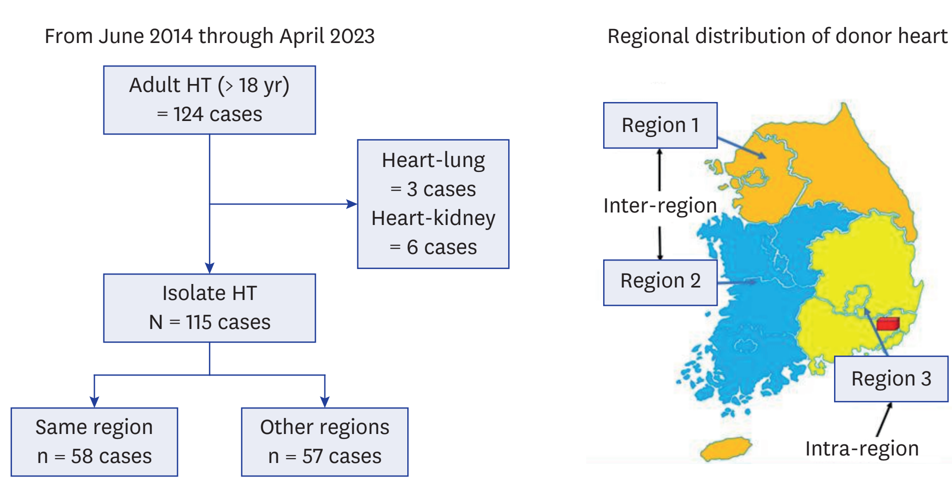

Fig. 1. Inclusion criteria and regional allocation of heart transplants in South Korea. Red rectangle: the location of our institution.
HT = heart transplantation.

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ice were employed, and a closely coordinated system was in place to minimize IT, with all efforts directed towards reducing the duration of transportation.

The detailed transport strategy and surgical technique have been described in detail in previous studies.[14,15] Briefly, regarding the implantation technique, the bicaval technique was primarily used for the anastomosis. The left atrium was anastomosed first, followed by the inferior vena cava, pulmonary artery, and aorta, in that order. After releasing the aortic clamp, the superior vena cava was connected. In cases where the cold IT was excessively long, perfusion was occasionally initiated after connecting the aorta prior to the pulmonary artery anastomosis. However, in most cases, the aforementioned standard procedure was followed.

Statistical analysis

Variables were summarized by frequency and percentage for categorical data and mean ± standard deviation and median (interquartile range) for numeric data. Group differences were tested using the χ^2 test or Fisher's exact for categorical data and independent *t*-test or Mann-Whitney *U* test for numeric data as appropriate. To check if its distribution is normal, we used Shapiro-Wilk's test. Overall survival was estimated using Kaplan-Meier curve. Survival curves were compared between groups using the log-rank test. Cox proportional hazard regression analysis was applied to investigate the influence of Inter-region on long-term survival. Considering the nature of the repeated measured data of echocardiography and cardiac index (CI), a generalized linear mixed model (GLMM) with random intercepts was used to fit a model. The GLMM model included repeated measures of numeric variables as dependent variables; group, time, and group × time interaction as fixed effects; and subject as a random effect. To avoid making any assumptions about the covariance structure, we used an unstructured covariance matrix that was allowed to differ across groups for the GLMM analysis.

To estimate the linear relationship between distance and time, we estimated linear regression line. Scatter plot with the fitted line was graphed for data visualization. Univariate and multivariate logistic regression analysis were performed to identify prognostic factors which are independently related to post-operative outcomes. Firth's penalized maximum likelihood bias reduction method for logistic regression which has been shown to provide a solution in case of monotone likelihood (nonconvergence of likelihood function) was employed (Heinze and Schemper [2002]). All statistical analyses were carried out using SPSS 26.0 statistical software (IBM SPSS Statistics for Windows, version 26.0, released 2019; IBM Corp., Armonk, NY, USA), R statistical software (version 3.4.0; R Foundation, Vienna, Austria, http://www.r-project.org/) and MedCalc® Statistical Software version 20.009 (MedCalc Software Ltd., Ostend, Belgium, https://www.medcalc.org, 2021). The *P* values less than 0.05 were considered statistically significant.

