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Mortality rates in physician staffed ground vs. air ambulance for severe trauma patients: retrospective analysis of the Japanese nationwide trauma registry

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While both physician-staffed ground ambulances (GA) and air ambulances (AA) can function as viable transportation options in severe trauma cases, no study has directly compared their efficacies. We aimed to compare the effects of physician-staffed GA and AA on the outcomes of patients with trauma. This retrospective cohort study used records from the Japan Trauma Data Bank collected between April 2004 and December 2021. Data from patients aged ≥ 15 years with an Injury Severity Score > 15, who were directly transferred from the injury scenes, were analyzed. Patients were categorized into two groups based on the transportation method: physician-staffed GA and AA. The primary outcome measure (in-hospital mortality) and secondary outcomes (time to emergency department arrival, time to physician contact and prehospital treatment) were compared between the propensity score-matched groups. Of the 3,508 propensity score-matched pairs, the AA group exhibited significantly lower in-hospital mortality (810 [23.0%]) than the GA group (894 [25.4%]), odds ratio: 0.88 (95% confidence interval [CI] 0.79–0.98). Time to emergency department was significantly longer in the AA group than in the GA group. While patients in the GA group were likely to receive more treatments during transportation, patients in the AA group were likely to receive more surgical interventions after hospital arrival.

Keywords Emergency medical service, Helicopter, Injury, Prehospital care, Trauma

In many countries, physicians and trauma surgeons are occasionally dispatched to the scene of injury in cases of severe trauma. Although the effect of physician-staffed transport on patient outcomes has not been fully evaluated, previous studies have associated it with reduced mortality rates of patients with trauma due to better proficiency in procedures and diagnostic techniques compared to transports staffed by paramedics only[1–6].

The primary patient transport methods used are ground and air ambulances. Previous studies comparing transport methods found better outcomes when patients were transported with helicopters[7–9], whereas others found no differences between the two modes[10,11]. However, no study has clarified which transport method is better when a physician is on board. Although transportation time may be longer with physician-staffed ground ambulances (GA) than a physician-staffed air ambulance (AA), repeated assessments and therapeutic procedures can be performed during transport, whereas confined space and communication challenges in AAs limit such interventions[5,6,9].

Physician-staffed GA are commonly used in Japan. Physician-staffed AA are also available; however, their operation is depends on the weather and daylight hours. Owing to the high operating costs and limited operating time of AA, the comparative effectiveness of a physician-staffed AA over a physician-staffed GA should be

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evaluated from the perspective of establishing an efficient prehospital emergency system. This study aimed to compare the effects of physician-staffed AA and GA on patient outcomes using a nationwide trauma registry.

Methods

Study design and context

This retrospective descriptive study used data from the Japan Trauma Data Bank (JTDB) spanning from April 2004 to December 2021. Since established in 2003, the JTDB serves as a nationwide trauma registry mandating the registration of all trauma patients with an abbreviated injury scale (AIS) score of ≥ 3, regardless of the anatomical site of injury. There are no exclusion criteria. Throughout the study duration, the JTDB collected records from 303 hospitals wherein 242 are tertiary emergency centers. Sixty-two hospitals operate physician-staffed AA services, while GA with a physician on board is operated in 279 hospitals. The database encompasses details on injury mechanisms, modes of transportation, prehospital timelines, and baseline patient characteristics, including vital signs at the injury scene and upon emergency department (ED) arrival, procedures performed, and survival status of patients at hospital discharge. Additionally, procedures performed in the emergency and operating rooms post-admission are documented.

In Japan, the operation of prehospital physician teams, including dispatch criteria and operating hours, varies depending on the medical control area, with coverage areas differing significantly between urban and rural regions. Physicians are transported either by car or helicopter, depending on the respective medical control area's protocol. While not always trauma surgeons, these physicians typically work in EDs and are trained to provide fundamental prehospital trauma management, such as sonography assessment, tracheal intubation, chest drainage, intraosseous infusion, and temporary hemostasis using a tourniquet.

