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## Original Research

## Ground Same Intratransport Efficacy as Air for Acute Aortic Diseases



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## A B S T R A C T

**Introduction:** Patients with acute aortic diseases (AAoD) usually require transfer to tertiary centers for possible surgical care, for which intratransport management represents important continuing spectrum of care. There is little information comparing intratransport efficacy of air (ART) vs ground transport (GRT), nor how effectively they manage these patients' pain. Our study aims to compare how effective ART and GRT manage patients' intratransport HR, pressure.

**Methods:** Charts were reviewed of adult patients interhospital transferred to a quaternary academic center (UMMC) between 01/01/2011 and 09/30/2015. Outcomes were percentages of patients achieving target hemodynamic parameters, mortality.

**Results:** We analyzed 226 patients, 58 (26%) transported by Air and 102 (45%) type A dissection. Ground transport was associated with higher percentage of patients with target HR 60–80 bpm comparing to ART (58% vs 43%, 95% CI 0.3–0.99). Both ART and GRT were associated with similar frequencies of patients achieving target SBP and adequate pain control. Time intervals from transfer request to surgery, and mortality were similar for both types of transport.

**Conclusion:** Ground transport teams were more successful at achieving predefined target heart rate than Air transport. Intra-transport management of other vital signs and pain were equally effectively between both Air and Ground transport.

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Acute aortic diseases (AAoDs) are a group of life-threatening hypertensive emergencies with high mortality and morbidity.<sup>1</sup> Aortic dissection is the most common condition and is classified into type A dissection, in which the dissection involves the ascending aorta, and type B dissection, which involves the descending aorta only.<sup>1,2</sup> Type A dissection is a surgical emergency, whereas type B can be treated medically.<sup>1</sup> However, when end organ damage occurs, type B dissection will also become a surgical emergency. Treatment for other less frequent AAoDs such as intramural hematoma, ulcers, and aneurysms is similar to dissections and managed according to the location of the lesions.<sup>1</sup> A majority of patients

with AAoD present to community hospitals where the necessary subspecialties for definitive care are often absent, necessitating transfer to a tertiary care center.<sup>3</sup> Consequently, transportation teams are an integral part of care for these critically ill patients. However, previous studies only examined the effectiveness of air but not ground transport.<sup>3–5</sup> Furthermore, these studies did not examine transport teams' management of pain or patients with hypotension. Therefore, we sought to compare the effectiveness of the management of air transport teams (ARTs) versus ground transport teams (GRTs) of patients' hemodynamic profiles and pain among patients with AAoDs who were transferred from a referring hospital to our quaternary academic medical center. Our study, which is the first study examining transport teams' management of both hypotensive patients and pain, aimed to assess transport teams' management according to our subspecialty surgical consultants' instructions.

**Acknowledgments:** The authors thank Drs Walesia Robinson and Rebecca Duncan for their help with this article.

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1067-991X/\$36.00

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<https://doi.org/10.1016/j.amj.2019.01.003>

Our institution requires all transfer requests for patients with AAOds to be accepted for transfer by the on-call subspecialty surgeons. As a result, our subspecialty surgical surgeons typically recommend the referring physicians and transport teams to maintain patients' heart rate (HR) at 60 to 80 beats/min and the systolic blood pressure (SBP) at 100 to 120 mm Hg until the surgeons evaluate the patients clinically and radiographically and definitive plans are decided. Besides, referring physicians and transport teams are recommended to treat patients' pain as much as possible. Although the recommendation to treat HR was specific for AAOd patients being transferred to our institution, the recommendations to treat blood pressure and pain are consistent with the American Heart Association (AHA) guidelines.<sup>2</sup>

## Methods

### Study Settings and Designs

We performed a retrospective study on adult patients who were admitted to our academic referral center (University of Maryland School of Medicine [UMMC], Baltimore, MD) for the management of AAOds. The study period was between January 1, 2011, and September, 30, 2015. Our study was approved by the institutional review board.

### Selection of Patients

Adult patients who were transferred from another hospital were identified in our electronic medical record using the *International Classification of Diseases, Ninth Revision* for aortic diseases 441.XX.<sup>6</sup> We excluded patients with traumatic aortic diseases who do not require similar HR and blood pressure management and patients with missing transport team records.

