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Research article

# Impact of interhospital transfer on emergency department timeliness of care and in-hospital outcomes of adult non-trauma patients

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ABSTRACT

*Background:* Patients who present to the emergency department (ED) from interhospital transfer (IHT) and non-IHT are known to have differences in various clinical outcomes including mortality. The ED timeliness of care is an effective indicator of the quality of ED care and operational efficiency. The impact of IHT on ED timeliness of care remains unclear. We evaluated the association between IHT and ED timeliness of care or in-hospital outcomes in adult non-trauma patients.

*Methods:* Data of consecutive hospital admission of adult non-trauma patients who visited the ED of a medical center from January 2018 to Jun 2020 were retrospectively analyzed. The patients were divided into IHT and non-IHT cohorts. Various data were recorded. The ED length of stay (LOS) was measured as the outcome of ED timeliness of care, while hospital LOS and in-hospital death were measured as the in-hospital outcomes. Multiple regression analyses were performed using unmatched and propensity-matched cohorts. In the later analyses, both groups were propensity matched for sex, age, and other covariates that showed significant differences between two groups to achieve a 1:4 balanced cohort.

*Results:* Data on 1856 IHT patients and 16295 non-IHT patients were analyzed. IHT was associated with a shorter ED LOS, longer hospital LOS, and higher odds of in-hospital death compared with non-IHT in unmatched and propensity-matched analyses. The shorter ED LOS was due to the slightly longer interval of arrival to ED physicians (~1 min) and considerably shorter intervals of ED physicians to decision (~120 min) and decision to departure (~105 min). Risk stratification revealed that IHT was associated with a shorter ED LOS in patients with all levels (1–5) of Taiwan Triage and Acuity Scale (TTAS) and associated with longer hospital LOS and higher odds of in-hospital death in patients with TTAS level $\geq$3.

*Conclusions:* IHT was associated with a shorter ED LOS, longer hospital LOS, and higher odds of in-hospital death in adult non-trauma patients compared with non-IHT. The expedited ED timeliness of care in the IHT cohort was due to considerably shorter intervals of both ED physicians to decision and decision to disposition.

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## 1. Introduction

The emergency department (ED) is the front-line defense of any health care system and is a highly effective setting for the urgent and lifesaving care of patients with various clinical conditions [1,2]. Optimizing the ED care of patients is important to meet their demand based on their characteristics and to improve their outcomes [1,2]. The ED receives patients from interhospital transfer (IHT) or non-IHT. Patients who undergo IHT from one hospital to a referral center are often medically complex and require more advanced care with qualified staff, specialized services, and sophisticated technologies [3,4]. In particular, non-trauma patients remain the major population of ED visits and usually have heterogeneous types of diseases [5,6]. Non-trauma patients who present to the ED from IHT and non-IHT exhibit different properties [7,8]. As such, much interest has been paid to investigate the differences in various clinical outcomes between these two patient groups [8–22]. However, from the perspective of ED care, one important issue remains to be addressed.

Previous studies comparing clinical outcomes in non-trauma patients from IHT and non-IHT focused on specialized conditions, such as surgery [9–11], stroke [12–14], acute myocardial infarction [15–18], critical illness [17–20], acute kidney injury [21], and severe sepsis [22]. In these studies, non-trauma patients were inter-transferred to referral special care units [9–11,15,18,19], or their data were collected from registry or healthcare datasets [7,8,12–14,16,17,21,22]. As such, these studies focused on clinical outcomes, such as hospital length of stay (LOS) [8–10,20], functional outcomes [12,14], mortality [, and medical cost [8,9,20,22]. To this end, the ED timeliness of care is an effective indicator of the ED performance and operational efficiency and can be measured by ED LOS [23,24], which is defined as the time interval from patient arrival to leaving the ED [25]. ED LOS is associated with patient characteristics and clinical outcomes [26–28]. However, the impact of IHT on ED timeliness of care in non-trauma patients remains unclear. Addressing this important issue is clinically important because the findings may provide helpful information for optimizing ED care for IHT patients who are inherently "sicker" than non-IHT patients [8].

This retrospective cohort study aimed to compare the ED timeliness of care and in-hospital outcomes of adult non-trauma patients who presented to the ED from IHT and non-IHT in an academic medical center. We explored the impact of IHT on both the ED timeliness of care and in-hospital outcomes because hospital LOS and in-hospital death are two immediate clinical outcomes after disposition from ED that are associated with ED LOS [8,29]. The Real-world data analyses using unmatched and propensity-matched cohorts were performed to achieve this goal.

## 2. Methods

### 2.1. Study design and setting

We performed a retrospective cohort study in a tertiary referral hospital. This hospital is the only academic medical center on the

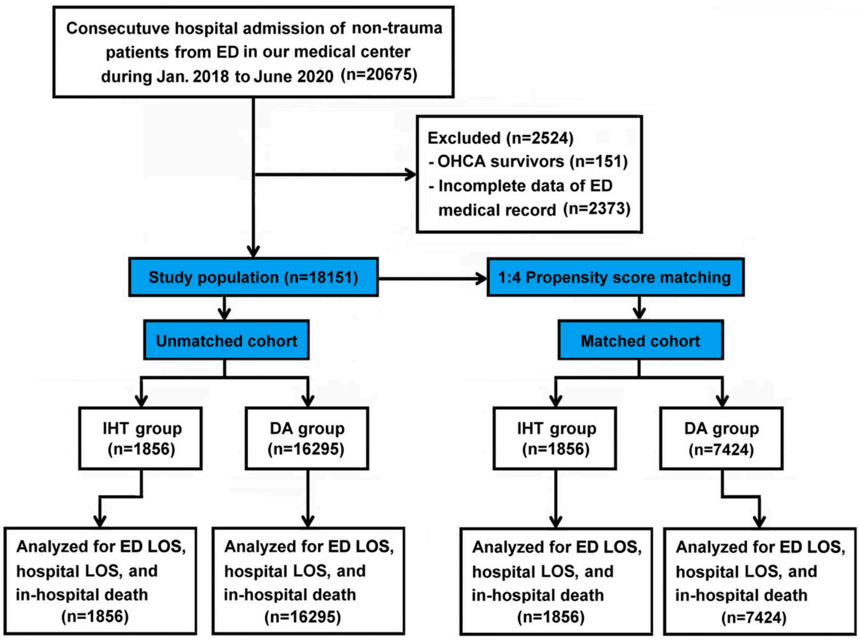


**Fig. 1.** Flowchart of patient selection. ED, emergency department; OHCA, out-of-hospital cardiac arrest; IHT, interhospital transfer; LOS, length of stay. In the propensity-matched analyses, the IHT and non-IHT groups were matched for sex, age, and other covariates that had significant differences between two groups to achieve a 1:4 balanced cohort. These covariates included hour of ED visit, year of ED visit, TTAS level, and coexisting diseases.