Ethics statement

Patient data collection was conducted through the analysis of a surgical database and electronic charts. The research received approval from the Institutional Review Board (IRB) at Pusan National University Yangsan Hospital (IRB approval No. 05-2020-035). Due to the study's retrospective design, the need for informed consent was waved.

RESULTS

Preoperative characteristics

The age and gender of the recipients did not differ between the two groups. In the case of dilated cardiomyopathy, the proportions were higher in the intra-region group, but this difference was not significant. In both groups, direct ECMO bridged to HT was more than 50%, and the last preoperative left ventricular ejection fraction (LVEF) was higher in the intra-region group. The difference in the number of patients classified as Status 0 and those receiving ECMO support is due to the inclusion of patients on awakening ECMO prior to the allocation revision. Before the revision, ECMO support without mechanical ventilation was categorized as Status 1. There were no other significant differences in recipient profiles between the two groups (**Table 1**).

In the case of donors, there was no difference in age between the two groups, but there were more male donors in the intra-region group. The median distance from the donor hospital was greater for the inter-region group at 371 km compared to 38 km for the intra-group, which also resulted in a significantly longer cold ischemic time (CIT). There was no difference in warm IT or recipient cardiopulmonary bypass time between the two groups. Except for 8 cases of in-hospital donors in the intra-region group, 100% of donor hearts were transported by ambulance, whereas about two-thirds of cases in the inter-region group required additional routes of transportation (**Table 1**).

Perioperative clinical outcomes and long-term outcomes

Within 30 days after transplantation, mortality occurred in 6 patients, with each group recording 3 deaths, showing no statistical difference. PGD was observed in 14.8% of cases, with no difference between the groups. The requirement for venoarterial ECMO post-surgery was reported at 12.1% and 12.3% in each group, respectively, and veno-venous ECMO was needed in 6.9% and 7.0% of cases, respectively. The need for ventilator support for more than 24 hours post-surgery was significantly higher in the inter-region group. Other adverse outcomes, including the duration of ICU stay, showed no significant difference between the groups. Details on other perioperative profiles were described in **Table 2**.

At 18 hours post-surgery, the CI was higher in the intra-region group; however, excluding this, there were no differences in the CI within 72 hours or the vasoactive inotropic score at 24 hours post-surgery between the two groups (**Table 2**).

The 1-year survival rate of transplant recipients was 91.3% and 83%, respectively, with no statistical difference between the groups. During the follow-up period, most mortality events occurred within the first year, with almost no deaths occurring after the first-year post-surgery among the study subjects (**Fig. 2**). In the risk analysis for 1-year survival, preoperative dialysis was not significant but approached the threshold of significance ($P = 0.054$), while preoperative ECMO showed a trend but did not reach significance ($P = 0.068$) (**Supplementary Table 1**). All surviving patients were followed up at our institution, and there was no difference in the average LVEF within 10 years between the two groups (**Supplementary Fig. 1**).

Correlation between distance from the donor and CIT

Among a total of 115 cases, there were 8 in-hospital donors, with an average CIT of 17.5 minutes. The overall CIT showed a strong positive correlation with distance (CIT [minute] = 39.462 + 0.410 × Distance [km]). Ambulance was used exclusively in 60.9% of the cases,