### Source of Data

We collected data from transport team records. Usually, the UMMC transport team or 1 of the commercial GRTs would transport patients depending on the availability of the transport team, the distance, and the location of the referring hospitals. Alternatively, 2 helicopter companies are contracted to provide air transport to UMMC. Both ARTs and GRTs would document their clinical care of the patient, and once the patient arrived at UMMC, a copy of this clinical documentation would be included with the patient's chart, along with clinical documentation from the referring hospital. These inclusions followed the requirements of the Emergency Medical Treatment and Active Labor Act.<sup>7</sup>

### Variables

From the referring hospitals' documentation, we collected patients' demographic data such as age, sex, type of referring unit (emergency department [ED], intensive care unit, catheterization laboratory, and so on), type of aortic diseases (type A, type B dissection, or others [intramural hematoma, ulcers]), and distance in kilometers between the referring facility and UMMC. We also collected patients' clinical data such as the need of invasive mechanical ventilation and whether they received continuous infusions. We collected patients' SBP, HR, and pain before their arrival at the referring hospitals. These vital signs could be within 60 minutes of the transport team's arrival. From the transport teams' documentation, we identified the type of transport (ART vs. GRT); the number of assessments; and the patients' SBP, HR, and pain when the transport teams departed the referring EDs and while en route, if any.

We also collected any pharmacologic interventions that were administered by the transport team, such as the administration of intravenously pushed medication or the initiation of continuous infusion. Continuous infusions that were started by referring providers were not considered interventions by the transport teams and were

not collected. Each intravenously pushed intervention administered by the transport team was recorded as a separate intervention. However, if the transport team initiated a new continuous infusion and titrated the doses, only the highest dose was recorded.

Vital signs upon arrival at UMMC such as SBP (ARRSBP), HR (ARRHR), and pain (ARRPain) were obtained from the patients' flow sheets at the intensive care unit.

### Outcome Measures

We defined our primary outcome a priori as the percentage of patients whose HRs were within the range of 60 to 80 beats/min during the transfer period. The secondary outcomes were the percentage of patients whose SBP decreased  $\geq 10$  mm Hg within the transfer period<sup>3</sup> and adequate pain control, which was defined as an ARRPain level the same or less than the pain level documented at the departing facility. Other outcomes included the change in the percentages of patients who achieved SBP and HR targets as recommended by the AHA guidelines<sup>2</sup> (ie, HR, < 60 beats/min; SBP, 100–120 mm Hg; and no ARRPain).

### Data Extraction

Data were extracted from records following the process of high-quality chart review standards.<sup>8</sup> Junior investigators, who were blinded to the study hypothesis, were first trained by the principal investigator (Q.K.T.) for data extraction using a standardized Microsoft Access form (Microsoft Corp, Redmond, WA). To avoid bias, independent variables from transport team documentation were extracted separately from dependent variables by different investigators, and then 30% was randomly reviewed by yet another study team member to maintain an interrater agreement of at least 90% throughout the course of data collection. The disagreement between investigators was adjudicated by the principal investigator.

