



Role of Helicopter Transfer and Cloud-Type Imaging for Acute Type A Aortic Dissection

Natsuya Ishikawa¹ Masahiko Narita¹ Tomonori Shirasaka¹ Ryouhei Ushioda¹ Masahiro Tsutsui¹
Nobuyoshi Azuma² Hiroyuki Kamiya¹

¹ Department of Cardiac Surgery, Asahikawa Medical University, Asahikawa, Hokkaido, Japan

² Department of Vascular Surgery, Asahikawa Medical University, Asahikawa, Hokkaido, Japan

Address for correspondence Masahiko Narita, MD, Department of Cardiac Surgery, Asahikawa Medical University, Midorigaoka Higashi 2-1-1, Asahikawa, Hokkaido 078-8510, Japan
(e-mail: m.s.e.narita@hotmail.com).

Thorac Cardiovasc Surg 2024;72:105–117.

Abstract

Background This study explored if long-distance transfer was safe for patients suffering from acute aortic dissection type A (AADA) and also analyzed the effectiveness of helicopter transfer and cloud-type imaging transfer systems for such patients in northern Hokkaido, Japan.

Methods and Results The study included 112 consecutive patients who underwent emergency surgical treatment for AADA from April 2014 to September 2020. The patients were divided into two groups according to the location of referral source hospitals: the Asahikawa city group (group A, $n = 49$) and the out-of-the-city group (group O, $n = 63$). Use of helicopter transfer ($n = 13$) and cloud-type telemedicine ($n = 20$) in group O were reviewed as subanalyses.

Transfer distance differed between groups (4.2 ± 3.5 km in group A vs 107.3 ± 69.2 km in group O; $p = 0.0001$), but 30-day mortality (10.2% in group A vs 7.9% in group O; $p = 0.676$) and hospital mortality (12.2% in group A vs 9.5% in group O; $p = 0.687$) did not differ. Operative outcomes did not differ with or without helicopter and cloud-type telemedicine, but diagnosis-to-operation time was shorter with helicopter (240.0 ± 70.8 vs 320.0 ± 78.5 minutes; $p = 0.031$) and telemedicine (242.0 ± 75.2 vs 319.0 ± 83.8 minutes; $p = 0.007$).

Conclusion We found that long-distance transfer did not impair surgical outcomes in AADA patients, and both helicopter transfer and cloud-type telemedicine system could contribute to the reduction of diagnosis-to-operation time in the large Hokkaido area. Further studies are mandatory to investigate if both the systems will improve clinical outcomes.

Keywords

- ▶ acute aortic dissection type A
- ▶ long-distance transfer
- ▶ helicopter
- ▶ telemedicine

Introduction

Acute aortic dissection type A (AADA) is a fatal disease that requires emergency surgery. The risk of death is estimated at 0.5 to 2% an hour, and nonoperative treatment is associated with

mortality in nearly 23 to 60% of patients.^{1,2} Therefore, the theoretically desirable onset-to-operation time should be as short as possible. To date, there have been several attempts to shorten the transfer time to a cardiovascular operating unit. One of the famous models is the Tokyo Acute Aortic Super-

received

July 26, 2022

accepted after revision

January 30, 2023

accepted manuscript online

February 9, 2023

article published online

March 20, 2023

DOI <https://doi.org/10.1055/a-2031-3763>.

ISSN 0171-6425.

© 2023. The Author(s).

This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or adapted, remixed, transformed or built upon. (<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

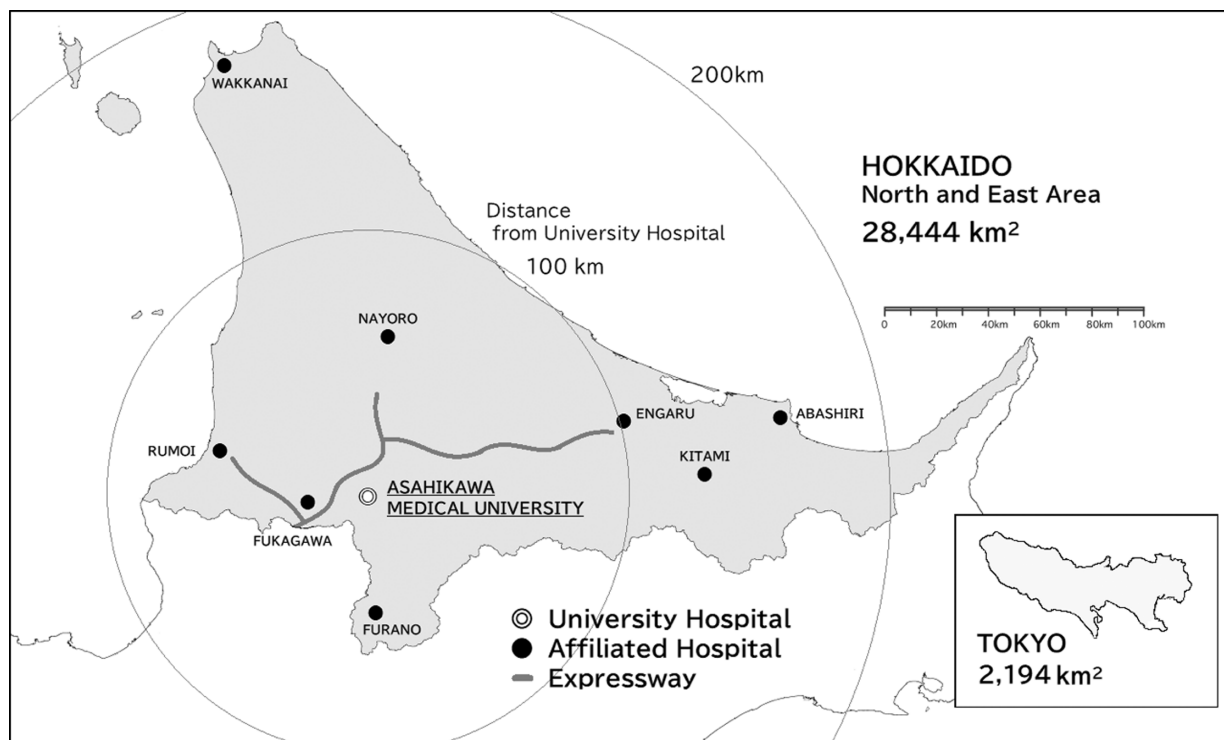


Fig. 1 Schematic demonstration of medical areas covered by our institute. Note: The northern Hokkaido area and the Okhotsk coast area were covered by our institute. The area is ~12 times larger than Tokyo, and expressways are partially established as yet.

network (TAAS).³ TAAS was established in 2010 and covers ~70 participating hospitals. It covers the entire metropolitan area of Tokyo with a population of 13 million with the help of ambulance units under the control of the Tokyo Fire Department.

However, Tokyo has a very small but high population density area, and the transfer distance is therefore quite limited, resulting in a short transfer time. However, long-distance transfer of patients suffering from AADA is sometimes unavoidable in local, large, and low population density areas, such as our location in northern Hokkaido, Japan. Our medical area consists of ~650,000 people, and the size of the area is 18,000 km², or 12 times larger than Tokyo (→Fig. 1). Consequently, long-distance transfer of AADA patients is common at our institute.