east coast of Taiwan providing medical care covering a longitudinal valley area (3144 square miles; about 220 miles between two ends) with a scattered population. The average number of patients who visit our ED is around 4000 per month. The study design was approved by the Research Ethics Committee of Hualien Tzu Chi Hospital (approval number: IRB 109-214-B). For this retrospective study, informed consent was waived according to the institutional guidelines.

### 2.2. Selection of participants

We extracted de-identified patient data from the hospital electronic record system, including ED visit, IHT system, and inpatient medical records. Data were reviewed independently by two abstractors who were blinded to the goal of this investigation. We identified 20675 adult non-trauma patients who were hospitalized within 5 days from January 1, 2018 to June 30, 2020 following the ED visit in our hospital. Survivors of out-of-hospital cardiac arrest (n = 151) and patients with incomplete ED medical records (n = 2373) were excluded. A total of 18151 patients were enrolled in this study and subdivided into the IHT (n = 1856) and non-IHT cohorts (n = 16295) based on the medical record of ED visit (Fig. 1). The IHT cohort included patients who underwent ground transfer by ambulances from other medical facilities to our hospital due to medical reasons. The non-IHT cohort included patients who directly visited our ED after the onset of disease.

### 2.3. Measurements of patients' data

We collected demographic variables (sex and age), coexisting diseases, Charlson comorbidity index (CCI) scores, triage and acuity scales, and ED-related variables (year of ED visit, hour of ED visit, physician seniority, specific treatments for time-sensitive diseases, and certain details after hospital admission). Coexisting diseases were based on the International Classification of Diseases, 10th edition (ICD-10) diagnoses registered in the electronic health record. We used the five-level Taiwan Triage and Acuity Scale (TTAS) computerized system that was implemented nationally in 2010 to classify illness severity and prioritize patient care [30]. The five levels of TTAS are: level 1, resuscitation; level 2, emergent; level 3, urgent; level 4, less urgent; and level 5, non-urgent. Specific treatments for time-sensitive diseases included antibiotics, anticoagulants, inotropic agents, non-invasive and invasive ventilation, central venous catheter placement, and cardiopulmonary resuscitation. Admitting services subsequent to the ED disposition were categorized as non-intensive care unit or intensive care unit in medical and surgery departments.

### 2.4. Outcome measures

We also collected data of ED LOS as the outcome of timeliness of care as well as hospital LOS and in-hospital death as the in-hospital outcomes (Fig. 1). ED LOS is the total time interval between a patient's arrival to the ED to the time the patient physically leaves the ED. ED LOS can be divided into three sub-intervals: arrival to ED physicians, ED physicians to decision, and decision to disposition (Fig. 2). The durations of these sub-intervals were calculated using electronic health record timestamps.

### 2.5. Statistical analysis

Kolmogorov–Smirnov test was used to check the normality of the distribution of the continuous variables. Continuous variables were compared using the independent sample *t*-test in the cases of normal distribution of data or Wilcoxon rank sum test in the cases of non-normal distribution of data and are presented as mean ± standard deviation (SD) or median with interquartile range (IQR), respectively. Chi-square test or Fisher's exact test was used to compare the categorical variables, which are presented as frequency and percentages.

Multiple linear regression was used to assess the association between IHT and ED LOS or hospital LOS after controlling for confounders, including sex, age, year of ED visit, hour of ED visit, triage scale, admitting service, and CCI score, and results are presented as regression coefficients (β) with 95% confidence intervals (CI). Multivariate logistic regression was used to assess the association between IHT and in-hospital death after controlling for potential confounders, including sex, age, year of ED visit, hour of ED visit,

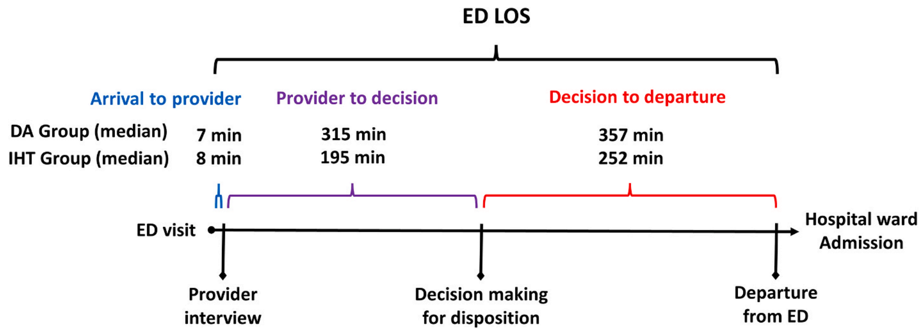


**Fig. 2.** Sub-intervals of the length of stay (LOS) and timeliness of care in the emergency department (ED). IHT, interhospital transfer; min, minutes.

triage scale, admitting service, CCI score, and ED LOS, and results are presented as odds ratio (OR) with 95% CI. Similar multiple regression methods were used for additional propensity-matched analyses and subgroup analyses. In the former analyses, the IHT and non-IHT groups were propensity matched for sex, age, and other covariates that showed significant differences between two groups to achieve a 1:4 balanced cohort by using the greedy nearest neighbor method without trimming. These covariates included hour of ED visit, year of ED visit, TTAS level, and coexisting diseases. In the later analyses, patients were stratified by different TTAS levels and coexisting diseases. $P < 0.05$ was considered statistically significant. All analyses were conducted using SAS statistical software program version 9.4.