### Data Analysis

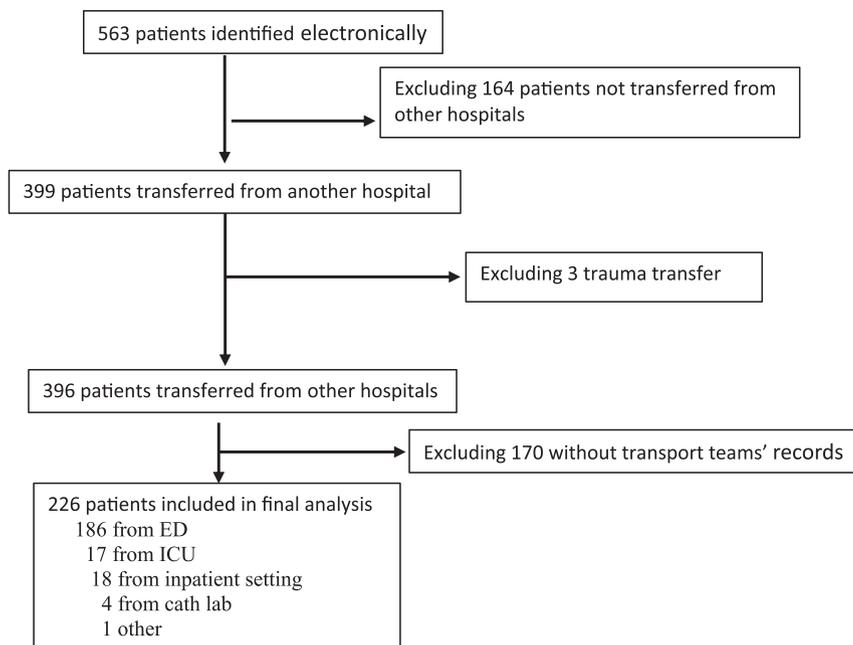
We used descriptive analysis to compare patients' characteristics and outcomes of all interhospital transferred patients in our study according to the mode of transport. Similarly, hemodynamic parameters and pain levels between the departing referring facilities (SBP, HR, and pain) and arrival at the quaternary academic center (ARRSBP, ARRHR, and ARRPain) were also compared. The intratransport effectiveness of hemodynamic management and pain control was assessed using the increment of the number of patients between the departing referring facilities and arrival at the quaternary care facility who achieved target levels and no pain.

Continuous variables were presented as the mean (standard deviation [SD]) or median (interquartile range [IQR]) and categorical variables as percentages. Continuous data (comparison of SBP and HR) were first assessed for normal distribution using the Shapiro-Wilk test. Parametric data were analyzed via the Student *t* test, whereas nonparametric data were analyzed using the Mann-Whitney *U* test; categorical data were compared using the Fisher test or chi-square test when appropriate. For intention-to-treat analysis, we imputed missing SBP, HR, or pain data with the mean of the population's mean. Because there were no reliable methods to evaluate pain among patients requiring invasive mechanical ventilation, we excluded these patients from our analysis of pain management. All 2-tailed *P* values < .05 were considered significant. Statistical calculations were performed using Sigma Plot version 13 (Systat Software, San Jose, CA).

## Results

### Patient Characteristics

We initially identified 563 patients via our electronic medical records. After exclusion, 226 patients met the eligibility criteria and were included in our final analysis (Fig. 1). Fifty-eight (25%) patients



**Figure 1.** The flow diagram for patient selection. ICU = intensive care unit.

were transported by ARTs. The patients' mean age was 61 years (SD = 15 years) (Table 1), and 59% were men. Most patients (82%) were transferred from other hospitals' EDs. Forty-five percent of patients were diagnosed with type A dissection, 41% with type B, and 14% of patients had other types of aortic diseases. The mean distance between the referring facilities and UMMC was 39 km (SD = 44 km).

There was not a significant difference in age, sex, or the type of referring units between the patients transported by ARTs or GRTs. Air transport was more likely to transport type A dissection (57%) compared with ground transport (41%,  $P = .04$ ). Air transport was also involved in a significantly longer distance transport, with a mean travel distance of 76 km (SD = 42 km) compared with 26 km (SD = 37 km) for ground transport ( $P < .001$ ). Both ARTs and GRTs had similar percentages of patients who required invasive mechanical ventilation and continuous infusions at referring facilities before the arrival of the transport team (Table 1). The time interval from the transfer request to the operating room was similar between air transport (170 minutes [IQR = 125–225 minutes]) and ground transport (169 minutes [IQR = 120–223 minutes],  $P = .76$ ) for patients with type A dissection.

#### Outcomes

With respect to the primary outcome between air transport versus ground transport, 54% of all transferred patients achieved an HR of 60 to 80 beats/min upon arrival at UMMC. A higher percentage of ground transport patients achieved this target (58%) compared with air transport patients (43%,  $P = .045$ ; 95% confidence interval [CI], 0.3–0.99). Both ARTs (34%) and GRTs (25%;  $P = .19$ ; 95% CI, 0.3–1.2) had a similar number of patients whose SBP was reduced  $\geq 10$  mm Hg within the transfer time. Additionally, adequate pain control was achieved similarly between ARTs (87%) and GRTs (86%;  $P = .84$ ; 95% CI, 0.4–2.3) (Table 2).