To overcome the geographic disadvantages, we applied two actions: to shorten the transfer time, a doctor helicopter system was made available since 2009; and to shorten the onset-to-operation time, a cloud-type telemedicine image transfer system has been available since 2016. However, it was still unknown whether such attempts were effective in reducing operative mortality among patients with AADA.

Therefore, this study aimed to (1) demonstrate operative outcomes in patients requiring long-distance transfer and (2) analyze the effectiveness of helicopter transfer and cloud-type imaging transfer systems in patients suffering from AADA.

Methods

Patients

From April 2014 to September 2020, 118 consecutive patients underwent surgical treatment for AADA, and the medical

records of all patients were reviewed. Of these, six patients underwent urgent surgery because they had AADA with thrombosed false lumen; they were initially treated conservatively, but urgent surgery was performed due to worsening of computed tomography (CT) findings. The remaining 112 patients were included in the study (→Table 1). The patients were divided into two groups according to the location of referral source hospitals: the Asahikawa city group (group A, $n = 49$) and the out-of-the-city group (group O, $n = 63$).

JapanSCORE

To estimate operative risk, we used JapanSCORE for all patients. JapanSCORE is an operative risk calculating system similar to EuroSCORE and STS Score. JapanSCORE is calculated based on the Japan Cardiovascular Surgery Database, which is generated from data contributed by 591 participating institutions. JapanSCORE was first established in 2008, and it is updated regularly using the Japan Cardiovascular Surgery Database.⁴

Geographical Condition of Referral Source Hospitals

The distribution of referral source hospitals is shown in →Fig. 1 and →Table 2. In group A, 16 patients were admitted directly from the emergency department of our institute, and the remaining 33 patients were transferred from other 10 hospitals in Asahikawa city. All 10 hospitals are located within 10 km from our institute. In group O, 63 patients were transferred from 21 hospitals located at northern Hokkaido. The nearest hospital is 39 km away, and the farthest hospital is 313 km from our institute. The details are described in Results section.

Table 1 Patient characteristics

	Group A (n = 49)	Group O (n = 63)	p-Value
Age (y)	67.0 ± 14.3	72.6 ± 12.4	0.028
Male (n)	26 (53.0%)	29 (46.0%)	0.460
Height (cm)	160.6 ± 10.6	156.2 ± 10.7	0.033
Body weight (kg)	61.3 ± 13.2	57.6 ± 15.8	0.183
Body mass index (kg/m ²)	23.6 ± 3.7	23.3 ± 4.6	0.712
Hypertension (n)	31 (63.2%)	49 (77.8%)	0.092
Hyperlipidemia (n)	13 (26.5%)	17 (27.0%)	0.957
Diabetes mellitus (n)	6 (12.2%)	1 (1.6%)	0.021
Current smoker (n)	18 (36.7%)	12 (19.0%)	0.036
Chronic kidney disease (n)	11 (22.4%)	11 (17.4%)	0.510
Serum creatinine (mg/dL)	1.25 ± 1.82	1.10 ± 1.24	0.593
History of percutaneous coronary intervention (n)	3 (6.1%)	5 (7.9%)	0.712
COPD (n)	4 (8.2%)	2 (3.2%)	0.245
Previous cardiac surgery (n)	1 (2.0%)	3 (4.7%)	0.441
Malperfusion (n)	10 (20.4%)	12 (19.0%)	0.255
Coronary (n)	2 (4.0%)	0 (0%)	0.106
Supra-aortic (n)	6 (12.2%)	5 (7.9%)	0.447
Visceral (n)	2 (4.0%)	3 (4.7%)	0.863
Iliac (n)	8 (16.3%)	1 (1.5%)	0.004
Shock (n)	9 (18.4%)	13 (20.6%)	0.764
Cardiac tamponade (n)	11 (22.4%)	16 (25.4%)	0.717
Impaired consciousness (n)	4 (8.2%)	11 (17.4%)	0.152
Cardiopulmonary resuscitation (n)	6 (12.2%)	2 (3.1%)	0.064
Predicted mortality by JapanSCORE (%)	11.3 ± 9.3	13.5 ± 10.9	0.277

Abbreviation: COPD, chronic obstructive pulmonary disease.

Table 2 Location of referral hospitals and time factors

	Group A (n = 49)	Group O (n = 63)	p-Value
Directly from our emergency department (n)	16 (32.6%)		
Within 10 km (n)	49 (100%)		
30–49.9 km (n)		11 (17.4%)	
50–99.9 km (n)		24 (38.1%)	
100–149.9 km (n)		11 (17.4%)	
150–199.9 km (n)		7 (11.1%)	
≥200 km (n)		10 (15.9%)	
Transfer distance (km)	4.2 ± 3.5	107.3 ± 69.2	0.0001
Helicopter transfer (n)		13 (20.6%)	
Use of JOIN (n)		20 (31.7%)	
Onset-to-operation time (min)	432.8 ± 348.3	572.6 ± 492.4	0.121
Arrival-to-operation time (min)	198.9 ± 94.6	128.9 ± 74.7	0.0001

Doctor Helicopter

To improve the quality of emergency medicine in the large northern Hokkaido area, a doctor helicopter has been in operation since 2009. A pilot, a board-certified flight doctor, and a trained flight nurse are allowed in the doctor helicopter, whose base is located in Asahikawa. The helicopter can reach all the northern Hokkaido areas and the Okhotsk coastal areas within an hour. Using this doctor helicopter, a patient suffering from AADA can be transferred to our institute within 2 hours (an hour each way). However, a doctor helicopter system has two disadvantages. First, the doctor helicopter can fly only during the day and in good weather conditions. It is critical, especially in winter, because of the shorter daytimes and occasional snowfall. Second, there is only one helicopter in northern Hokkaido, and if it is in operation, any other request will be canceled automatically. Therefore, the doctor helicopter cannot be used for all patients requiring long-distance transfers.

Ground Transfer

To shorten the transfer time, a doctor helicopter is the choice of transfer in our institute. If a doctor helicopter is not available for aforementioned reasons, ground transfer with an ambulance car is performed. However, ground transfer in northern Hokkaido takes more time than in other areas because (1) expressways are not available for all areas, (2) car speed is limited in winter, especially during a blizzard, and (3) car speed is limited at night due to increasing deer accidents. Thus, ground transfer in northern Hokkaido may have a more critical impact on the transfer time than in other areas.