This study adhered to the principles outlined in the 1964 Declaration of Helsinki and its subsequent amendments and received approval from the Ethics Committee of Tsuchiura Kyodo General Hospital (approval number: 2022FY10). Due to its retrospective nature, the requirement for informed consent was waived by the Ethics Committee of Tsuchiura Kyodo General Hospital, with an opt-out method implemented, allowing individuals to decline participation via online information disclosure at the hospital.

Patient selection

Inclusion criteria included patients aged ≥ 15 years who sustained injuries with an Injury Severity Score (ISS) of > 15 and patients who were directly transferred from the injury scene with the availability of specific information regarding injury times, physician contact, and hospital arrival. Exclusion criteria were patients who experienced cardiac arrest during contact with paramedic, those with unsalvageable injuries (AIS = 6), individuals with missing essential data for analyses, and cases with unrealistic or outlier values in prehospital timelines, which were identified statistically and subsequently removed. To examine common emergency transport cases, cases with outlier values where the time from injury to physician contact exceeded 90 min were also excluded based on clinical perspective.

Data collection

Data extracted from the JTDB included patient demographics (age, sex, injury year), prehospital vital signs, transportation details, prehospital treatment, vital signs upon ED arrival, Glasgow Coma Scale and Japan Coma Scale (JCS) scores[12], AIS, ISS, surgical interventions, and survival status at hospital discharge. The JCS has four main categories that can be subdivided according to eye response test[13]. It evaluates consciousness levels using a single-, double- or triple-digit numeric code, categorized into three levels of responsiveness (Supplemental Table 1). Eligible patients were categorized into two groups: those transported by physician-staffed GA (GA group) and those transported by physician-staffed AA (AA group). Patients were differentiated based on the timing of physician contact and hospital arrival, with injury times divided into four 6-h zones starting at 00:00. The primary study outcome was the in-hospital mortality rate.

Definition and outcomes

Consciousness levels at the injury scene were assessed using the JCS[12]. Injury time aligned with the time of the emergency medical service call. Day and night shifts were defined as 08:00 a.m. to 17:59 p.m. and 18:00 p.m. to 07:59 a.m., respectively. Primary outcome measures included in-hospital mortality, while secondary outcomes comprised the time from injury to ED arrival, time from injury to physician contact, prehospital treatment, and changes in vital signs at physician contact and ED arrival.

Statistical analysis

Given the uneven distribution of patient characteristics between the GA and AA groups, propensity score matching analysis was employed for outcome comparison. A logistic regression model estimated the propensity score for each patient based on various factors, including age, sex, injury mechanism, vital signs, AIS, and ISS, which were selected based on a chronological perspective and subject matter knowledge. Propensity score matching yielded 1:1 matched pairs from the GA and AA groups, with match balance assessed using the absolute standardized mean difference. Subgroup analysis within the propensity score-matched cohort explored potential beneficiaries of physician-staffed GA transport management.

Several sensitivity analyses were performed: (i) a multivariate logistic regression model using the same variables used in the primary analysis, (ii) a propensity score-matching analysis, in which age, pre-hospital vital signs, and vital signs upon ED arrival were treated as categorical variables, and (iii) a propensity score-matching analysis in the population among whom the time from injury to physician contact was less than 120 min. Statistical analyses were conducted using R 4.3.1. A significance level set at two-sided $p < 0.05$ for all analyses.

Results

A diagram of the patient selection process is shown in Fig. 1. Data from 16,181 patients were used for the analyses, with a study period from April 2004 to December 2021. The number of patients in the GA group was 4,170, while that in the AA group was 7,838. After propensity matching, 3,508 patients in each group were matched. The backgrounds of all patients and matched patients are presented in Table 1. All the absolute mean differences of the variables used for propensity score estimation was < 10%, indicating well-matched balance. The median ages of the matched patients in the GA and AA groups were 61 and 62 years, respectively. The GA and AA groups comprised 2509 (75.4%) and 2511 (71.5%) male patients, respectively. The most common type of trauma was blunt trauma, which accounted for 3397 (96.8%) and 3403 (97.0%) cases in the two groups, respectively. Regarding the AIS codes for trauma, both groups had a median score of 3 for the head and chest, and a median score of 25 for ISS.