Table 1. Preoperative characteristics

Variables	Overall (N = 115)	Group		*P* value
		Intra-region (n = 58)	Inter-region (n = 57)	
Recipient profiles				
Age, yr	54.5 ± 12.3	55.0 ± 10.3	53.9 ± 14.1	0.958
Male	76 (66.1)	37 (63.8)	39 (68.4)	0.600
Height, cm	165.3 ± 9.1	166.0 ± 9.8	164.6 ± 8.5	0.412
Weight, kg	62.6 ± 11.7	63.9 ± 12.0	61.3 ± 11.3	0.234
Blood type				0.061
A+	40 (34.8)	14 (24.1)	26 (45.6)	
AB+	24 (20.9)	13 (22.4)	11 (19.3)	
B+	28 (24.3)	19 (32.8)	9 (15.8)	
O+	23 (20.0)	12 (20.7)	11 (19.3)	
Dilated cardiomyopathy	52 (45.2)	31 (53.4)	21 (36.8)	0.074
Diabetes mellitus	37 (32.2)	16 (27.6)	21 (36.8)	0.288
Hypertension	23 (20.0)	11 (19.0)	12 (21.1)	0.780
Prior CVA	8 (7.0)	4 (6.9)	4 (7.0)	< 0.999
Hemodialysis	22 (19.1)	11 (19.0)	11 (19.3)	0.964
Prior cardiac surgery	24 (20.9)	11 (19.0)	13 (22.8)	0.612
ECMO support	60 (52.2)	29 (50.0)	31 (54.4)	0.638
LVAD implantation	3 (2.6)	3 (5.2)	0	0.243
Mechanical ventilation	38 (33.0)	15 (25.9)	23 (40.4)	0.099
ICU admission	70 (60.9)	32 (55.2)	38 (66.7)	0.207
Preoperative LVEF, %	24.8 ± 9.6	27.3 ± 10.3	22.4 ± 8.2	0.013
Donor profiles				
Age, yr	40.7 ± 12.9	41.6 ± 12.6	39.8 ± 13.2	0.447
Male	81 (70.4)	46 (79.3)	35 (61.4)	0.035
Height, cm	168.5 ± 8.1	168.6 ± 7.6	168.4 ± 8.6	0.730
Weight, kg	70.2 ± 13.8	70.7 ± 11.0	69.6 ± 16.3	0.252
Blood type				0.327
A+	42 (36.5)	17 (29.3)	25 (43.9)	
AB+	8 (7.0)	5 (8.6)	3 (5.3)	
B+	30 (26.1)	17 (29.3)	13 (22.8)	
O+	35 (30.4)	19 (32.8)	16 (28.1)	
LVEF, %	58.9 ± 7.9	59.1 ± 6.5	58.6 ± 9.2	0.913
Distance to recipient	191.0 (38.0–371.0)	38.0 (32.0–112.0)	371.0 (300.0–390.5)	< 0.001
Allocation region				< 0.001
Region 1	42 (36.5)	0 (0.0)	42 (73.7)	
Region 2	15 (13.0)	0 (0.0)	15 (26.3)	
Region 3	58 (50.4)	58 (100.0)	0 (0.0)	
Transportation type				< 0.001
In hospital donor	8 (7.0)	8 (13.8)	0 (0.0)	
Ambulance only	70 (60.9)	50 (86.2)	20 (35.1)	
Ambulance + train	23 (20.0)	0 (0.0)	23 (40.4)	
Ambulance + airplane	13 (11.3)	0 (0.0)	13 (22.8)	
Helicopter	1 (0.9)	0 (0.0)	1 (1.8)	
Cold ischemic time, min	118.0 (68.0–184.0)	70.0 (49.0–80.5)	184.0 (160.0–207.5)	< 0.001
Total ischemic time, min	213.0 (153.0–267.0)	153.0 (123.0–169.8)	265.0 (243.5–298.0)	< 0.001
Cardiopulmonary bypass time, min	153.4 ± 43.9	147.2 ± 30.1	159.7 ± 54.1	0.538

Values are presented as number (%), mean ± standard deviation, or median (interquartile range).
CVA = cerebrovascular accident, ECMO = extracorporeal membrane oxygenation, LVAD = left ventricular assist device, ICU = intensive care unit, LVEF = left ventricular ejection fraction.

and the correlation formula was (CIT [minute] = 42.815 + 0.419 × Distance [km]). A strong positive correlation with distance was confirmed when ambulances were used alone or in combination with trains, but the positive correlation with distance was not clear when airplanes were utilized (**Fig. 3**).