## 3. Results

### 3.1. Patient characteristics

A total of 18151 patients were analyzed in this study and subdivided into the IHT (n = 1856) and non-IHT (n = 16295) cohorts (Fig. 1) with mean ages of 66.3 ± 16.1 and 65.7 ± 17.6 years ($P = 0.164$), respectively. Table 1 shows the demographic and baseline clinical characteristics of patients in these two groups. Compared with the non-IHT cohort, the IHT cohort had lower percentages of female, ED visit hour from 6 p.m. to 8 a.m., and ED visit at 2018 but had higher percentages of ED visit at 2020 and TTAS levels 1 and 2.

**Table 1**
Demographic and baseline clinical characteristics of patients in the two study groups.

| Variables | non-IHT (*n* = 16295) | IHT (*n* = 1856) | *P*-value |
|---|---|---|---|
| Female, *n* (%) | 7290 (44.7) | 750 (40.4) | <0.001* |
| Age, mean (SD) | 65.7 (17.6) | 66.3 (16.1) | 0.164 |
| Hour of ED visit (6 p.m.–8 am), *n* (%) | 6985 (42.9) | 632 (34.1) | <0.001* |
| **Year of ED visit, *n* (%)** | | | |
| 2018 | 6389 (39.2) | 667 (36.0) | 0.006* |
| 2019 | 6782 (41.6) | 756 (40.7) | 0.459 |
| 2020 | 3124 (19.2) | 433 (23.3) | <0.001* |
| **Five-Level Taiwan triage and acuity scale, *n* (%)** | | | |
| 1 | 1326 (8.1) | 248 (13.4) | <0.001* |
| 2 | 5018 (30.8) | 749 (40.4) | <0.001* |
| ≥3 | 9951 (61.1) | 859 (46.3) | <0.001* |
| **Ambulance arrivals, *n* (%)** | 3112 (19.1) | 1856 (100) | <0.001* |
| **Seniority of emergency physician (years), *n* (%)** | | | |
| <3 | 980 (6.1) | 128 (6.9) | 0.085 |
| 3–5 | 2846 (17.6) | 294 (15.9) | |
| ≥5 | 12352 (76.3) | 1429 (77.2) | |
| **Charlson comorbidity index, mean (SD)** | 3.2 (2.1) | 3.1 (1.8) | <0.001* |
| **Cardiovascular disorders, *n* (%)** | | | |
| Congestive heart failure | 1388 (8.5) | 150 (8.1) | 0.552 |
| Myocardial infarction | 470 (2.9) | 98 (5.3) | <0.001* |
| Peripheral vascular disease | 103 (0.6) | 28 (1.5) | <0.001* |
| **Neurological disorders, *n* (%)** | | | |
| Cerebrovascular disease | 1549 (9.5) | 183 (9.9) | 0.653 |
| Dementia | 243 (1.5) | 13 (0.7) | 0.004* |
| Hemiplegia or paraplegia | 20 (0.1) | 0 (0.0) | 0.256 |
| **Endocrine disorders, *n* (%)** | | | |
| Diabetes without chronic complication | 2473 (15.2) | 213 (11.5) | <0.001* |
| Diabetes with chronic complication | 727 (4.5) | 42 (2.3) | <0.001* |
| **Hematologic and oncologic disorders, *n* (%)** | | | |
| Any malignancy | 1507 (9.3) | 123 (6.6) | <0.001* |
| Leukemia | 126 (0.8) | 12 (0.7) | 0.542 |
| Metastatic solid tumor | 50 (0.3) | 2 (0.1) | 0.167 |
| Lymphoma | 30 (0.2) | 4 (0.2) | 0.771 |
| **Renal and genitourinary disorders, *n* (%)** | | | |
| Chronic kidney disease | 1413 (8.7) | 134 (7.2) | 0.038* |
| **Pulmonary disorders, *n* (%)** | | | |
| Chronic pulmonary disease | 1001 (6.1) | 72 (3.9) | <0.001* |
| **Gastrointestinal disorders, *n* (%)** | | | |
| Mild liver disease | 801 (4.9) | 77 (4.1) | 0.161 |
| Peptic ulcer disease | 548 (3.4) | 63 (3.4) | 0.997 |
| Moderate or severe liver disease | 19 (0.1) | 1 (0.1) | 0.714 |
| **Systemic rheumatic disorders, *n* (%)** | | | |
| Rheumatic disease | 89 (0.5) | 1 (0.1) | 0.001* |
| **Infectious disorders, *n* (%)** | | | |
| AIDS/HIV | 23 (0.1) | 2 (0.1) | 0.970 |

IHT, interhospital transfer; AIDS/HIV, acquired immune deficiency syndrome/human immunodeficiency virus.
Data of continuous and categorical variables were compared using independent two sample *t*-test and Chi-square test or Fisher's exact test, respectively. *P < 0.05.

The percentages of patients arriving by ambulance were 19.1% and 100% in the non-IHT and IHT cohorts, respectively. The remaining non-IHT patients arrived our ED via walk-in or intrahospital transfer. Analyses of coexisting diseases indicated that the IHT cohort had a slightly lower CCI score and lower percentages of patients with dementia, diabetes with or without chronic complication, any malignancy, chronic kidney disease, and chronic pulmonary disease but had higher percentages of patients with myocardial infarction, peripheral vascular disease, and rheumatic disease. Other between-group comparisons did not show statistical differences.

### 3.2. Comparisons of variables between two study groups

Table 2 shows the ED timeliness of care, ED-related variables, and in-hospital outcomes of patients in the two study groups. Analyses of the ED timeliness of care demonstrated that the IHT cohort had a slightly longer interval of arrival to ED physicians but had considerably shorter intervals of ED physicians to decision and decision to disposition compared with the non-IHT cohort (Fig. 2). As a result, the IHT cohort had a substantially shorter ED LOS. Analyses of the specific treatments to time-sensitive diseases in the ED indicated that the IHT cohort had higher percentages of the use of anticoagulants, inotropic agents, invasive ventilation, and cardiopulmonary resuscitation but had a lower percentage of the use of antibiotics. Analyses of admitting services subsequent to ED disposition showed that the IHT cohort had higher percentages of admission to critical care in medical and surgical departments but had a lower percentage of admission to non-critical care in medical departments. Analysis of in-hospital outcomes revealed that the IHT cohort had a longer hospital LOS and a higher rate of in-hospital death.