Regarding the primary outcome, in-hospital mortality was observed in 810 patients (23.0%) in the AA group and in 894 patients (25.4%) in the GA group; the AA group had a significantly lower mortality rate (the odds ratio, 0.86; 95% confidence interval, 0.77–0.96, $p < 0.001$). A comparison of prehospital treatment, time from injury to physician contact, time from injury to ED, vital signs in the ED, hospital treatment, and mortality for both groups is shown in Table 2. In prehospital treatment, chest compression, intubation, mechanical ventilation, pelvic binder use, and tourniquet use were performed more frequently in the GA group. Both the time from injury to physician contact and the time from injury to ED arrival were shorter in the GA group than in the AA group. The vital signs in the ED were similar between the two groups. Surgical intervention was performed more frequently in the AA than in GA group (48.0% vs. 52.0%). Subgroup analysis (Fig. 2) showed a trend towards lower mortality in the AA group for most items.

The sensitivity analyses using a logistic regression model, a propensity score matching model using categorized variables, and a propensity score-matching model in a population among whom the time from injury to physician contact was less than 120 min showed similar results to the main analysis (Supplemental Tables 2, 3, 4, and 5).

Discussion

This study compared the mortality rates of patients with severe trauma transported by physician-staffed GA with those transported by physician-staffed AA. More frequent treatments during transportation and shorter transport times to a hospital were observed in the GA group, while the AA group had a lower mortality rate. This study represents the first attempt to directly compare the efficacy of physician-staffed GA transport with that of physician-staffed AA transport. Regarding in-hospital mortality, no specific significant interaction was observed in the subgroup analysis, indicating the consistency of the main results. The sensitivity analysis, using categorical variables for age and vital signs based on clinically meaningful cut-off values, demonstrated similar results from the main analysis, which corroborated the robustness and clinical significance of the main analysis.

Considering that the survival rate was lower in the GA group, which received more treatments during transport and had a shorter total transport time, suggests that improving patient survival rates simply by prehospital treatment or transport time is challenging. In many cases in Japan, patients with cardiac arrest are not