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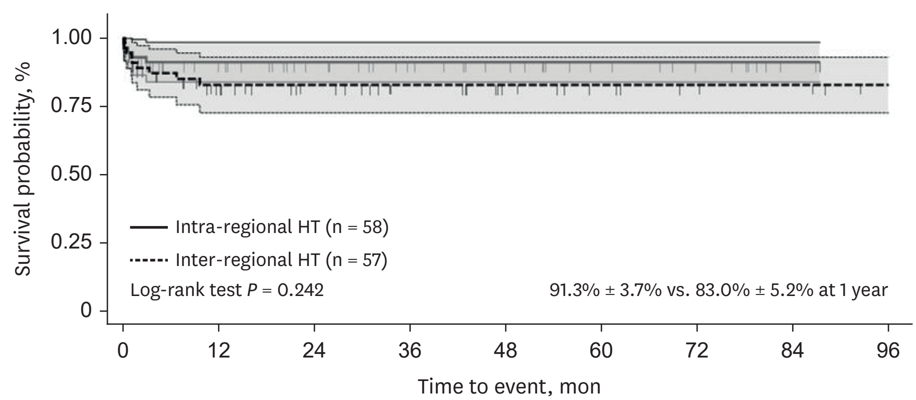
Table 2. Perioperative clinical outcomes

Variables	Overall (N = 115)	Group		*P* value
		Intra-region (n = 58)	Inter-region (n = 57)	
Duration of ICU	246.5 ± 303.9	211.4 ± 178.7	281.6 ± 389.8	0.330
Postoperative ECMO support				> 0.999
VA ECMO	14 (12.2)	7 (12.1)	7 (12.3)	
VV ECMO	8 (7.0)	4 (6.9)	4 (7.0)	
PGD	17 (14.8)	9 (15.5)	8 (14.0)	0.823
VIS at ICU arrival	25.2 ± 19.9	24.4 ± 22.3	25.9 ± 17.5	0.258
VIS after 6 hr	21.4 ± 15.8	20.3 ± 17.6	22.4 ± 14.1	0.146
Peak VIS within 24 hr	34.9 ± 24.2	34.3 ± 25.0	35.6 ± 23.6	0.473
Prolonged MV > 24 hr	41 (35.7)	15 (25.9)	26 (45.6)	0.027
Pneumonia	7 (6.1)	1 (1.7)	6 (10.5)	0.061
New on set dialysis	20 (17.4)	8 (13.8)	12 (21.1)	0.304
Postoperative CVA	2 (1.7)	2 (3.4)	0 (0.0)	0.496
Reoperation for bleeding control	16 (13.9)	7 (12.1)	9 (15.8)	0.564
Mortality within 30 days	6 (5.2)	3 (5.2)	3 (5.3)	> 0.999

ICU = intensive care unit, ECMO = extracorporeal membrane oxygenation, VA = venoarterial, VV = veno-venous, PGD = primary graft dysfunction, VIS = vasoactive inotropic score, MV = mechanical ventilation, CVA = cerebrovascular accident.



No. at risk									
——	58	41	32	24	19	12	8	2	0
------	57	34	26	19	13	9	6	5	2

Fig. 2. Long-term survival analysis between two groups.
HT = heart transplantation.

Clinical impacts of distance from donor in HT

In the risk factor analysis, long distance (inter-region group) was not identified as a risk factor for early mortality, PGD, or long-term mortality. Furthermore, even when analyzed as subgroups, regions 1 and 2, compared to intra-region (region 3), were not significant risk factors for early mortality, PGD, or long-term mortality (**Table 3**).