We also assessed transport teams' management effectiveness according to AHA guidelines. Both air transport (12%) and ground transport (5%) patients were associated with low frequencies of patients with ARRHR  $\leq 59$  beats/min ( $P = .13$ ; 95% CI, 0.86–6.8) (Fig. 2). Air transport patients were associated with 28% of patients

achieving the target ARRSBP of 100 to 120 mm Hg compared with 22% among ground transport patients ( $P = .39$ ; 95% CI, 0.68–2.7) (Appendix 1). For patients with no pain upon arrival at the accepting facility (no ARR Pain), pain management was equally effective between air transport and ground transport. Fifty-six percent of air transport patients had no ARR Pain compared with 48% among ground transport patients ( $P = .37$ ; 95% CI, 0.72–2.5) (Fig. 3).

In-hospital mortality was 12% for all patients in our study. Air transport patients were associated with lower (9%) mortality than ground transport patients (13%), but it was not statistically significant ( $P = .43$ ; 95% CI, 0.54–4.2) (Table 2).

#### Pharmacologic Interventions by Transport Teams

There were 142 new pharmacologic interventions administered by transport teams (Appendix 2) for 100 patients (44% of the total). Antihypertensive medications (62%) were the most frequent medication followed by narcotic pain medication (30%). There were 8% of other medications such as vasopressors (4%), sedatives (3%), and antiarrhythmics (1%). Continuous infusions accounted for 56% of the new interventions. The frequencies of beta-blocker and non-beta-blocker antihypertensive medications were similar between ARTs and GRTs. However, ARTs initiated more pain medication than GRTs (41% vs. 25%;  $P = .048$ ; 95% CI, 0.22–0.99). In contrast, GRTs initiated more continuous infusions than ARTs (66% vs. 35%, respectively;  $P < .001$ ; 95% CI, 1.7–7.5).

#### Discussion

Our study showed that GRTs were associated with significantly more patients achieving the target HR of 60 to 80 beats/min than ARTs and no statistically significant differences between transport teams for achieving all other vital sign and pain management targets. Managing HR is the first step in AAOd patient management according to the 2010 AHA guidelines.<sup>2</sup> Winsor et al.,<sup>5</sup> in a study involving 62 patients, reported that ARTs were able to maintain HR at less than 80 beats/min among 57% upon arrival at the accepting facilities. In our study, GRTs, but not ARTs, achieved a similar result. However, our transport teams did have a significant

**Table 1**  
The Characteristics of Patients Transferred From Referring Hospitals to a Quaternary Academic Medical Center With Acute Aortic Diseases

	All Patients (N = 226)	Air Transport (n = 58)	Ground Transport (n = 168)	P Value (Air vs. Ground)
Age, y, mean (SD)	61 (15)	62 (13)	60 (15)	.52
Sex				
Female, n (%)	92 (41)	20 (34)	72 (43)	.26
Male, n (%)	134 (59)	38 (66)	96 (57)	
Type of referring unit, n (%)				
ED	186 (82)	49 (84)	137 (82)	.62
ICU	17 (8)	3 (5)	14 (8)	
Inpatient	18 (8)	5 (9)	13 (8)	
Catheterization laboratory	4 (2)	1 (2)	3 (2)	
Other	1 (0)	0 (0)	1 (0)	
Type of AAoD, n (%)				
Type A	102 (45)	33 (57)	69 (41)	.04
Type B	92 (41)	17 (29)	75 (45)	
Other	32 (14)	8 (14)	24 (14)	.9
Distance of ground travel, mean (km)	39 (44)	76 (42)	26 (37)	<.001
Clinical level of transport team, n (%)				
Nursing level	205 (91)	58 (100)	147 (88)	.005
ALS	21 (9)	0 (0)	21 (12)	
PTA iMV, n (%)	15 (7)	4 (7)	11 (7)	1
PTA continuous infusion, n (%)	93 (41)	29 (50)	64 (41)	.11
Time of travel, minute, median (IQR)	18 (12-28)	23 (17-36)	17 (10-27)	<.001
No. of clinical assessments, median (IQR)	2 (1-3)	2 (1-3)	2 (1-2)	.031
Before transport teams' arrival				
SBP, mm Hg, mean (SD)	138 (31)	134 (30)	139 (31)	.17
HR, beats/min, mean (SD)	78 (15)	79 (17)	78 (15)	.59
Pain, <sup>a</sup> median (IQR)	3 (0-5)	3 (0-5)	3 (0-5)	.88
Departing referring facilities				
SBP, mm Hg, mean (SD)	137 (30)	131 (33)	140 (28)	.07
HR, beats/min, mean (SD)	78 (16)	80 (17)	77 (16)	.32
Pain, <sup>a</sup> median (IQR)	2 (0-5)	2 (0-4)	2 (0-5)	.65
Transfer request to OR, <sup>b</sup> minutes, median (IQR)	170 (121-222)	170 (125-225)	169 (120-223)	.76