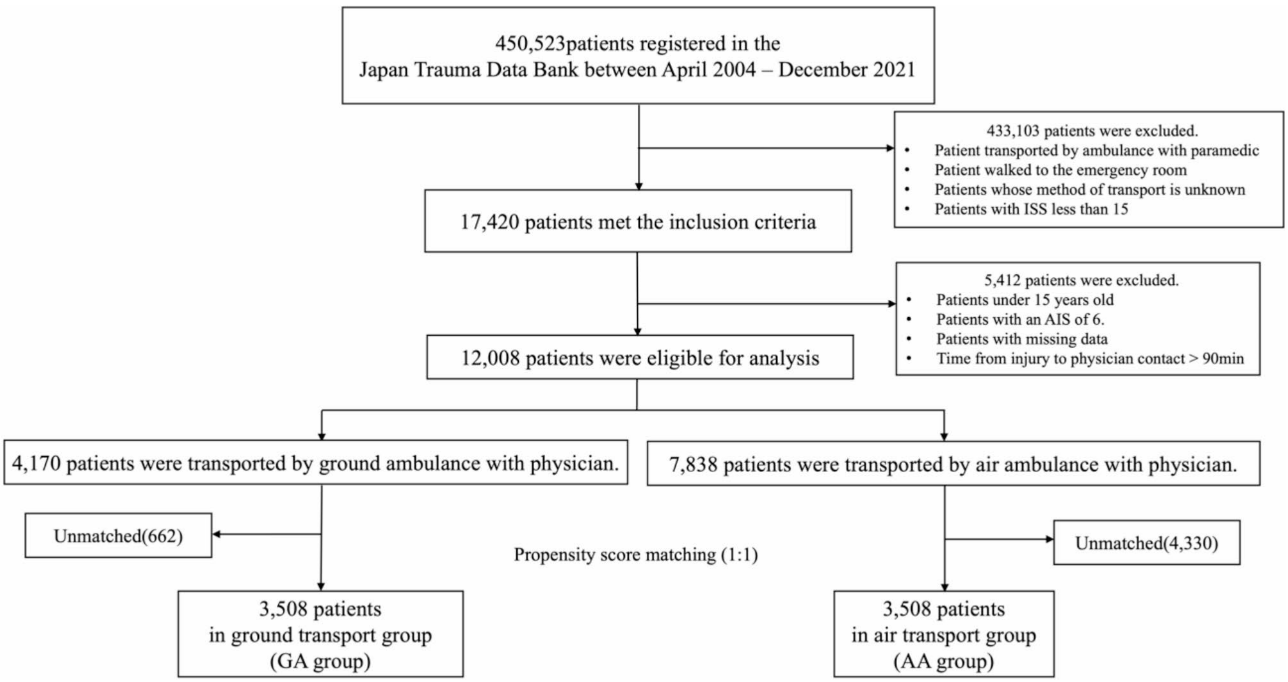

Fig. 1. Diagram of the process of patient selection. *AIS* abbreviated injury scale, *ISS* injury severity score.

Variables	Overall study cohort			Propensity score-matched cohort		
	GA group ($n=4170$)	AA group ($n=7838$)	ASMD	GA group ($n=3508$)	AA group ($n=3508$)	ASMD
*Age, years, median [IQR]	59 [39–73]	64 [47–75]	0.201	61 [41–74]	62 [44–73]	0.007
*Sex, male, N (%)	2923 (70.1)	5910 (75.4)	0.075	2509 (71.5)	2511 (71.5)	< 0.001
*Mechanism, N (%)			0.120			0.002
Blunt	3983 (95.5)	7676 (97.9)		3397 (96.8)	3403 (97.0)	
Penetrate	153 (3.6)	128 (1.6)		90 (2.57)	85 (2.42)	
*Time zone, N (%)			0.790			0.009
Daytime shift	2031 (48.7)	6124 (78.1)		2020 (57.5)	1997 (56.9)	
Nighttime shift	2139 (51.3)	1714 (21.8)		1488 (42.4)	1511 (43.0)	
Time of injury, o'clock, N (%)			0.25			0.134
0–6	445 (10.6)	171 (2.1)		432 (12.6)	146 (4.1)	
6–12	1349 (32.3)	3365 (42.9)		1256 (35.8)	1619 (46.1)	
12–18	1516 (36.3)	3975 (50.7)		1444 (41.6)	1453 (41.4)	
18–24	860 (20.6)	327 (4.1)		376 (10.7)	290 (8.2)	
Pre-hospital vital signs, median [IQR]						
*JCS	10 [1–300]	2 [0–100]	0.360	3 [1–200]	3 [1–200]	0.005
*PR, beat pear minute	85 [70–102]	84 [70–100]	0.023	84 [69–101]	84 [70–100]	0.024
*sBP, mmHg	130 [106–154]	131 [110–156]	0.072	125 [99–151]	127 [100–151]	0.020
dBP, mmHg	80 [63–94]	79 [64–93]	0.001	76 [59–91]	76 [60–91]	0.004
*RR, breath per minute	20 [18–26]	24 [18–28]	0.215	21 [18–28]	22 [18–26]	0.025
*AIS, median [IQR]						
*Head	3 [0–4]	2 [0–4]	0.089	3 [0–4]	3 [0–4]	< 0.001
*Face	0 [0–1]	0 [0–0]	0.084	0 [0–0]	0 [0–0]	0.009
*Neck	0 [0–0]	0 [0–0]	0.071	0 [0–0]	0 [0–0]	0.012
*Chest	3 [0–4]	3 [0–4]	0.107	3 [0–4]	3 [0–4]	0.008
*Abdomen	0 [0–0]	0 [0–0]	0.069	0 [0–0]	0 [0–0]	0.006
*Spine	0 [0–2]	0 [0–2]	0.122	0 [0–2]	0 [0–2]	0.009
*Upper Ex	0 [0–2]	0 [0–2]	0.016	0 [0–2]	0 [0–2]	0.017
*Pelvis lower Ex	0 [0–3]	0 [0–2]	0.169	0 [0–3]	0 [0–3]	0.007
*Surface	0 [0–0]	0 [0–0]	0.040	0 [0–0]	0 [0–0]	0.007
*ISS, median [IQR]	25 [19–34]	25 [18–30]	0.184	25 [18–34]	25 [18–33]	0.009