DISCUSSION

In the present study, we examined the correlation between the distance from the donor hospital and IT in HT and compared the clinical outcomes according to the distance within allocation regions. Inter-region HT were, on average, over 300 km further away compared to intra-region HT, requiring about 2 additional hours of transport time. Despite this, clinical outcomes including 30-day mortality, perioperative outcomes, and long-term survival rates,

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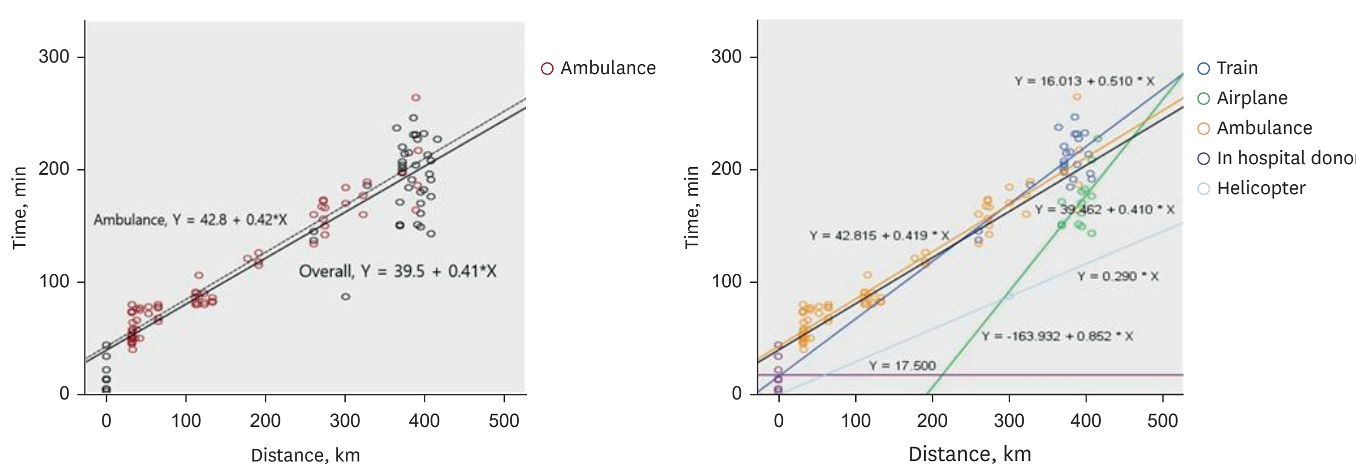
Table 3. Analysis of PGD incidence and mortality risk by regions

Variables	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Early mortality				
Intra-region vs. Inter-regions	1.02 (0.20–5.27)	0.983		
Intra-region vs. Region 1	1.41 (0.00–1.94)	0.665	-	-
Intra-region vs. Region 2	0.51 (0.00–1.74)	0.638	-	-
PGD				
Intra-region vs. Inter-regions	0.89 (0.32–2.49)	0.823		
Intra-region vs. Region 1	0.74 (0.23–2.38)	0.608	-	-
Intra-region vs. Region 2	1.36 (0.32–5.81)	0.677	-	-
Long-term mortality				
Intra-region vs. Inter-regions	1.90 (0.64–5.67)	0.250		
Intra-region vs. Region 1	1.77 (0.50–6.23)	0.376	-	-
Intra-region vs. Region 2	2.65 (0.56–12.64)	0.222	-	-

OR = odds ratio, CI = confidence interval, PGD = primary graft dysfunction.

showed no significant differences. In South Korea, despite the relatively long ITs, inter-region HT also demonstrated comparable outcomes to those of intra-region HT.

It is well established that an increase in IT during HT is associated with poor outcomes.[16-18] However, there are paucity of studies focusing on the correlation between distance and IT, as well as their clinical effects. Lechiancole and colleagues[19] examined 471 patients who underwent HT, showed that an increase in distance was associated with an increase in IT, but did not demonstrate significant clinical differences. The authors mentioned that the distance from the transplantation center does not serve as a barrier to the progress of transplantation. Crawford and colleagues[20] reported that despite the prolonged IT associated with increasing donor distance, both 30-day and 1-year survival rates paradoxically increased. They mentioned that hidden factors might have contributed to this phenomenon, noting



· Correlation between distance and cold ischemic time based on mode of transportation