Cloud-Type Telemedicine Imaging Transfer System

Even if the transfer time cannot be shortened, wait time for starting operation, that is, the time from starting transfer to starting operation, could be shortened if preparations for operation (gathering medical staff and preparation of operating room [OR]) can be performed in parallel with the transfer process on the basis of board-certified surgeons' adequate judgment on the surgery decision. To facilitate pretransfer decision-making by board-certified surgeons, a cloud-type telemedicine imaging transfer system (JOIN, Alm, Japan) was introduced (▶Fig. 2). Our institute and six referral hospitals (Rumoi Municipal Hospital, Fukagawa Municipal Hospital, Furano Kyokai Hospital, Engaru Kosei Hospital, Kitami Doritsu Hospital, and Kitami Red-Cross Hospital) participated in this study (▶Fig. 1). Immediately after the diagnosis of AADA by a doctor in a referral hospital, the CT images are uploaded to JOIN and the information is shared with all related medical staff (surgeons, anesthesiologists, intensive care unit staff, nursing staff in OR, and perfusionist) at our institute. A decision for emergency surgery is made by a board-certified cardiac surgeon, and communication among staff is performed similar to the chat modality in social media platforms (▶Fig. 2). Thus, preparation for surgery is normally completed during the transfer process, and patients can be carried directly into the OR after arrival.

Operative Strategy

In our institute, replacement of the ascending aorta with resection of the primary entry is the strategy of choice. Total arch replacement is performed if (1) the primary entry is located on the greater curvature of the aortic arch, (2) the true lumen at the descending aorta is extremely narrowed,

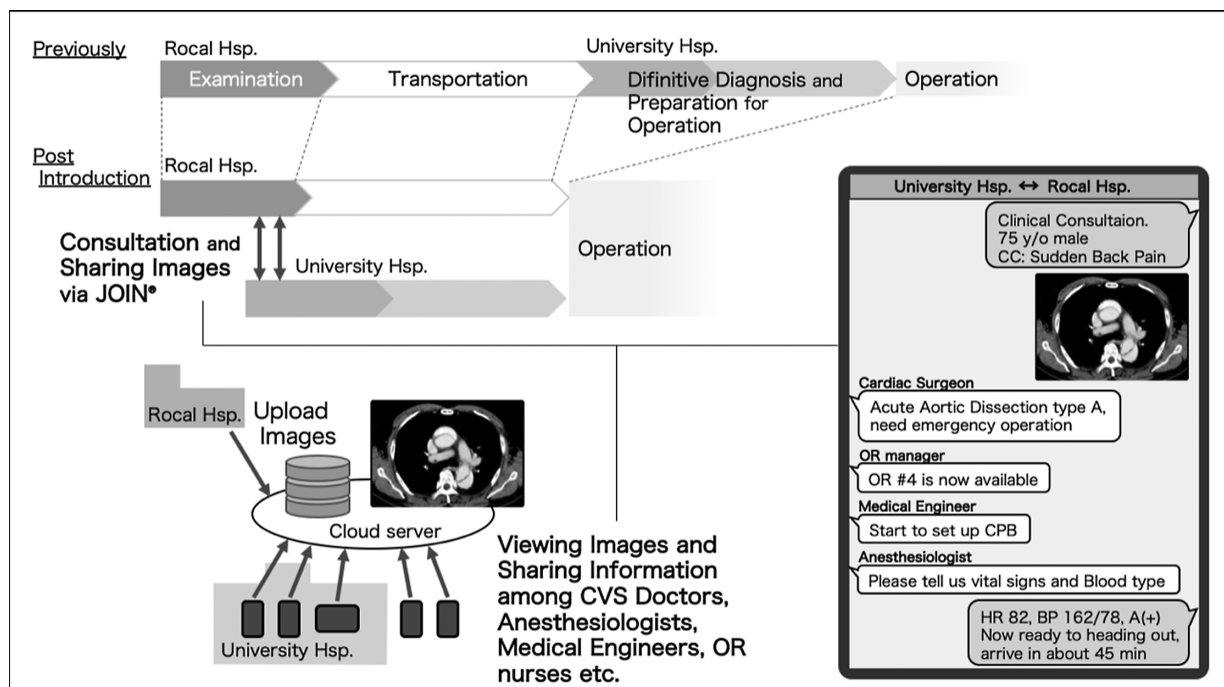


Fig. 2 Schematic demonstration of the cloud-type telemedicine system.

and/or (3) patients are aged <50 years. Aortic root replacement is performed if (1) the primary entry is located in the sinus of Valsalva and/or (2) the aortic root is dilated over 50 mm and the patient is aged <70 years. Moreover, additional surgery, such as coronary artery bypass grafting and aortic valve replacement due to degenerative changes of the aortic cusps, was performed in selected patients during the present series.

The arterial cannulation site is selected according to the patient's condition using the following three methods: direct aortic cannulation with the Seldinger technique, femoral direct cannulation, or right axillary artery cannulation using a vascular graft. Bicaval venous cannulation is performed in all patients to insert a cannula for retrograde cardioplegia under direct vision. Distal anastomosis is performed under hypothermic circulatory arrest (HCA) with a rectal temperature of 25 to 28°C. Retrograde cerebral perfusion is immediately started at the time of HCA and is switched to selective cerebral perfusion after inspection of the inner lumen of the aortic arch.

Follow-up

Follow-up information on all patients was collected through planned outpatient visits in the course of regular clinical follow-ups, and the follow-up rate in this study is 100%.

Statistical Analysis

Categorical variables are expressed as proportions and continuous variables as mean \pm standard deviation throughout this study. Survival and freedom from aortic events were analyzed using the Kaplan–Meier actuarial methods (SPSS 22.0; IBM, Armonk, New York, United States).

Results

Patient Characteristics and Preoperative Condition

The patient characteristics in each group are shown in ►Table 1, and patient distribution in each group is shown in ►Fig. 3. There were certain heterogeneities in patient characteristics and preoperative patient conditions. In short, patients in group O were significantly older and smaller than those in group A, whereas the percentages of diabetes mellitus, current smoking, and iliac malperfusion were greater in group A than in group O. Notably, the preoperative cardiopulmonary resuscitation ratio tended to be higher in group A than in group O (12.2 vs 3.1%; $p = 0.064$). Thus, patient characteristics and preoperative conditions were not completely the same between groups; however, predicted mortality calculated by JapanSCORE did not differ between groups, indicating that preoperative risk seemed to be comparable between groups.

Location of Referral Hospitals and Preoperative Time Factors

As briefly described in the Methods section, in group A 16 patients were admitted directly from the emergency department of our institute and the remaining 33 patients were transferred from 10 hospitals in Asahikawa city. Additionally, in group O 63 patients were transferred from 21 hospitals located in northern Hokkaido. The main referral sites are Fukagawa city (35 km away, $n = 8$), Furano city (55 km away, $n = 13$), Takikawa city (64 km away, $n = 2$), Rumoi city (71 km away, $n = 8$), Engaru city (130 km away, $n = 9$), Kitami city (167 km away, $n = 6$). Abashiri city