Table 1. Characteristics of the patients before and after propensity score matching. *ASMD* absolute standardized mean difference, *GA* physician-staffed ground ambulance transport, *AA* physician-staffed air ambulance transport, *JCS* Japan Coma Scale, *PR* pulse rate, *sBP* systolic blood pressure, *dBP* diastolic blood pressure, *RR* respiratory rate, *AIS* abbreviated injury scale, *ISS* injury severity score, *Upper Ex* upper extremities, *Pelvis lower Ex* pelvic lower extremities. *Variables used in propensity score matching.

transported by AA but by GA with a physician[1,3,6,14,15]. Although this study excluded patients who experienced cardiac arrest at the time of contact with paramedics, those experiencing cardiac arrest at the time of contact with physicians could not be excluded because of a lack of information, potentially leading to worse outcomes in the GA group. This can be considered from the fact that the PR and HR0-39 bpm values are higher in the GA group for the categorized pre-hospital and emergency department vital signs. In addition, patients in the AA group were likely to be transported to facilities providing high-level trauma care, such as favorable accessibility for appropriate emergency surgery, since AA can transport a patient to the appropriate hospital in the distant place in a shorter time than GA. Notably, the AA group had significantly more cases of surgical intervention than the GA group (52.0% vs. 48.0%).

In this study, the AA group had a longer transport time than did the GA group. Similarly, the time from injury to physician contact was longer in the AA group, with ED arrival delayed by an additional 10 min. One possible reason for this is the nature of AA, where any therapeutic intervention during flight is challenging owing to unstable circumstances, such as noise and rolling in confined spaces[9,10,14–16]. Flight physicians are generally required to complete the necessary treatments before take-off, potentially extending total prehospital time[17,18]. Another reason could be the time required to transfer a patient from a primary-dispatched GA, which is an ambulance dispatched from a fire department to a physician-staffed AA. The rendezvous of AA and primary-dispatched GA is permitted at pre-specified limited locations, which sometimes requires additional time for ground transportation to contact AA. Because accessibility to large hospitals is favorable in most of Japan, the advantage of high helicopter speed may be canceled out[1,14,15]. While it takes longer transport time in

Variables	Overall study cohort			Propensity score-matched cohort		
	GA group (n = 4170)	AA group (n = 7838)	p-value	GA group (n = 3508)	AA group (n = 3508)	p-value
Prehospital treatment, N (%)						
Airway	68 (2.1)	64 (1.0)	0.002	60 (1.7)	46 (1.3)	0.002
Airway Secure	595 (14.2)	567 (7.2)	< 0.001	428 (12.2)	319 (9.0)	< 0.001
Backboard	2589 (62.0)	4940 (63.0)	0.320	2168 (61.8)	2107 (60.0)	< 0.001
Chest Compression	387 (9.28)	209 (2.6)	< 0.001	267 (7.6)	137 (3.9)	< 0.001
Neck collar	2358 (56.5)	4575 (58.3)	0.056	2002 (57.0)	1966 (56.0)	0.053
Defibrillation	32 (1.0)	24 (0.3)	< 0.001	36 (1.0)	31 (0.9)	0.25
Intubation	31 (3.0)	37 (2.1)	0.166	1542 (43.9)	1409 (40.1)	< 0.001
Intravenous drip	1348 (32.3)	1696 (21.6)	< 0.001	1125 (32.0)	764 (21.7)	< 0.001
Mechanical Ventilation	424 (10.1)	325 (4.1)	< 0.001	299 (8.5)	186 (5.3)	< 0.001
Oxygenation	2745 (65.8)	5082 (64.8)	0.287	2307 (65.7)	2156 (61.4)	< 0.001
Pelvic Binder	4 (0.4)	10 (0.6)	0.610	1502 (42.8)	1418 (40.4)	< 0.001
Shockpants	5 (0.1)	7 (0.1)	0.779	12 (0.3)	10 (0.3)	0.40
Splint	35 (0.8)	55 (0.7)	0.470	31 (0.8)	27 (0.7)	0.26
Tourniquet	3 (0.3)	12 (0.79)	0.218	1459 (41.6)	1371 (39.1)	< 0.001
Transfusion	1 (0.1)	3 (0.2)	0.958	0 (0)	0 (0)	1
Time from injury to physician contact, min, median [IQR]	12 [8–28]	13 [8–29]	< 0.001	12 [8–29]	14 [8–32]	< 0.001
Time from injury to ED arrival, min, median [IQR]	45 [32–62]	57 [43–75]	< 0.001	45 [32–63]	55 [40–72]	< 0.001
Vital signs upon ED arrival, median [IQR]						
BT, ℃	36.2 [35.6–36.7]	36.3 [35.8–36.8]	< 0.001	36.2 [35.5–36.7]	36.2 [35.6–36.7]	< 0.001
HR, beat per minute	84 [68–102]	84 [70–100]	< 0.001	84 [69–101]	84 [69–101]	0.003
sBP, mmHg	122 [86–148]	129 [103–152]	< 0.001	125 [94–150]	126 [96–150]	0.051
dBP, mmHg	76 [58–91]	78 [62–90]	< 0.001	75 [56–90]	74 [56–90]	0.65
RR, breath per minute	20 [15–25]	20 [17–25]	< 0.001	20 [16–25]	20 [16–25]	0.040
GCS	13 [3–14]	14 [7–15]	< 0.001	13 [5–15]	13 [6–15]	0.002
JCS	10 [1–300]	2 [0–100]	< 0.001	10 [1–200]	3 [1–200]	0.026
RTS, median [IQR]	6.90 [4.09–7.84]	7.84 [5.97–7.84]	< 0.001	7.11 [5.03–7.84]	7.55 [5.03–7.84]	< 0.001
FAST, positive, N (%)	548 (13.1)	888 (11.3)	< 0.001	442 (12.6)	450 (12.8)	< 0.001
Whole body CT, N (%)	3558 (88.3)	7212 (92.0)	< 0.001	3032 (86.4)	3156 (89.9)	< 0.001
Operation, N (%)	2014 (48.3)	3966 (50.6)	0.017	1686 (48.0)	1825 (52.0)	< 0.001
Outcome, death, N (%)	1258 (30.1)	1501 (19.2)	< 0.001	894 (25.4)	810 (23.0)	< 0.001