Transportation	Number	Fitted regression line	*P* value
Overall	115	Y = 39.462 + 0.410*X	< 0.001
Ambulance	70	Y = 42.815 + 0.419*X	< 0.001
Train	23	Y = 16.013 + 0.510*X	< 0.001
Airplane	13	Y = −163.932 + 0.852*X	0.55
Same hospital	8	Y = 17.500	-
Helicopter	1	Y = 0.290*X	-

X = Distance, km
Y = Cold ischemic time, min

Fig. 3. Relationship between distance and transport time, and the derived formula.

that the association between lower volume transplant centers and increased post-transplant complications and decreased survival rates could be one of the causes.[20] In our study, despite an increase in average IT by more than 2 hours in inter-region HT cases, it was observed that neither the 30-day mortality rate nor long-term mortality rates were increased. This suggests that despite the increase of IT in inter-region HT, the relatively short average cold IT of approximately 3 hours might have mitigated significant clinical impacts.

As HT becomes more common worldwide, efforts to reduce IT continue. In some advanced countries, dedicated aircraft are operated, or new technological devices like the Organ Care System are utilized to reduce IT. However, many countries still rely on ground transportation for donor heart transport due to geographical and financial reasons similar to those of South Korea. To our knowledge, this study, although based on data from a hospital located in a provincial city in South Korea, is the first to provide empirical evidence of changes in actual transport times with increasing distance. While ground transportation conditions may vary from country to country, if we assume that ambulances are used in most countries, the formula: Time (minute) = 42.8 + 0.419 × Distance (km) could be helpful in calculating specific transport times. For other modes of transport, the situation varies too much from country to country to apply universally.

The shortage of donor hearts is already a common phenomenon in almost every country. Despite the shortage of donor hearts, a significant number of donated hearts are discarded due to being classified as marginal donors. Especially, the long distances between centers are considered akin to a guarantee of extended ITs and are recognized as a risk factor. According to this study, distances within 400 km can be transported on the ground within 4 hours, and it has been shown that this does not increase clinical adverse events. We believe that, in countries with relatively short transportation distances like South Korea, geographical limitations do not pose a problem for the progression of HT.

Additionally, we believe that our results could be helpful for countries with relatively long ground transportation distances when dividing regions for efficient donor heart allocation.

However, this study has some limitations. Primarily, it cannot exclude the potential for selection bias inherent in retrospective observational studies. Additionally, since the prognosis of recipients is most significantly influenced by the recipients' preoperative status, many confounding variables exist that make it difficult for distance alone to explain the outcomes of the subjects. Furthermore, the paper is based on the experience of a single center in a provincial area of South Korea, and the relatively small number of subjects makes it difficult to generalize and apply the findings broadly. Despite these limitations, all data on the subjects were collected in a relatively detailed and accurate manner, and all patients were fully followed up, providing high-quality information for analysis. Moreover, while it is challenging to completely eliminate selection bias between the two groups, it was considered unnecessary to make further adjustments as the preoperative profiles of both groups were well-balanced before correction.

The conclusion of this study, which states that there is no significant difference HT outcomes based on the distance between hospitals within South Korea, does not mean that IT is unimportant. We still believe that IT remains one of the critical factors in HT and every effort to minimize transport time should always be maintained. However, in a country like South Korea, where transport distances are relatively short, long distances between hospitals may not necessarily be a decisive factor in proceeding with the transplant. Similar to some of the previously mentioned studies,[19,20] we want to emphasize that even if the distance is relatively long, if the best efforts are made to minimize transport time, the impact of transport distance on clinical outcomes could be minimal within the tolerable range of IT.

As the distance from the donor center increases, the transport time shows a strong positive correlation with the increase. Despite this, inter-region HT within South Korea demonstrates comparable clinical outcomes to intra-region HT. Especially, it has been shown that donor hearts from farther distances do not become risk factors for early and late mortality or postoperative PGD. We believe that the location of the donor center does not become an obstacle to the progression of HT in South Korea.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Risk factor analysis for 1 year mortality

Supplementary Fig. 1

Comparison of changes in the cardiac index and left ventricular ejection fraction in the two groups

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