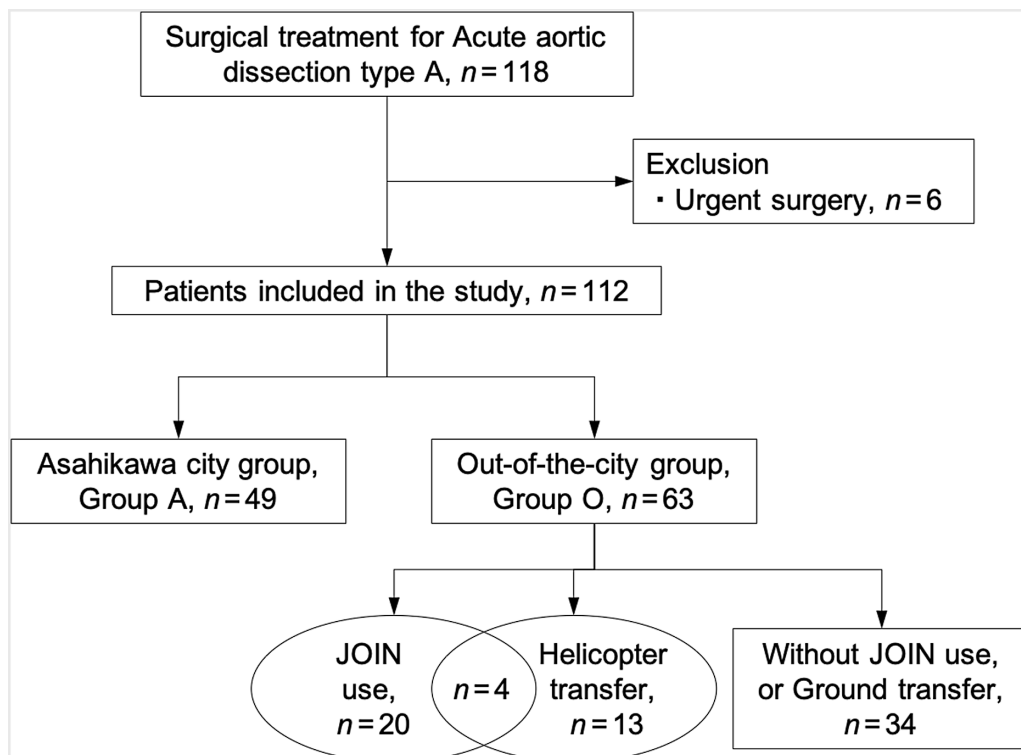


Fig. 3 Patient selection and study flow.

(215 km away, $n=7$), and Wakkanai city (248 km away, $n=2$). The farthest site was Rishiri Island, 313 km from our institute.

As a matter of course, transfer distance differed between groups (4.2 ± 3.5 km in group A vs 107.3 ± 69.2 km in group O; $p=0.0001$). In group O, helicopter transfer was used for 13 patients, and JOIN was used for 20 patients. Interestingly, onset-to-operation time did not differ between groups (432.8 ± 348.3 minutes in group A vs 572.6 ± 492.4 minutes in group O; $p=0.121$). However, arrival-to-operation time was significantly shorter in group O than in group A (198.9 ± 94.6 minutes in group A vs 128.9 ± 74.7 minutes in group O; $p=0.0001$).

Operative Factors and Outcome

Operative modality, that is, hemiarch versus total arch replacement, with or without root procedures and other concomitant surgeries, did not differ between groups (►Table 3). However, operation time and cardiopulmonary

bypass time tended to be shorter in group A than in group O because HCA time was shorter in group A than in group O (34.9 ± 10.9 minutes in group A vs 41.5 ± 18.9 minutes in group O; $p=0.031$). In our institute, bleeding salvaged with a cell saver was also counted as the bleeding amount; therefore, the bleeding amount was greater than in other institutes. However, the bleeding amount and blood products used did not differ between the groups.

Thirty-day mortality (10.2% in group A vs 7.9% in group O; $p=0.676$) and hospital mortality (12.2% in group A vs 9.5% in group O; $p=0.687$) did not differ between groups. The occurrence rate of complications also did not differ between the groups.

Long-term Outcome

The mean follow-up period was 35.3 ± 27.1 months, ranging from 0 to 87 months. The survival curve for each group is shown in ►Fig. 4. There was no difference in the long-term survival between the groups.

Table 3 Operation and outcome

	Group A ($n=49$)	Group O ($n=63$)	<i>p</i> -Value
Operative factors			
Hemiarch replacement (n)	34 (69.4%)	42 (66.6%)	0.951
Partial arch replacement (n)	2 (4.1%)	3 (4.8%)	
Total arch replacement (n)	13 (26.5%)	18 (28.5%)	
Root replacement (n)	4 (8.1%)	7 (11.1%)	0.603
Bentall procedure (n)	0 (0%)	4 (6.3%)	
David procedure (n)	4 (8.1%)	3 (4.8%)	
Coronary artery bypass grafting (n)	4 (8.1%)	3 (4.8%)	0.461
Aortic valve replacement (n)	1 (2.0%)	0 (0%)	0.437
Operation time (min)	336.0 ± 103.8	370.5 ± 124.7	0.121
Cardiopulmonary bypass time (min)	160.0 ± 53.5	188.4 ± 104.2	0.086
Myocardial ischemia time (min)	103.7 ± 38.2	115.1 ± 68.4	0.301
Hypothermic circulatory arrest time (min)	34.9 ± 10.9	41.5 ± 18.9	0.031
Minimal rectal temperature (°C)	26.6 ± 1.6	26.3 ± 1.6	0.346
Bleeding amount (mL)	$4,843 \pm 4,177$	$5,915 \pm 5,256$	0.245
Red blood cells (U)	21.4 ± 14.8	24.4 ± 9.7	0.199
Frozen fresh plasma (U)	26.0 ± 12.9	28.3 ± 12.7	0.342
Platelet concentrate (U)	42.6 ± 18.8	44.4 ± 17.4	0.586
Outcome			
30-day mortality (n)	5 (10.2%)	5 (7.9%)	0.676
Hospital mortality (n)	6 (12.2%)	6 (9.5%)	0.687
Rethoracotomy for bleeding (n)	3 (6.1%)	4 (6.3%)	0.961
Mediastinitis (n)	1 (2.0%)	3 (4.8%)	0.441
Temporary neurological deficit (n)	1 (2.0%)	4 (6.3%)	0.273
Stroke (n)	3 (6.1%)	3 (4.8%)	0.751
Paraplegia (n)	2 (4.1%)	4 (6.3%)	0.597
Acute kidney injury (n)	5 (10.2%)	10 (15.9%)	0.382

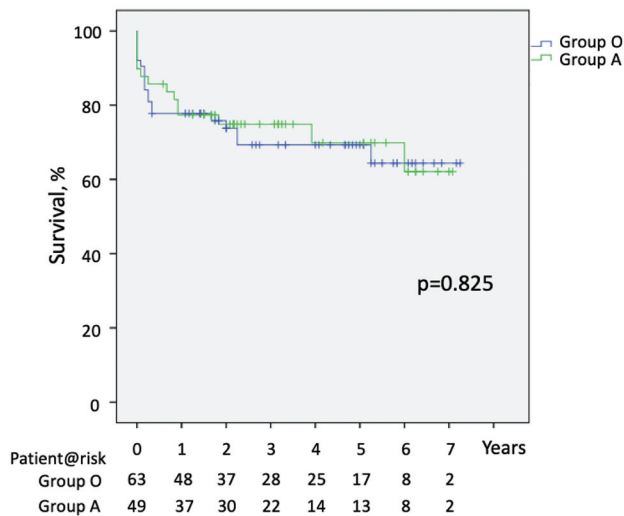


Fig. 4 Long-term survival in patients suffering from AADA with or without long-distance transfer.