### 3.3. Impact of IHT on ED timeliness of care and in-hospital outcomes

Table 3 shows the association between IHT and ED timeliness of care or in-hospital outcomes in unmatched and propensity-matched (1:4 matching for sex, age, and other covariates that showed significant differences between two groups) cohorts. The analyses using unmatched cohorts revealed that IHT was an independent factor associated with a shorter ED LOS, longer hospital LOS, and higher odds of in-hospital death when comparing with the non-IHT cohort after adjustment for confounding factors. Similar results were also obtained in the analyses using propensity-matched cohorts whose variables were well matched (Table A1, supplementary data was provided in Appendix).

Further subgroup analyses (Table 4) revealed that IHT was an independent factor associated with a shorter ED LOS in patients with TTAS levels 1 and 2 or level ≥3 and in patients with coexisting cerebrovascular disease, diabetes without chronic complication, and chronic kidney disease when compared with the non-IHT cohort. Additionally, IHT was an independent factor associated with a longer hospital LOS and a higher odds of in-hospital death in patients with TTAS level ≥3. Furthermore, IHT was an independent factor associated with a low odds of in-hospital death in patients with ambulance arrivals. IHT had no remarkable impacts on ED LOS, hospital LOS, and odds of in-hospital death in the other subgroups analyzed (Table 4).

**Table 2**
ED timeliness of care, ED-related variables, and in-hospital outcomes of patients in the two study groups.

| Variables | non-IHT ($n$ = 16295) | IHT ($n$ = 1856) | $P$-value |
|---|---|---|---|
| **ED timeliness of care (min), median (interquartile range)** | | | |
| Arrival to ED physicians | 7.0 (4.0–12.0) | 8.0 (4.0–13.0) | <0.001* |
| ED physicians to decision | 315.0 (137.0–1016.0) | 195.0 (85.0–864.5) | <0.001* |
| Decision to disposition | 357.0 (118.0–1185.5) | 252.0 (98.0–1022.8) | <0.001* |
| ED LOS | 1068.0 (413.0–2194.0) | 706.0 (277.8–1783.3) | <0.001* |
| **ED specific treatments to time-sensitive diseases, *n* (%)** | | | |
| Antibiotics usage | 8364 (51.3) | 870 (46.8) | <0.001* |
| Anticoagulant usage | 1377 (8.4) | 201 (10.8) | <0.001* |
| Inotropic agent usage | 744 (4.5) | 141 (7.6) | <0.001* |
| Non-invasive ventilation | 455 (2.8) | 46 (2.5) | 0.433 |
| Invasive ventilation | 375 (2.3) | 163 (8.8) | <0.001* |
| CVC placement | 176 (1.1) | 18 (1.0) | 0.661 |
| CPR | 23 (0.1) | 7 (0.4) | 0.018* |
| **Admitting services, *n* (%)** | | | |
| Medical, non-critical care | 11571 (71.0) | 1052 (56.7) | <0.001* |
| Medical, critical care | 1473 (9.0) | 349 (18.8) | <0.001* |
| Surgery, non-critical care | 2772 (17.0) | 315 (17.0) | 0.968 |
| Surgery, critical care | 479 (3.0) | 140 (7.5) | <0.001* |
| **In-hospital outcomes** | | | |
| Hospital LOS (day), median (interquartile range) | 6.0 (4.0–11.0) | 8.0 (5.0–14.0) | <0.001* |
| In-hospital death, *n* (%) | 946 (5.8) | 169 (9.1) | <0.001* |

IHT, inter-hospital transfer; CVC, central venous catheter; CPR, cardiopulmonary resuscitation; LOS, length of stay.
Data of continuous and categorical variables were compared by using the Wilcoxon rank sum test and Chi-square test or Fisher's exact test, respectively. *P < 0.05.

**Table 3**
Multiple regression analyses of association between interhospital transfer and ED length of stay or in-hospital outcomes in unmatched and propensity-matched patients.

| | Unadjusted β or OR (95% CI) | Adjusted β or OR (95% CI) |
|---|---|---|
| **Unmatched cohort (IHT, *n*=1856; non-IHT, *n*=16295)** | | |
| ED LOS (minutes)[a] | −315.17[c] (−423.04, −207.30) | −266.22[c] (−374.19, −158.26) |
| Hospital LOS (days)[a] | 2.55[c] (2.02, 3.10) | 1.01[c] (0.50, 1.54) |
| In-hospital death[b] | 1.63[c] (1.37, 1.93) | 1.23[c] (1.02, 1.48) |
| **Propensity-matched cohort (IHT, *n*=1856; non-IHT, *n*=7424)** | | |
| ED LOS (minutes)[a] | −257.90[c] (−370.98, −144.83) | −174.08[c] (−286.42, −61.74) |
| Hospital LOS (days)[a] | 2.19[c] (1.60, 2.79) | 1.17[c] (0.61, 1.74) |
| In-hospital death[b] | 1.35[c] (1.12, 1.64) | 1.32[c] (1.08, 1.59) |

IHT, interhospital transfer; LOS, length of stay; β, regression coefficient (ED LOS and hospital LOS); OR, odds ratio (in-hospital death); CI, confidence interval.
Non-IHT was used as the reference group for analyses.
In the propensity-matched analyses, the IHT and non-IHT groups were matched for sex, age, and other covariates that had significant differences between two groups to achieve a 1:4 balanced cohort. These covariates included hour of ED visit, year of ED visit, TTAS level, and coexisting diseases.
[a] Linear regression with β
[b] : Logistic regression with OR. Adjusted β or OR was obtained after adjustment for potential confounders.
[c] $P < 0.05$.