AAoD = acute aortic disease; ALS = advanced life support; ED = emergency department; HR = heart rate; ICU = intensive care unit; iMV = invasive mechanical ventilation; IQR = interquartile range; OR = operating room; PTA, before transport team arrival; SD = standard deviation.

<sup>a</sup> Fifteen patients requiring invasive mechanical ventilation at referring facilities, 4 (7%) by air and 11 (7%) by ground, were excluded from pain analysis.

<sup>b</sup> Time intervals from the transfer request to the operating room were calculated for patients with type A dissection only.

**Table 2**  
The Effectiveness of Hemodynamic and Pain Management Among Interhospital Transferred Patients With Acute Aortic Diseases Between Air and Ground Transport Teams

	All Patients (N = 226)	Air Transport (n = 58)	Ground Transport (n = 168)	P Value (Air vs. Ground)
ARRHR 60-80 beats/min, n (%)	123 (54)	25 (43)	98 (58)	.045 <sup>b</sup>
Reduction of SBP $\geq$ 10mm Hg, n (%)	61 (27)	20 (34)	41 (24)	.14
ARRPain <sup>a</sup> same/decreasing, n (%)	182 (86)	47 (87)	135 (86)	.84
In-hospital mortality, n (%)	26 (12)	5 (9)	21 (13)	.42

ARRHR = heart rate upon arrival at the quaternary accepting facility; ARRPain = pain level upon arrival at the quaternary accepting facility; SBP = systolic blood pressure.

Outcomes, at arrival at the quaternary accepting facility, were compared between patients transported via air versus ground. The same/decreasing pain level upon arrival at the quaternary accepting facility was defined as the same or decreasing from the pain level at the departing referring facility.

<sup>a</sup> Fifteen patients requiring invasive mechanical ventilation, 4 (7%) from air transport and 11 (7%) from ground transport group, were excluded from pain analysis.

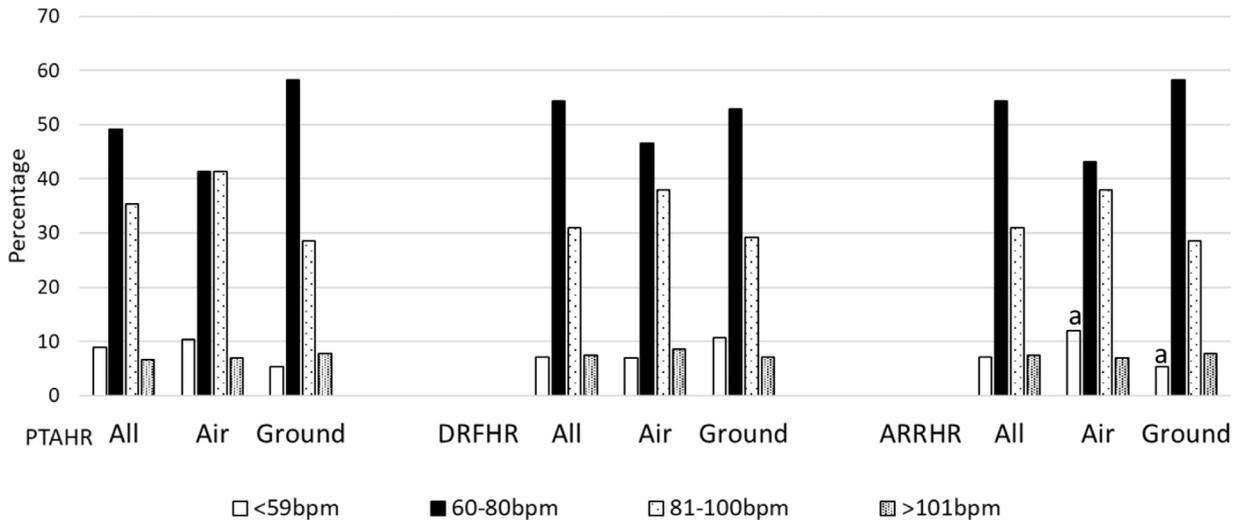
<sup>b</sup> 95% confidence interval, 0.3-0.99.