Subanalysis: Outcome in Patients Operated within 5 Hours from the Onset

In this study, 32 patients underwent surgery within 5 hours from the onset, regardless of transfer distance. Predicted mortality by JapanSCORE was $11.8 \pm 8.9\%$ in patients operated within 5 hours and $12.8 \pm 10.8\%$ in other patients ($p = 0.661$), indicating that the two groups had comparative preoperative risk. Thirty-day mortality of the 32 patients was 14.3% (5/32 patients), and the 30-day mortality of the remaining 80 patients was 6.3% (5/80 patients); there was no significant difference between the groups ($p = 0.116$).

Subanalysis: Helicopter Transfer in Group O

In group O, 13 patients were transferred to our institute with a helicopter, who were then compared with the other 50 patients who underwent ground transfer (→ **Table 4**). Patient characteristics and preoperative patient conditions did not differ between the groups, nor did the transfer distance and onset-to-operation time. However, the time from CT

Table 4 Subanalysis: helicopter transfer in group O ($n = 63$)

	Helicopter ($n = 13$)	Ground transfer ($n = 50$)	p-Value
Patient characteristics			
Age (y)	74.7 ± 4.9	72.2 ± 13.7	0.521
Male (n)	6 (46.2%)	23 (46.0%)	0.992
Height (cm)	156.7 ± 8.9	156.2 ± 11.2	0.875
Body weight (kg)	58.3 ± 10.9	57.4 ± 17.0	0.860
Body mass index (kg/m^2)	23.7 ± 3.8	23.2 ± 4.9	0.741
Hypertension (n)	8 (61.5%)	41 (82.0%)	0.114
Hyperlipidemia (n)	3 (23.1%)	14 (28.0%)	0.722
Diabetes mellitus (n)	0 (0%)	1 (2%)	0.607
Current smoker (n)	2 (15.4%)	10 (20%)	0.706
Chronic kidney disease (n)	1 (7.7%)	10 (20%)	0.298
Serum creatinine (mg/dL)	0.77 ± 0.15	1.19 ± 1.38	0.286
History of percutaneous coronary intervention (n)	2 (15.4%)	3 (6%)	0.265
COPD (n)	1 (7.7%)	1 (2%)	0.297
Previous cardiac surgery (n)	0 (0%)	3 (6%)	0.365
Malperfusion (n)	1 (7.7%)	9 (18.0%)	0.365
Coronary (n)	0 (0%)	0 (0.0%)	
Supra-aortic (n)	1 (7.7%)	4 (8.0%)	
Visceral (n)	0 (0%)	3 (6.0%)	
Iliac (n)	0 (0%)	1 (2.0%)	
Shock (n)	4 (30.8%)	9 (18.0%)	0.311
Cardiac tamponade (n)	5 (38.5%)	11 (22.0%)	0.224
Impaired consciousness (n)	4 (30.8%)	7 (14.0%)	0.156
Cardiopulmonary resuscitation (n)	1 (7.7%)	1 (2.0%)	0.297
Predicted mortality by JapanSCORE (%)	12.5 ± 8.9	13.7 ± 11.5	0.720
Location of referral hospitals and time factors			
30–49.9 km (n)	0 (0%)	11 (22.0%)	
50–99.9 km (n)	9 (69.2%)	15 (30.0%)	

(Continued)

Table 4 (Continued)

	Helicopter (<i>n</i> = 13)	Ground transfer (<i>n</i> = 50)	<i>p</i> -Value
100–149.9 km (<i>n</i>)	1 (7.7%)	10 (20.0%)	
150–199.9 km (<i>n</i>)	2 (15.4%)	5 (10.0%)	
≥200 km (<i>n</i>)	1 (7.7%)	9 (18.0%)	
Transfer distance (km)	98.4 ± 60.9	109.6 ± 71.6	0.609
Use of JOIN (<i>n</i>)	4 (30.8%)	16 (32.0%)	0.932
Onset-to-operation time (min)	407.7 ± 107.3	614.9 ± 542.7	0.239
Diagnosis-to-operation time (min)	240.0 ± 70.8	320.0 ± 78.5	0.031
Arrival-to-operation time (min)	103.9 ± 58.3	135.7 ± 77.7	0.175
Operative factors			
Hemiarch replacement (<i>n</i>)	11 (84.6%)	31 (62.0%)	0.277
Partial arch replacement (<i>n</i>)	0 (0%)	3 (6.0%)	
Total arch replacement (<i>n</i>)	2 (15.4%)	16 (32.0%)	
Root replacement (<i>n</i>)	1 (7.7%)	6 (12.0%)	0.660
Bentall procedure (<i>n</i>)	1 (7.7%)	3 (6.0%)	
David procedure (<i>n</i>)	0 (0%)	3 (6.0%)	
Coronary artery bypass grafting (<i>n</i>)	0 (0%)	3 (6.0%)	0.365
Aortic valve replacement (<i>n</i>)	0 (0%)	0 (0%)	1
Operation time (min)	361.4 ± 70.1	372.9 ± 135.9	0.770
Cardiopulmonary bypass time (min)	169.4 ± 52.2	193.3 ± 113.8	0.465
Myocardial ischemia time (min)	111.8 ± 29.3	115.9 ± 75.5	0.847
Hypothermic circulatory arrest time (min)	42.8 ± 17.1	41.1 ± 19.4	0.774
Minimal rectal temperature (°C)	26.7 ± 1.0	26.2 ± 1.7	0.303
Bleeding amount (mL)	6,131 ± 6,666	5,858 ± 4,905	0.869
Red blood cells (U)	25.1 ± 11.5	24.2 ± 9.3	0.785
Frozen fresh plasma (U)	30.8 ± 12.1	27.7 ± 12.9	0.436
Platelet concentrate (U)	45.8 ± 12.9	44.1 ± 18.5	0.758
Outcome			
30 days mortality (<i>n</i>)	1 (7.7%)	4 (8.0%)	0.971
Hospital mortality (<i>n</i>)	2 (15.4%)	4 (8.0%)	0.375
Rethoracotomy for bleeding (<i>n</i>)	0 (0%)	4 (8.0%)	0.572
Mediastinitis (<i>n</i>)	0 (0%)	3 (6.0%)	0.494
Temporary neurological deficit (<i>n</i>)	1 (7.7%)	3 (6.0%)	0.824
Stroke (<i>n</i>)	0 (0%)	3 (6.0%)	0.365
Paraplegia (<i>n</i>)	0 (0%)	4 (8.0%)	0.292
Acute kidney injury (<i>n</i>)	1 (7.7%)	7 (14.0%)	0.543

Abbreviation: COPD, chronic obstructive pulmonary disease.

diagnosis to operation was ~80 minutes shorter in the helicopter group. Operative modality and intraoperative factors were almost the same between groups, and mortality and complications did not differ between the groups.