**Table 4**
Multiple regression analyses of association between interhospital transfer and ED length of stay or in-hospital outcomes in various subgroups.

| | ED LOS | Hospital LOS | In-hospital death |
|---|---|---|---|
| | Adjusted β (95% CI) | Adjusted β (95% CI) | Adjusted OR (95% CI) |
| **Five-level Taiwan triage and acuity scale** | | | |
| 1 and 2 (*n* = 7341) | **−312.23 (−465.22, −159.25)** | 0.72 (−0.02, 1.47) | 1.13 (0.91, 1.41) |
| ≥3 (*n* = 10810) | **−224.36 (−377.98, −70.73)** | **1.51 (0.79, 2.23)** | **1.62 (1.18, 2.24)** |
| **Ambulance arrivals** (*n* = 4968) | **−241.7 (-376.8, −106.7)** | −0.19 (−0.90, 0.52) | **0.76 (0.62, 0.93)** |
| **Cardiovascular disorders** | | | |
| Congestive heart failure (*n* = 1538) | −142.05 (−466.35, 182.25) | 0.74 (−0.62, 2.10) | 1.21 (0.61, 2.41) |
| Myocardial infarction (*n* = 568) | −339.10 (−733.28, 55.07) | −0.29 (−1.82, 1.22) | 0.64 (0.25, 1.63) |
| **Neurological disorders** | | | |
| Cerebrovascular disease (*n* = 1732) | **−338.28 (−655.33, −21.23)** | 1.15 (−0.59, 2.90) | 1.59 (0.88, 2.88) |
| **Endocrine disorders** | | | |
| Diabetes without chronic complication (*n* = 2686) | **−539.69 (−863.83, −215.56)** | 0.78 (−0.79, 2.36) | 1.14 (0.62, 2.11) |
| Diabetes with chronic complication (*n* = 769) | −554.37 (−1253.54, 144.79) | 0.01 (−3.52, 3.56) | 0.70 (0.14, 3.51) |
| **Hematologic and oncologic disorders** | | | |
| Any malignancy (*n* = 1630) | −55.32 (−460.11, 349.46) | 1.13 (−1.10, 3.37) | 0.76 (0.44, 1.29) |
| **Renal and genitourinary disorders** | | | |
| Chronic kidney disease (*n* = 1547) | **−416.62 (−823.89, −9.36)** | 0.90 (−1.25, 3.05) | 0.71 (0.30, 1.64) |
| **Pulmonary disorders** | | | |
| Chronic pulmonary disease (*n* = 1073) | 9.97 (−465.78, 485.73) | −0.51 (−2.79, 1.77) | 1.76 (0.72, 4.30) |
| **Gastrointestinal disorders** | | | |
| Mild liver disease (*n* = 878) | −261.89 (−784.58, 260.79) | 1.45 (−1.09, 3.99) | 1.00 (0.45, 2.22) |
| Peptic ulcer disease (*n* = 611) | 57.44 (−414.13, 529.03) | −0.38 (−2.14, 1.37) | 0.87 (0.19, 3.89) |

LOS, length of stay; β, regression coefficient; OR, odds ratio; CI, confidence interval.
Non-IHT was used as the reference group for analyses.
Adjusted β or OR was obtained after adjustment for all potential confounders. Numbers in bold format indicate $P < 0.05$.

## 4. Discussion

In this retrospective cohort study, our results showed that non-trauma adult patients in the IHT cohort who presented to the ED exhibited several characteristics and clinical features that were considerably different from those in the non-IHT cohort (Tables 1 and 2). After adjustment for confounding factors, we found that IHT was associated with a shorter ED LOS, longer hospital LOS, and higher odds of in-hospital death compared with non-IHT (Table 3). These findings were further validated by our analyses using a propensity-matched cohort (Table 3), which minimized confounding and other sources of bias arising from the use of observational data. Subgroup analyses (Table 4) indicated that IHT was associated with a shorter ED LOS in patients with all TTAS levels and with certain coexisting diseases. Additionally, IHT was associated with a longer hospital LOS and higher odds of in-hospital death only in patients with TTAS level ≥3. Our study thus highlights the impact of IHT on ED LOS, hospital LOS, and in-hospital death in adult non-trauma patients.

Although many studies have compared the characteristics and clinical outcomes of IHT versus non-IHT in non-trauma patients [8–22], the impact of IHT on the ED timeliness of care remains unclear. It has been suggested that IHT patients may use more resources and stay longer in the ED [31], particularly in cases of unforeseen transfer [32]. Insufficient inter-hospital communication and incompleteness of handoff documentation during IHT may lead to duplication of labor (e.g., laboratory testing, imaging, and procedures) and delay in diagnosis and treatment [3,4,33], both of which result in an increase in ED LOS [31,34]. Unfortunately, there are no clear guidelines regarding the information that should be included in inter-hospital communications to ensure high quality handoffs [35]. Also, an increase in ED boarding time may also be a consequence of low efficiency of hospital bed management [36]. In the present study, we measured ED LOS, which can be partitioned into three sub-intervals (Fig. 2), to evaluate the ED timeliness of care [25]. Given the circumstances which ED LOS are similar or different for IHT and non-IHT patients, it remains unclear which sub-intervals are shortened or prolonged. The above-mentioned factors influencing ED LOS may lead to changes in one or more of these sub-intervals. Thus, exploring the impact of IHT on the ED timeliness may provide helpful information for optimizing IHT strategies or ED care for these patients.