lower frequency of patients with HR  $\leq$  60 at arrival (Fig. 2) compared with 30% as reported by another study involving 235 patients with AAoDs.<sup>3</sup> The low frequency of patients with HR  $\leq$  60 beats/min according to the 2010 AHA guidelines<sup>2</sup> was likely because of our institution's clinical practice as explained earlier. Furthermore, having an HR at 60 to 80 beats/min temporarily would not affect a patient's outcome; Ohnuma et al's study<sup>9</sup> suggested that 10-year outcomes for type A dissection patients with perioperative ranges of HRs  $\leq$  70 beats/min, 70 to 90 beats/min, and  $\geq$  90 beats/min, were similar.

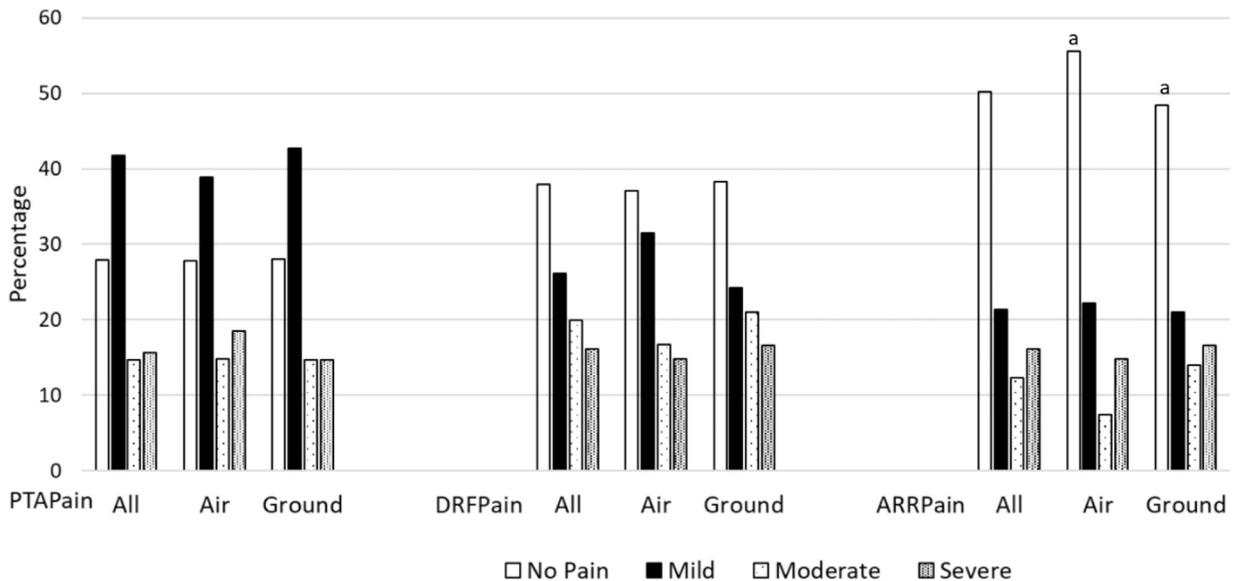
An important step of managing patients with AAoDs is aggressive pain control<sup>1,2</sup> because persistent pain was associated with worse outcomes among patients with acute aortic

dissection.<sup>10</sup> However, there has been no literature about effective pain management of transport teams because previous studies of medical transport and aortic diseases did not investigate pain management.<sup>3-5</sup> Moreover, the AHA guidelines also did not specify what would be acceptable as adequate pain control. According to our predefined outcome of pain control, both ARTs and GRTs did well with pain management during transfer time. Future studies about transport teams and pain management should focus on patient-centered metrics such as how much pain reduction was acceptable by patients and what percentage of patients with no pain would be considered acceptable.