Table 2. Post-transportation procedures and information in the ED. *GA group* physician-staffed ground ambulance transport group, *AA group* physician-staffed air ambulance transport group, *ED* emergency department, *BT* blood temperature, *HR* heart rate, *sBP* systolic blood pressure, *dBP* diastolic blood pressure, *RR* respiratory rate, *GCS* Glasgow Coma Scale, *JCS* Japan Coma Scale, *RTS* revised trauma score, *FAST* focused assessment with sonography for trauma, *CT* Computed Tomography.

the AA group, it might be beneficial for patient outcomes that a flight physician achieves temporal fixation of physiological status before take-off.

Limitations
This study had several limitations. As this was a retrospective study using a large database, residual confounding factors existed, including changes in vital signs after paramedic contact, proficiency of the dispatched physician, accessibility for emergency surgery, and the level of the hospital to which the patient was transported. The information on the level of the hospital, which could have had a significant impact on survival rates, was not available in the JTDB. These potential residual confounding might have caused selection bias. In addition, regional factors were not considered. As prehospital trauma care systems in Japan are developed in each medical control area, they may differ. The direction and extent of the effects may have differed depending on the distribution density of tertiary emergency medical centers and differences in regional prehospital systems such as the criteria to select a hospital to transport. Although data from a nationwide database were analyzed, registration errors may have occurred at different institutions. Finally, because prehospital activities by physicians were not uniformly protocolized, the quality of the activities might have differed.

Conclusions
In emergency transport with physicians for critical trauma patients, air ambulance transport was significantly associated with lower mortality rates than ground ambulance transport. However, considering potential biases including the lack in information on regional and hospital disparities, further research will be needed.