The ED timeliness of care is clinically important, because it is an effective indicator of the ED performance and operational efficiency [23,24] and is associated with clinical outcomes [27,28]. First, we found a slightly longer interval of arrival to ED physicians (~1 min) in the IHT cohort compared with the non-IHT cohort. This increase was apparently due to the extra process for receiving and checking hard copies of the handoff documentation of the transferred patients. Second, we found a considerably shorter interval of ED physicians to decision (~120 min) in the IHT cohort compared with the non-IHT cohort. This reduction may be explained by the fact that a greater portion of patients in the IHT cohort had low TTAS levels and thus have a high priority for inpatient level of care. This reduction may also be based on sufficient interhospital communication prior to IHT and the complete medical information provided by the referring hospitals. The interval of ED physicians to decision can be adversely prolonged if ED manpower and resource are insufficient to give urgent treatments to time-sensitive diseases in IHT patients who are often medically complex, leading to delays in care and disposition [37]. Third, we found a substantially shorter interval of decision to disposition (~105 min) in the IHT cohort compared with the non-IHT cohort. This finding is intriguing because this interval, known as the bed wait time, has a strong relation to inpatient services and availability of beds [38], which is controlled by the Bed Management Center in our hospital. One possible reason to this reduction is that a greater portion of IHT patients required critical care following ED disposition and thus had a fast bed assignment. A second possible reason is that all IHT patients need to be immediately hospitalized following ED disposition, whereas some of the non-IHT patients were retained in the ED observation unit and later admitted to the hospital. A third possible reason is that, due to the communication prior to transfer, the arrival of IHT patients can be expected, which could promote the active management of inpatient beds for these patients. Collectively, our detailed analyses indicate that the time profile of the three sub-intervals of ED LOS is vastly different between the IHT and non-IHT cohorts. Our findings may provide helpful information for optimizing the ED timeliness of care for these two groups of patients.

Our results signify the fact that ED timeliness of care for IHT patients should not be considered as just an ED operational issue and relies on the established IHT system among hospitals, including the communication prior to transfer and handoff/handover strategies during transfer [3,4,39]. Sufficient interhospital communication, complete medical data transfer, timely ED treatments, and active bed management may contribute to expediting ED care for IHT patients.

The ED LOS defined in this study specifically refers to the duration of stay in our ED. The timeliness of care did not include the time spent at the transferring hospital during which the patients would also be getting treatment. Indeed, our IHT patients were diagnosed and treated during either ED stay or ward stay by transferring hospitals. The total time durations in two or more hospitals where these patients stayed should be longer than the ED LOS measured in our study.

In this study, we found that IHT was associated with adverse clinical outcomes (hospital LOS and in-hospital death), a finding that is in agreement with observations reported previously [. The worse clinical outcomes of IHT patients have been attributed to the reason that they are inherently "sicker" than non-IHT patients [8]. The IHT patients in this study indeed had higher percentages of low TTAS levels but had a slightly lower CCI than the non-IHT patients. The IHT patients also had higher percentages of several specific treatments to time-sensitive diseases in the ED. Our risk stratification revealed that IHT was associated with adverse in-hospital outcomes only in patients with TTAS level ≥3, suggesting that special attention should be paid to this subgroup of IHT patients. The fact that IHT remained associated with adverse in-hospital outcomes in the propensity score-matched analysis indicated that TTAS levels or coexisting diseases may not be the sole factors contributing to this result. Indeed, although it is a necessary intervention, IHT *per se* may impose several negative impacts on patients, including treatment discontinuation, stressful mobile environment, and limited equipment to resolve the problems during transfer [3,4]. Intriguingly, we found that IHT was associated with lower odds of in-hospital death in the subgroup with ambulance arrivals (Table 4). This suggests that, the non-IHT patients arriving by ambulance had a higher incidence of in-hospital death compared to the IHT patients who were all transferred by ambulance. The exact explanations for this finding remain to be explored. One possible reason is that IHT patients have been adequately treated by transferring hospitals, whereas non-IHT patients via ambulance arrivals were temporarily stabilized before ED arriving. The time duration and distance for the transport to ED are crucial for the clinical outcomes of non-IHT patients via ambulance arrivals. This is particularly true when ambulance transports of non-IHT patients are conducted in a large area with limited medical resources.

Our hospital is an academic medical center on the east coast of Taiwan providing medical care covering a longitudinal valley area with a scattered population. ED crowding is a critical issue that affects EDs' capacity to provide safe, timely, and quality care [37]. Our previous data indicates that our ED has a volume around 4000 per month. Thus, ED crowding usually is not an issue in our hospital, unless encountering mass-casualty disasters [40,41]. Diversion for outside hospital transfers is rarely executed except under these disaster conditions or recent situations during the COVID-19 pandemic due to the limited number of quarantine beds.

### 4.1. Limitations

Several limitations need to be considered in this study. First, our study was designed to analyze pre-existing data and is subject to several biases, including data collection from the medical records of patients and the inherent differences between patients in the non-IHT and IHT cohorts. We believed that these biases could be minimized by the study design of collecting consecutive patients and the propensity-matched analyses. However, it is still possible that there were unmeasured differences between these two cohorts that may account for our observed results. Second, our participants were non-trauma patients mostly elderly who visited the ED of a single medical center. Moreover, the participants in the non-IHT cohort were confined to hospitalized patients following their ED disposition due to the reasons that all participants in the IHT cohort required hospitalization. As such, our results cannot be generalized to all ED patients or all hospitals. Third, the data were collected from the hospital-based database; therefore, we were not able to include possible non-IHT cases who were discharged from our ED but were later hospitalized by another medical facility. For the same reason, we were also not able to obtain data of out-of-hospital mortality. Fourth, findings from our subgroup analyses should be interpreted with caution as stratification results in limited statistical power.

## 5. Conclusion

In summary, IHT was associated with a shorter ED LOS, longer hospital LOS, and higher odds of in-hospital death in adult non-trauma patients compared with non-IHT. The expedited ED timeliness of care in the IHT cohort was due to considerably shorter intervals of both ED physicians to decision and decision to disposition.

## Author contribution statement

Kun-Chuan Chen: Contributed reagents, materials, analysis tools or data; Analyzed and interpreted the data; Wrote the paper.
Shu-Hui Wen: Conceived and designed the analysis; Analyzed and interpreted the data; Wrote the paper.

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## Data availability statement

The authors do not have permission to share data.

## Declaration of interest's statement

The authors declare no competing interests.

## Additional information

No additional information is available for this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e13393.