Other than antihypertensive and pain medication, transport teams in our study also initiated vasopressors and sedatives to improve



**Figure 2.** The frequencies of different HR ranges in beats/min of interhospital transferred patients with AAOds at different time points during the transfer process. The percentage of patients with HR  $\leq 59$  beats/min at arrival at the quaternary accepting facility (ARRHR) between air versus ground transport was compared. <sup>a</sup> $P=0.13$  (95% CI, 0.86-6.8). DRFHR = heart rate at the departing referring facilities; PTAHR = heart rate before the arrival of the transport teams.



**Figure 3.** The frequencies of different pain levels of interhospital transferred patients at different times during the transfer process. The percentage of patients with no pain upon arrival at the quaternary accepting facility (ARRPain) between air versus ground transport was compared. Pain levels were divided into groups according to pain score: no pain (pain score = 0), mild (pain = 1-3), moderate (pain = 4-6), and severe (pain = 7-10). <sup>a</sup> $P=.37$  (95% CI, 0.72-2.5). DRFPain = the pain level at the departing referring facilities; PTA-Pain = pain levels at the referring facilities before the arrival of the transport teams.

patients' hemodynamics and comfort during transport. These interventions were not reported in studies by others because they<sup>3,5</sup> excluded hypotensive patients.

Our observation that GRTs of interhospital transferred patients with AAOds were associated with similar outcomes compared with ARTs was consistent with previous studies. The association between improved outcomes and ARTs was observed in trauma patients<sup>11,12</sup> but not in other medical conditions. There was no association between ARTs with better outcomes in cardiac patients,<sup>13</sup> patients with ST-elevation myocardial infarction,<sup>14</sup> or type A aortic dissection.<sup>15</sup> Most patients with type A dissection in our study were transported by air, probably because the referring

physicians would hope to get these patients to surgery faster. However, our observation that both air transport and ground transport patients in our study had similar time intervals between the transfer request and operating room time was consistent with a previous study<sup>15</sup> that ARTs and GRTs had similar transport times. Although a detailed investigation about our observation was beyond the focus of this study, a study by Nicholl et al<sup>16</sup> suggested that air transport was associated with a longer activation time, response time, and on-scene time than ground transport and, mostly, a longer distance. Therefore, although air transport has a shorter transport time, air transport may result in a similar time interval to surgery.

Therefore, referring physicians may consider both modalities of transport when the referring facilities are within a reasonable distance to the accepting facilities to transfer patients with AAOds. If no immediate surgery is needed and the distance is reasonable, ground transport may be an equivalent option to air transport because outcomes are similar, but air transport was associated with an 8 times higher cost than ground transport among patients with type A dissection.<sup>16</sup>

Our study has several strengths. It is the first study to our knowledge to investigate transport teams' management of pain and to compare the management effectiveness between ARTs and GRTs. Furthermore, we also included hypotensive (SBP < 90 mm Hg) and bradycardic (HR < 60 beats/min) patients. We believe that future studies on the effectiveness of transport teams should include pharmacologic interventions and any dosage titrations to better assess the effectiveness of patient care.