Subanalysis: JOIN Use in Group O

In group O, JOIN was used in 20 patients. Here, the 20 patients were compared with the other 43 patients without

JOIN use (→Table 5). Patient characteristics, preoperative patient conditions, and transfer distance did not differ between groups. However, diagnosis-to-operation time and arrival-to-operation time were significantly shorter in the JOIN group, that is, ~80-minute reduction for diagnosis-to-operation time and 55-minute reduction for arrival-to-operation time. However, the operative outcomes were similar between the groups.

Table 5 Subanalysis: use of JOIN

	JOIN (<i>n</i> = 20)	No JOIN (<i>n</i> = 43)	<i>p</i> -Value
Patient characteristics			
Age (y)	72.7 ± 11.8	72.7 ± 12.9	0.983
Male (<i>n</i>)	9 (45.0%)	20 (46.5%)	0.911
Height (cm)	157.0 ± 12.0	155.9 ± 12.9	0.715
Body weight (kg)	58.0 ± 15.1	57.4 ± 16.3	0.892
Body mass index (kg/m ²)	23.3 ± 3.8	23.3 ± 5.1	0.952
Hypertension (<i>n</i>)	13 (65.0%)	36 (83.7%)	0.096
Hyperlipidemia (<i>n</i>)	7 (35.0%)	10 (23.3%)	0.328
Diabetes mellitus (<i>n</i>)	0 (0%)	1 (2.3%)	0.492
Current smoker (<i>n</i>)	5 (25.0%)	7 (16.3%)	0.412
Chronic kidney disease (<i>n</i>)	4 (20.0%)	7 (16.3%)	0.717
Serum creatinine (mg/dL)	1.32 ± 2.07	1.00 ± 0.54	0.334
History of percutaneous coronary intervention (<i>n</i>)	1 (5.0%)	4 (9.3%)	0.556
COPD (<i>n</i>)	1 (5.0%)	1 (2.3%)	0.573
Previous cardiac surgery (<i>n</i>)	1 (5.0%)	2 (4.7%)	0.852
Malperfusion (<i>n</i>)	3 (15.0%)	7 (16.3%)	0.897
Coronary (<i>n</i>)	0 (0%)	0 (0%)	
Supra-aortic (<i>n</i>)	2 (10.0%)	3 (7.0%)	
Visceral (<i>n</i>)	1 (5.0%)	2 (4.7%)	
Iliac (<i>n</i>)	0 (0%)	1 (2.3%)	
Shock (<i>n</i>)	6 (30.0%)	7 (16.3%)	0.210
Cardiac tamponade (<i>n</i>)	5 (25.0%)	11 (25.6%)	0.961
Impaired consciousness (<i>n</i>)	4 (20.0%)	7 (16.3%)	0.717
Cardiopulmonary resuscitation (<i>n</i>)	1 (5.0%)	1 (2.3%)	0.873
Predicted mortality by JapanSCORE (%)	13.5 ± 7.8	13.4 ± 12.1	0.989
Location of referral hospitals and time factors			
30–49.9 km (<i>n</i>)	2 (10.0%)	9 (20.9%)	
50–99.9 km (<i>n</i>)	11 (55.0%)	13 (30.2%)	
100–149.9 km (<i>n</i>)	4 (20.0%)	7 (16.3%)	
150–199.9 km (<i>n</i>)	3 (15.0%)	4 (9.3%)	
≥200 km (<i>n</i>)	0 (0%)	10 (23.3%)	
Transfer distance (km)	88.0 ± 46.0	116.3 ± 76.5	0.132
Use of helicopter (<i>n</i>)	4 (20.0%)	9 (20.9%)	0.932
Onset-to-operation time (min)	454.8 ± 309.6	629.7 ± 555.4	0.248
Diagnosis-to-operation time (min)	242.0 ± 75.2	319.0 ± 83.8	0.007
Arrival-to-operation time (min)	90.5 ± 50.6	146.2 ± 77.8	0.006
Operative factors			
Hemiarch replacement (<i>n</i>)	14 (70.0%)	28 (65.1%)	0.912
Partial arch replacement (<i>n</i>)	1 (5.0%)	2 (4.7%)	
Total arch replacement (<i>n</i>)	5 (25.0%)	13 (30.2%)	
Root replacement (<i>n</i>)	0 (0%)	7 (16.3%)	0.056
Bentall procedure (<i>n</i>)	0 (0%)	4 (9.3%)	
David procedure (<i>n</i>)	0 (0%)	3 (7.0%)	

(Continued)

Table 5 (Continued)

	JOIN (<i>n</i> = 20)	No JOIN (<i>n</i> = 43)	<i>p</i> -Value
Coronary artery bypass grafting (<i>n</i>)	1 (5.0%)	2 (4.7%)	0.952
Aortic valve replacement (<i>n</i>)	0 (0%)	0 (0%)	1.000
Operation time (min)	361.6 ± 113.0	374.7 ± 130.9	0.700
Cardiopulmonary bypass time (min)	186.1 ± 88.6	189.1 ± 111.6	0.935
Myocardial ischemia time (min)	111.5 ± 39.9	116.7 ± 78.6	0.781
Hypothermic circulatory arrest time (min)	42.8 ± 20.1	40.9 ± 18.4	0.721
Minimal rectal temperature (°C)	26.6 ± 2.2	26.1 ± 1.2	0.267
Bleeding amount (mL)	5,717 ± 5,264	6,007 ± 5,312	0.841
Red blood cells (U)	25.9 ± 7.4	23.7 ± 10.6	0.413
Frozen fresh plasma (U)	30.5 ± 14.3	27.3 ± 11.9	0.342
Platelet concentrate (U)	47.3 ± 18.7	43.1 ± 16.9	0.385
Outcome			
30-day mortality (<i>n</i>)	2 (10.0%)	3 (7.0%)	0.679
Hospital mortality (<i>n</i>)	3 (15.0%)	3 (7.0%)	0.344
Rethoracotomy for bleeding (<i>n</i>)	1 (5.0%)	3 (7.0%)	0.765
Mediastinitis (<i>n</i>)	1 (5.0%)	2 (4.7%)	0.952
Temporary neurological deficit (<i>n</i>)	1 (5.0%)	3 (7.0%)	0.765
Stroke (<i>n</i>)	3 (15.0%)	0 (0%)	0.009
Paraplegia (<i>n</i>)	2 (10.0%)	2 (4.7%)	0.418
Acute kidney injury (<i>n</i>)	2 (10.0%)	6 (14.0%)	0.661

Abbreviation: COPD, chronic obstructive pulmonary disease.

Discussion

The study found that (1) long-distance transfer did not impair surgical outcomes in patients with AADA and (2) both helicopter transfer and cloud-type telemedicine system could contribute to the reduction of diagnosis-to-operation time in large northern Hokkaido areas.