## References

[1] Institute of Medicine, Hospital-based Emergency Care: at the Breaking Point, first ed., National Academies Press, Washington, D.C., 2007.
[2] C. Magnusson, J. Herlitz, C. Axelsson, Patient characteristics, triage utilisation, level of care, and outcomes in an unselected adult patient population seen by the emergency medical services: a prospective observational study, BMC Emerg. Med. 20 (1) (2020) 1–19, https://doi.org/10.1186/s12873-020-0302-x.
[3] J. Luster, F.S. Yanagawa, C. Bendas, C.L. Ramirez, J. Cipolla, S.P. Stawicki, Interhospital transfers-managing competing priorities while ensuring patient safety, in: Vignettes in patient safety-vol 2, IntechOpen, London, 2017.
[4] K. Gupta, S.K. Mueller, Interhospital transfers: the need for standards, J. Hosp. Med. 10 (6) (2015) 415–417, https://doi.org/10.1002/jhm.2320.

[5] G. Hymel, J.J. Leskovan, Z. Thomas, J. Greenbaum, D. Ledrick, Emergency department boarding of non-trauma patients adversely affects trauma patient length of stay, Cureus 12 (9) (2020), https://doi.org/10.7759/cureus.10354.

[6] K. Challen, S.W. Goodacre, Predictive scoring in non-trauma emergency patients: a scoping review, Emerg. Med. J. 28 (10) (2011) 827–837, https://doi.org/10.1136/emj.2010.099291.

[7] S.K. Mueller, J. Zheng, E.J. Orav, J.L. Schnipper, Rates, predictors and variability of interhospital transfers: a national evaluation, J. Hosp. Med. 12 (6) (2017) 435–442, https://doi.org/10.12788/jhm.2747.

[8] S. Mueller, J. Zheng, E.J. Orav, J.L. Schnipper, Inter-hospital transfer and patient outcomes: a retrospective cohort study, BMJ Qual. Saf. 28 (11) (2019), https://doi.org/10.1136/bmjqs-2018-008087.

[9] C.J. Crippen, S.J. Hughes, S. Chen, K.E. Behrns, The impact of interhospital transfers on surgical quality metrics for academic medical centers, Am. Surg. 80 (7) (2014) 690–695.

[10] A.M. Limmer, M.B. Edye, Interhospital transfer delays emergency abdominal surgery and prolongs stay, ANZ J. Surg. 87 (11) (2017) 867–872, https://doi.org/10.1111/ans.13824.

[11] S. Yelverton, N. Rozario, B.D. Matthews, C.E. Reinke, Interhospital transfer for emergency general surgery: an independent predictor of mortality, Am. J. Surg. 216 (4) (2018) 787–792, https://doi.org/10.1016/j.amjsurg.2018.07.055.

[12] I.E.R. MacKenzie, T. Arusoo, D. Sigounas, Impact of direct admission versus interfacility transfer on endovascular treatment outcomes for acute ischemic stroke: systematic review and meta-analysis, World Neurosurg. 152 (2021) e387–e397, https://doi.org/10.1016/j.wneu.2021. 05.106.

[13] S. Man, A.S. Tang, J.D. Schold, M.K. Kolikonda, K. Uchino, The patterns and outcomes of inter-hospital transfer among medicare patients with ischemic stroke, J. Stroke Cerebrovasc. Dis. 29 (12) (2020), https://doi.org/10.1016/j.jstrokecerebrovasdis.2020.105331.

[14] E. Venema, A.E. Groot, H.F. Lingsma, W. Hinsenveld, K.M. Treurniet, V. Chalos, et al., Effect of interhospital transfer on endovascular treatment for acute ischemic stroke, Stroke 50 (4) (2019) 923–930, https://doi.org/10.1161/STROKEAHA.118.024091.

[15] K.S. Rathod, A.K. Jain, S. Firoozi, P. Lim, R. Boyle, J. Nevett, et al., Outcome of inter-hospital transfer versus direct admission for primary percutaneous coronary intervention: an observational study of 25,315 patients with ST-elevation myocardial infarction from the London Heart Attack Group, Eur. Heart J. Acute Cardiovasc. Care 9 (8) (2020) 948–957, https://doi.org/10.1177/2048872619882340.

[16] D. Kawecki, M. Gierlotka, B. Morawiec, M. Hawranek, M. Tajstra, M. Skrzypek, et al., Direct admission versus interhospital transfer for primary percutaneous coronary intervention in ST-segment elevation myocardial infarction, JACC Cardiovasc, Intervention 10 (5) (2017) 438–447, https://doi.org/10.1016/j.jcin.2016. 11.028.

[17] K. Nakatsuma, H. Shiomi, T. Morimoto, Y. Furukawa, Y. Nakagawa, K. Ando, et al., Inter-facility transfer vs. direct admission of patients with ST-segment elevation acute myocardial infarction undergoing primary percutaneous coronary intervention, Circ. J. 80 (8) (2016) 1764–1772, https://doi.org/10.1253/circj. CJ-16-0204.

[18] A.H. Rishu, A.S. Aldawood, S.H. Haddad, H.M. Tamim, H.M. Al-Dorzi, A. Al-Jabbary, et al., Demographics and outcomes of critically ill patients transferred from other hospitals to a tertiary care academic referral center in Saudi Arabia, Ann, Intensive Care 3 (1) (2013) 26, https://doi.org/10.1186/2110-5820-3-26.

[19] J. Oras, M. Strube, C. Rylander, The mortality of critically ill patients was not associated with inter-hospital transfer due to a shortage of ICU beds a single-centre retrospective analysis, J. Inten. Care 8 (1) (2020) 82, https://doi.org/10.1186/s40560-020-00501-z.

[20] E. Golestanian, J.E. Scruggs, R.E. Gangnon, R.P. Mak, K.E. Wood, Effect of interhospital transfer on resource utilization and outcomes at a tertiary care referral center, Crit. Care Med. 35 (6) (2007) 1470–1476, https://doi.org/10.1097/01.CCM.0000265741.16192.D9.

[21] A. Kitchlu, J. Shapiro, J. Slater, K.S. Brimble, J.S. Dirk, N. Jeyakumar, et al., Interhospital transfer and outcomes in patients with AKI: a population-based cohort study, Kidney 1 (11) (2020) 1195–1205, https://doi.org/10.34067/KID.0003612020.