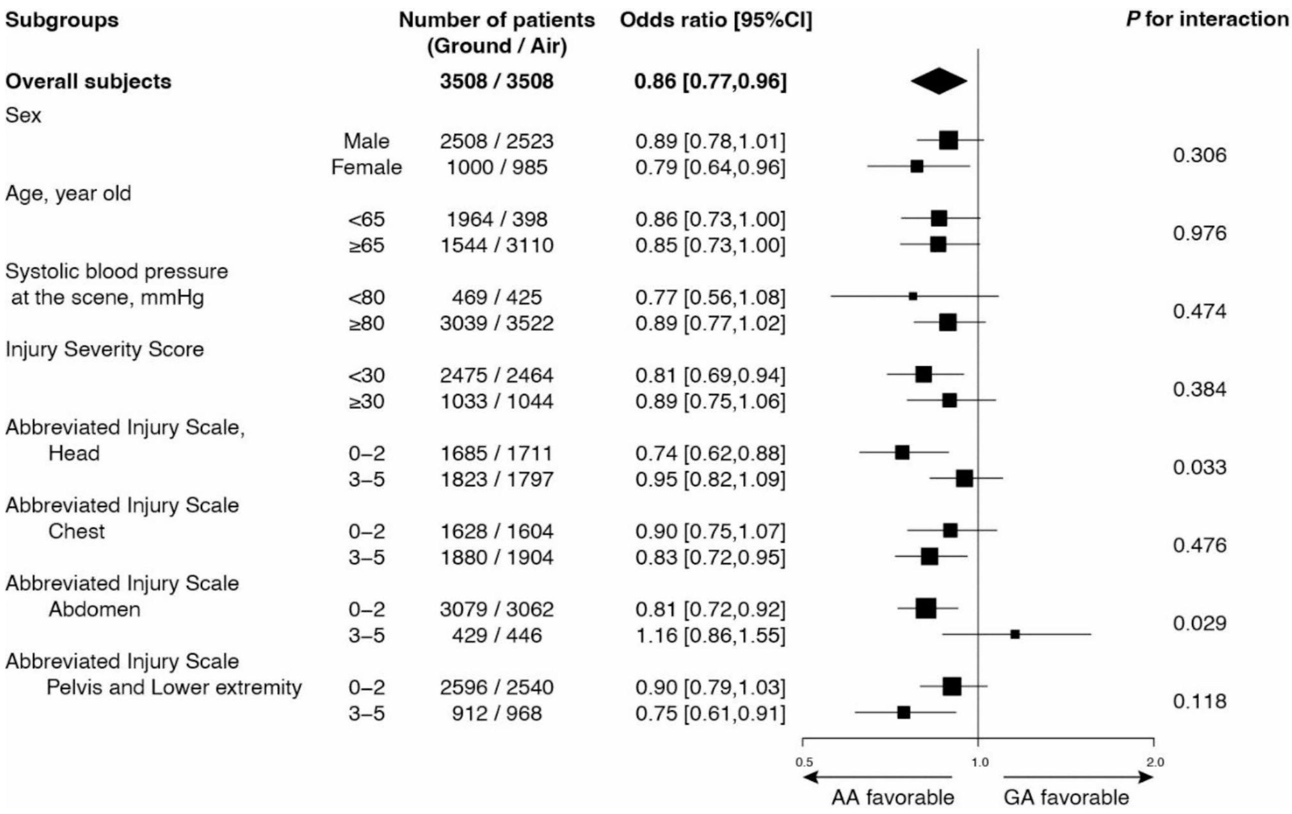

Fig. 2. Subgroup analysis for the effect of air ambulance transport on in-hospital management. *CI* confidence interval.

Data availability

An overview of the Japan Trauma Data Bank (JTDB) is available at http://www.jtcr-jatec.org/traumabank/index.htm. The detailed data in the JTDB that support the findings of this study are available from Japan Trauma Care and Research; however, restrictions apply to the availability of these data, which were used under license for the current study and, hence, are not publicly available. However, are available from the corresponding author on reasonable request.

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Author contributions
TA drafted and revised the manuscript, prepared the study concept and design, performed the statistical analysis and data interpretation, and supervised the study; AE revised the manuscript, prepared the study concept and design, and performed data interpretation; RY, KY, KS, HO, and HH performed data acquisition and revised the manuscript; YO and KM revised the manuscript and interpreted the data. All authors accept responsibility for the conduct of research and final approval and have read and approved the final manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Consent to participate/Consent to publish
As this is a retrospective observational study, informed consent is not required, but the hospital's website includes an opt-out option, and it is clearly stated that patients can opt out of the study and refuse to participate.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-89489-w.

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