Long-distance Transfer Justified for AADA Treatment

In this study, there was no difference in surgical outcomes between intercity patients and patients who needed long-distance transfer due to AADA. Because the risk of death due to untreated AADA is estimated to be 0.5 to 2% an hour,^{1,2} the findings of this study may seem misleading, but other studies too faced similar results. Tseng et al investigated the surgical outcomes of interhospital transfer for AADA in Taiwan.⁵ In their study, 112 patients with AADA were divided into two groups, one comprising patients sent directly to their emergency department (group 1, *n* = 59) and the other consisting of patients who had been transferred from another hospital after being diagnosed with AADA (group 2, *n* = 53). Although the interval between CT and OR differed between the groups (87 vs 141 minutes; *p* < 0.001), there was no significant difference in hospital mortality (16.3 vs 22.6%; *p* = 0.32). They concluded that the transfer of patients with AADA to an experienced surgical unit may not increase surgical risk. Similar to their report, Goldstone et al investigated the interfacility transfer of patients with AADA based on the

Medicare database and included 16,886 patients.⁶ In their analysis, interfacility transfer was not associated with a change in operative or long-term mortality. Despite delaying surgery, a regionalization policy that transfers patients to high-volume hospitals was associated with a 7.2% absolute risk reduction in operative mortality; this association persisted in the long term. The median distance needed to reroute each patient to a high-volume hospital was ~80 km. They concluded that interfacility transfer does not increase operative risk in patients with AADA; therefore, these patients should be transferred to experienced high-volume centers. Using the Japanese clinical database, Izumisawa et al reported the association between prehospital transfer distance and surgical mortality in emergency thoracic aortic surgery.⁷ They analyzed 12,004 patients who underwent emergency thoracic aortic surgeries at 495 Japanese hospitals; with a risk-adjusted mortality odds ratio for standardized distance (mean, 12.8 km; standard deviation, 15.2 km) of 0.94 (95% confidence interval, 0.87–1.01; *p* = 0.09), they concluded that patients with emergency thoracic aortic disease should be transferred to distant high-volume hospitals.

Our findings are similar to those of previous studies⁵; however, the transfer distance was possibly longer in our area. Tseng et al⁵ did not provide a transfer distance, but their additional time for transfer compared with the no-transfer group was only 34 minutes, implying that the transfer distance may have been very short. In the report by Goldstone

et al,⁶ the mean transfer distance was 80 km, and the maximal transfer distance was 168 km. In contrast, the mean transfer distance in group O was 107 km and the maximal transfer distance was 313 km in the out cohort. The findings of our study indicate that long-distance transfer of patients with AADA does not increase surgical risk, even if the distance is very long. However, one should be aware that those studies focused only on operative risk, and death during transfer was not taken into consideration. Our results suggest that transfer distance plays a very limited role in those patients with AADA who are stable enough to tolerate the transfer.

Possibility of Patient Death during Transfer

Very little data are available regarding death during transfer in patients with AADA. In the 2021 expert consensus document from the American Association for Thoracic Surgery and newest report from International Registry of Acute Aortic Dissection (IRAD), the risk of death due to AADA was estimated at 0.5 to 2% per hour and nonoperative treatment was associated with mortality in nearly 60% of patients^{1,2,9,10}; however, these estimates were based on dated data. In the contemporary era, Kuang et al reported on the preoperative mortality risk in patients with AADA.¹¹ In their study, 673 patients with AADA unable to receive surgical treatment within 3 days after onset were involved, and the 3-day mortality in nonsurgical patients was 21.7%. Thus, it should be emphasized that mortality immediately after the onset of AADA is very high. Although several studies have advocated the transfer of AADA patients to a high-volume center,^{5–7,9,10,12} many cardiac surgeons might have experienced patient death in an emergency room during CT examination and/or during transfer. In the present series, there were no exact data on preoperative death, but at least five patients died during transfer and two patients without transfer died in our hospital and could not reach the OR alive. Therefore, not all but certain patients would benefit from nontransfer or a very quick transfer to reduce the onset-to-operation time as much as possible.

Need for Minimal Diagnosis-to-Operation Time

In addition to the issue of whether preoperative transfer would be safe in patients with AADA, several reports claim that short onset-to-operation time is associated with favorable results.^{13–15} Gasser et al stratified patients undergoing surgery for AADA into three groups: within 4 hours, between 4 and 10 hours, and over 10 hours from the onset to operation. Patients who underwent surgery within 4 hours had significantly severe critical preoperative conditions, resulting in the worst postoperative outcome; however, the outcome in patients who underwent surgery between 4 and 10 hours after onset was significantly better than that in patients who underwent surgery more than 10 hours after the onset.¹³ In our subanalysis of outcomes in patients operated within 5 hours from the onset, there was a trend toward worse outcomes in patients who underwent surgery within 5 hours after the onset (14% mortality within 5 hours vs 6% mortality over 5 hours), although the preoperative

JapanSCORE did not differ between groups. Gasser et al's and our results may suggest that the general condition of AADA patients in the super-acute phase is very poor, resulting in a high postoperative mortality rate; survivors during the super-acute phase would have better preoperative conditions because very critical patients died before reaching the OR in the super-acute phase. Therefore, diagnosis-to-operation time should be shortened as much as possible not only to improve the surgical outcome, but also to improve the survival rate of patients.

Ensuring the Efficacy of Helicopter Transfer

There have been several reports on the safety and efficacy of helicopter transfer for AADA patients.^{16–19} Patients transported by a helicopter suffer from machine noise, vibration, and low atmospheric pressure, which is harmful to very unstable patients with AADA. Mitchell and Tallon reported that 9% of patients with AADA died during helicopter transport.¹⁹ However, mortality in AADA patients during the super-acute phase is generally very high, and it is not clear whether this 9% mortality was due to helicopter transport. Knobloch et al and Rose et al reported that operative outcomes did not differ between ground transfer and helicopter transfer.^{16,17} Similar to previous research, this study demonstrates that the operative outcome in patients with AADA was not worsened by helicopter transfer. Our finding would be an augment for the more aggressive introduction of doctor helicopters in very large medical areas, such as Hokkaido.

While this study could prove the safety of helicopter transport in AADA patients, it has not demonstrated the efficacy of helicopter transport. The diagnosis-to-operation time was shorter in the helicopter group, but mortality did not differ between ground transfer and helicopter transfer. One reason for this may be the too small sample size. In a future study with a larger patient volume, operative mortality would be better in helicopter transfer because of shorter diagnosis-to-operation time. The other reason for the non-superiority of helicopter transfer in this study may be that the doctor helicopter can fly only in good weather conditions, and there is only one helicopter in our area. Therefore, while helicopter transfer plays a complementary role among AADA patients in a large medical area, this may not be sufficient. If life-saving effect of helicopter transfer in AADA patients may be limited, the cost-effectiveness should be discussed from the view point of national health care administration.