[22] N.M. Mohr, K.K. Harland, D.M. Shane, A. Ahmed, B.M. Fuller, J.C. Torner, Inter-hospital transfer is associated with increased mortality and costs in severe sepsis and septic shock: an instrumental variables approach, J. Crit. Care 36 (2016) 187–194, https://doi.org/10.1016/j.jcrc.2016.07.016.

[23] D. Handel, S. Epstein, R. Khare, D. Abernethy, K. Klauer, R. Pilgrim, et al., Interventions to improve the timeliness of emergency care, Acad. Emerg. Med. 18 (12) (2011) 1295–1302, https://doi.org/10.1111/j.1553-2712.2011. 01230.x.

[24] S.T. Le, R.Y. Hsia, Timeliness of care in US emergency departments: an analysis of newly released metrics from the centers for Medicare & Medicaid services, JAMA Intern. Med. 174 (11) (2014) 1847–1849, https://doi.org/10.1001/jamainternmed.2014.3431.

[25] A.M. Chang, A. Lin, R. Fu, K.J. McConnell, B. Sun, Associations of emergency department length of stay with publicly reported quality-of-care measures, Acad. Emerg. Med. 24 (2) (2017) 246–250, https://doi.org/10.1111/acem. 13102.

[26] S. Cournane, D. Byrne, D. O'Riordan, B. Silke, Factors associated with length of stay following an emergency medical admission, Eur. J. Intern. Med. 26 (4) (2015) 237–242, https://doi.org/10.1016/j.ejim.2015.02.017.

[27] L. Burgess, G. Ray-Barruel, K. Kynoch, Association between emergency department length of stay and patient outcomes: a systematic review, Res. Nurs. Health 45 (1) (2022) 59–93, https://doi.org/10.1002/nur.22201.

[28] A. Guttmann, M.J. Schull, M.J. Vermeulen, T.A. Stukel, Association between waiting times and short-term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada, BMJ 342 (2011) d2983, https://doi.org/10.1136/bmj.d2983.

[29] D. Lauque, A. Khalemsky, Z. Boudi, L. Östlundh, C. Xu, M. Alsabri, et al., Length-of-stay in the emergency department and in-hospital mortality: a systematic review and meta-analysis, J. Clin. Med. 12 (1) (2022) 32, https://doi.org/10.3390/jcm12010032.

[30] C.J. Ng, Z.S. Yen, J.C. Tsai, L.C. Chen, S.J. Lin, Y.Y. Sang, et al., Validation of the Taiwan triage and acuity scale: a new computerised five-level triage system, Emerg. Med. J. 28 (12) (2011) 1026–1031, https://doi.org/10.1136/emj.2010.094185.

[31] H. Lee, S. Lee, H. Kim, Factors Affecting the Length of Stay in the Emergency Department for Critically Ill Patients Transferred to Regional Emergency Medical Center, Nurs Open, 2022, https://doi.org/10.1002/nop2.1573.

[32] S.W. Moon, J.H. Lee, H.S. Lee, H.Y. Kim, M. Lee, I. Park, et al., Effects of emergency transfer coordination center on length of stay of critically ill patients in the emergency department, West, J. Emerg. Med. 23 (6) (2022) 846–854.

[33] J. Bertrand, C. Fehlmann, O. Grosgurin, F. Sarasin, O. Kherad, Inappropriateness of repeated laboratory and radiological tests for transferred emergency department patients, J. Clin. Med. 8 (9) (2019) 1342, https://doi.org/10.3390/jcm8091342.

[34] M.G. Usher, C. Fanning, D. Wu, C. Muglia, K. Balonze, D. Kim, et al., Information handoff and outcomes of critically ill patients transferred between hospitals, J. Crit. Care 36 (2016) 240–245, https://doi.org/10.1016/j.jcrc.2016.08.006.

[35] S. Fernandes-Taylor, D.-Y. Yang, J. Schumacher, F. Ljumani, B.S. Fertel, A. Ingraham, Factors associated with interhospital transfers of emergency general surgery patients from emergency departments, Am. J. Emerg. Med. 40 (2021) 83–88, https://doi.org/10.1016/j.ajem.2020.12.012.

[36] N.M. Mohr, B.T. Wessman, B. Bassin, M.-C. Elie-Turenne, T. Ellender, L.L. Emlet, et al., Boarding of critically ill patients in the emergency department, Crit. Care Med. 48 (8) (2020) 1180–1187, https://doi.org/10.1097/CCM.0000000000004385.

[37] E.E. Austin, B. Blakely, C. Tufanaru, A. Selwood, J. Braithwaite, R. Clay-Williams, et al., Strategies to measure and improve emergency department performance: a scoping review, Scand. J. Trauma Resuscitation Emerg. Med. 28 (1) (2020) 55, https://doi.org/10.1186/s13049-020-00749-2.

[38] N. Al Nhdi, H. Al Asmari, A. Al Thobaity, Investigating indicators of waiting time and length of stay in emergency departments, Open Access Emerg, Med 13 (2021) 311–318, https://doi.org/10.2147/OAEM.S316366.

[39] C.N. Theobald, N.N. Choma, J.M. Ehrenfeld, S. Russ, S. Kripalani, Effect of a handover tool on efficiency of care and mortality for interhospital transfers, J. Hosp. Med. 12 (1) (2017) 23–28, https://doi.org/10.1002/jhm.2669.

[40] J.H. Nieh, T.H. Hsu, H.C. Cheng, K.C. Chong, P.F. Lai, Taiwan Hualien earthquake-disaster lessons we learned in the emergency department of a tertiary Hospital, 2020, J. Acute Med. 10 (4) (2018) 149–155, https://doi.org/10.6705/j.jacme.202012_10(4).0003.

[41] Y.K. Lin, K.C. Chen, J.H. Wang, P.F. Lai, Simple triage and rapid treatment protocol for emergency department mass casualty incident victim triage, Am. J. Emerg. Med. 53 (2022) 99–103, https://doi.org/10.1016/j.ajem.2021.12.037.