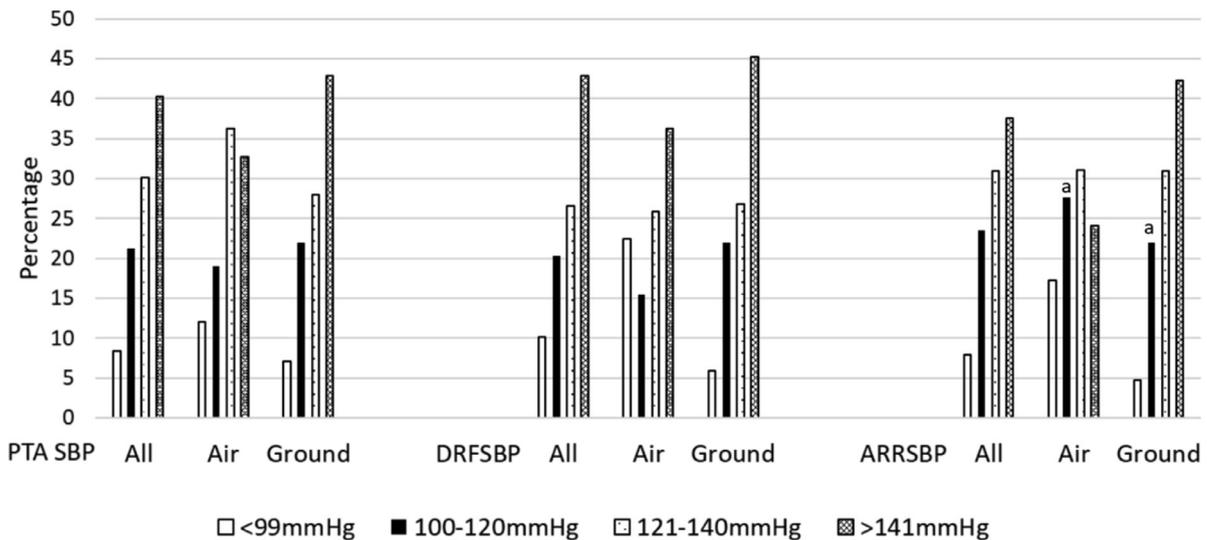
**Limitations**

Our study has several limitations. Documentation by transportation teams is generally poor, requiring the exclusion of many patients. Another limitation of our study was that it involved multiple medical transport companies, and we cannot be assured they all had similar skills and scope of practice. As a result, this may limit our study's generalizability to other systems.

**Conclusion**

Ground transport was associated with higher percentage of inter-hospital transferred patients with AAOds achieving the predefined target of HR compared with air transport. However, intratransport management of SBP, pain, and outcomes among these AAOd patients were similar whether patients were transported by air or ground. Therefore, GRTs are as effective as air transport for patients with AAOds.

**Appendix 1**



The frequencies of different systolic blood pressure (SBP) ranges of interhospital transferred patients at different time points during the transfer process. The percentage of patients with a systolic blood pressure of 100 to 120 mm Hg upon arrival at the quaternary care facility (ARRSBP) between air versus ground transport was compared. <sup>a</sup>P = .39 (95% confidence interval, 0.68-2.7). DRFSBP = systolic blood pressure at the departing referring facilities; PTA SBP, systolic blood pressure before the arrival of the transport teams.

**Appendix 2**

**New Pharmacologic Interventions Initiated by Transport Teams**

	All Interventions (N=142)	Air Transport (N=46)	Ground Transport (N=96)	p-value (Air vs Ground)
Unique patients, N	100	30	70	N/A
Anti-hypertensive, N (%)	88 (62)	27 (59)	61 (64)	0.58
Beta-blocker	49 (56) <sup>a</sup>	15 (56)	34 (56)	1
Non-Beta blocker	39 (44) <sup>a</sup>	12 (44)	27 (44)	
Pain medication, N (%)	43 (30)	19 (41)	24 (25)	0.048 <sup>b</sup>
Vasopressor, N (%)	6 (4)	0	6	N/A
Sedatives, N (%)	4 (3)	0	4	
Anti-arrhythmia, N (%)	1 (1)	0	1	
Infusion, N (%)	79 (56)	16 (35)	63 (66)	<0.001 <sup>c</sup>

N/A = statistical analysis not performed.

<sup>a</sup> Percentages were calculated from the numbers of antihypertensive medications, not from the total numbers of pharmacologic interventions.

<sup>b</sup> 95% CI 0.22-0.99.

<sup>c</sup> 95% CI 1.7-7.5.

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