Cloud-Type Telemedicine: An Attractive Option

Telemedicine has been widespread, especially in the last 2 years due to the coronavirus disease 2019 (COVID-19) pandemic. Telemedicine involves various and heterogeneous concepts, but in the field of cardiovascular medicine, there are three main uses of telemedicine: (1) image and patient's information transfer for triaging and expert diagnosis, (2) prehospital electrocardiogram for optimizing receiving hospital, and (3) home-monitoring for outpatients after cardiovascular treatments.^{20,21} The cloud-type telemedicine imaging transfer system used in the present series was

introduced to facilitate pretransfer decision-making by board-certified surgeons and to shorten the diagnosis-to-operation time. In fact, diagnosis-to-operation time was shorter with JOIN than without JOIN in patients needing long-distance transfer in our study, although it did not improve the operative outcome, perhaps due to the small number of patients involved.

Another favorable effect of this telemedicine system is avoidance of the unnecessary attendance of home on-call staff, including surgeons, anesthesiologists, nursing staff in OR, and perfusionists. Moreover, the working time of the staff can be shortened because the wait time for starting the operation can be minimized. Thus, the telemedicine system is useful for patient safety and an improved work–life balance of the medical staff.

Limitations

There are several limitations to this research. First, this was a retrospective, single-institutional study. Second, the number of patients was too small to detect the effects of helicopter transfer and cloud-type telemedicine systems. Third, patients who died during transfer were not analyzed, which is the most crucial limitation. Because of the retrospective nature of the present study and limitation of our institutional ethical review board, we could not analyze death during transport. To analyze the real danger of long-distance transfer and the merits of helicopter transfer and cloud-type telemedicine systems, prospective and multicenter studies are needed. Because of these limitations, this study has a low statistical power, resulting in a narrative description. Nevertheless, it is useful in recognizing the current status and problems of long-distance transfer of AADA patients in a large geographical area of Japan with low population density. We hope that the present study would be worth as a stimulator for further large-scale study focusing on this important issue.

Conclusion

This study demonstrated that long-distance transfer did not impair surgical outcomes in patients with AADA and that both helicopter transfer and cloud-type telemedicine system could contribute to the reduction of diagnosis-to-operation time in large northern Hokkaido areas. However, this study did not analyze the safety of long-distance transfer; therefore, further prospective and multicenter studies are required.

Ethical Approval Statement

This retrospective study was approved by the institutional review board (IRB) (No. 19207), which waived the need for written patient consent because of the retrospective nature of this study. Furthermore, the refusal right was warranted for all patients, as documented on our homepage.

Conflict of Interest

None declared.

References

- 1 Malaisrie SC, Szeto WY, Halas M, et al; AATS Clinical Practice Standards Committee: Adult Cardiac Surgery. 2021 The American Association for Thoracic Surgery expert consensus document: surgical treatment of acute type A aortic dissection. *J Thorac Cardiovasc Surg* 2021;162(03):735–758.e2
- 2 Harris KM, Nienaber CA, Peterson MD, et al. Early mortality in type A acute aortic dissection: insights from the International Registry of Acute Aortic Dissection. *JAMA Cardiol* 2022;7(10):1009–1015
- 3 Yamasaki M, Yoshino H, Kuniyama T, et al. Risk analysis for early mortality in emergency acute type A aortic dissection surgery: experience of Tokyo Acute Aortic Super-network. *Eur J Cardiothorac Surg* 2021;60(04):957–964
- 4 Motomura N, Miyata H, Tsukihara H, Takamoto S Japan Cardiovascular Surgery Database Organization. Risk model of thoracic aortic surgery in 4707 cases from a nationwide single-race population through a web-based data entry system: the first report of 30-day and 30-day operative outcome risk models for thoracic aortic surgery. *Circulation* 2008;118(14, Suppl):S153–S159
- 5 Tseng YH, Kao CC, Lin CC, et al. Does interhospital transfer influence the outcomes of patients receiving surgery for acute type A aortic dissection? Type A aortic dissection: is transfer hazardous or beneficial?. *Emerg Med Int* 2019;2019:5692083
- 6 Goldstone AB, Chiu P, Baiocchi M, et al. Interfacility transfer of Medicare beneficiaries with acute type A aortic dissection and regionalization of care in the United States. *Circulation* 2019;140(15):1239–1250
- 7 Izumisawa Y, Endo H, Ichihara N, et al. Association between prehospital transfer distance and surgical mortality in emergency thoracic aortic surgery. *J Thorac Cardiovasc Surg* 2022;163(01):28–35.e1
- 8 Hagan PG, Nienaber CA, Isselbacher EM, et al. The International Registry of Acute Aortic Dissection (IRAD): new insights into an old disease. *JAMA* 2000;283(07):897–903
- 9 Hirst AE Jr, Johns VJ Jr, Kime SW Jr. Dissecting aneurysm of the aorta: a review of 505 cases. *Medicine (Baltimore)* 1958;37(03):217–279
- 10 Aggarwal B, Raymond CE, Randhawa MS, et al. Transfer metrics in patients with suspected acute aortic syndrome. *Circ Cardiovasc Qual Outcomes* 2014;7(05):780–782
- 11 Kuang J, Yang J, Wang Q, Yu C, Li Y, Fan R. A preoperative mortality risk assessment model for Stanford type A acute aortic dissection. *BMC Cardiovasc Disord* 2020;20(01):508
- 12 Manzur M, Han SM, Dunn J, et al. Management of patients with acute aortic syndrome through a regional rapid transport system. *J Vasc Surg* 2017;65(01):21–29
- 13 Gasser S, Stastny L, Kofler M, et al. Rapid response in type A aortic dissection: is there a decisive time interval for surgical repair? *Thorac Cardiovasc Surg* 2021;69(01):49–56
- 14 Nakai C, Izumi S, Haraguchi T, et al. Impact of time from symptom onset to operation on outcome of repair of acute type A aortic dissection with malperfusion. *J Thorac Cardiovasc Surg* 2023;165(03):984–991.e1
- 15 Matthews CR, Madison M, Timsina LR, Namburi N, Faiza Z, Lee LS. Impact of time between diagnosis to treatment in acute type A aortic dissection. *Sci Rep* 2021;11(01):3519
- 16 Knobloch K, Dehn I, Khaladj N, Hagl C, Vogt PM, Haverich A. HEMS vs. EMS transfer for acute aortic dissection type A. *Air Med J* 2009;28(03):146–153

- 17 Rose M, Newton C, Boualam B, et al. Ground same intratransport efficacy as air for acute aortic diseases. *Air Med J* 2019;38(03): 188–194
- 18 Murphy DL, Danielson KR, Knutson K, Utarnachitt RB. Management of acute aortic dissection during critical care air medical transport. *Air Med J* 2020;39(04):291–295
- 19 Mitchell AD, Tallon JM. Air medical transport of suspected aortic emergencies. *Air Med J* 2002;21(03):34–37
- 20 Ajibade A, Younas H, Pullan M, Harky A. Telemedicine in cardiovascular surgery during COVID-19 pandemic: A systematic review and our experience. *J Card Surg* 2020;35(10): 2773–2784
- 21 Kronenfeld JP, Kang N, Kenel-Pierre S, et al. Establishing and maintaining a remote vascular surgery aortic program: a single-center 5-year experience at the Veterans Affairs. *J Vasc Surg* 2021;75(03):1063–1072