Intubation during A Medevac Flight: Safety and Effect on The Total Prehospital Time in Helicopter Emergency Medical Service System

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Abstract

Introduction: Endotracheal intubation is an essential skill in emergency medicine requiring technical proficiency and sufficient preparation for a safe procedure. In the Helicopter Emergency Medical Service (HEMS), it is common to intubate the patient who needs an advanced airway prior to take-off. In-flight-intubation (IFI) is avoided because it is considered difficult due to environmental limitations of space, communication, and vibration. In contrast, IFI may shorten the total prehospital time since the procedure is conducted during the flight. We tested whether IFI can be performed safely and shorten transportation time.

Methods: We conducted a retrospective cohort study with patients transported from Apr 2010 to Mar 2017 in a single center. We included patients ≥ 18 years who received prehospital intubation and excluded patients with emergent intubation at the scene. We divided the observational cohort into two groups. The Flight group (FG): included patients intubated during the flight. The Ground group (GG): included patients intubated prior to take-off. HEMS crews transported both groups. The primary outcome was the proportion of successful intubations. Secondary outcomes included total prehospital time and the incidence of complications such as hypoxia and hypotension.

Result: We analyzed 376 patients during the study period. There were 192 cases in FG and 184 cases in GG. Intubation success rate did not differ between the two groups (FG vs GG: 98.4% vs 97.3%, $p = 0.50$). There were no differences in hypoxia (FG vs GG: 3.4% vs 4.2%, $p = 1.00$) or hypotension (FG vs GG: 5.1% vs 5.3%, $p = 1.00$) between two groups. Scene time was shorter in FG (FG vs GG: 7 min vs 14 min, $p < 0.001$), as was total prehospital time (FG vs GG: 33.5 min vs 40.0 min, $p < 0.001$).

Conclusions: In-flight-intubation during HEMS could be safely performed without additional hypoxia or hypotension. In-flight-intubation by experienced providers shortened transportation time by an average of 7 minutes.

Background

Endotracheal intubation (ETI) is an essential skill in prehospital emergency medicine requiring technical proficiency and sufficient preparation for a safe procedure[1][2]. In the Helicopter Emergency Medical Service (HEMS), it is common to assess the patient’s condition then intubate the patient who needs advanced airway management prior to take-off because in-flight-intubation (IFI) is constrained by limitations of space, communication, vibration and gravitational forces[3].

To intubate the emergency patients, various procedures such as pre-oxygenation, preparation of endotracheal tube, establishing the IV access, and administration of induction medications are needed[1]. Moreover, it takes more time to complete the procedure (ETI) and secure both the endotracheal tube and the patient. Intubation prior to take-off may increase overall total prehospital time as compared to patients who are intubated during the flight (IFI). IFI can shorten the total prehospital time since the procedure is conducted during the flight. Among some cohorts, such as trauma patients with shock, this time difference may alter the patient outcome[4].

IFI is described in only few reports. Harrison et al. found no difference in the IFI success rates from HEMS with that of intubations done either in the field or the in-hospital setting. Paramedical flight crew completed ETI with success rate of 96.4%.[5]. Thomas et al. analyzed flight crew airway management in four different settings (in flight, at trauma scenes, in ambulances, and in referring hospitals) and found that airway management success rates comparable even in the in-flight setting [6]. However, the rate of complications associated with IFI have not been reported. Moreover, the time necessary to complete IFI has not been described.

The efficacy, safety or complications of IFI remain unclear. We tested whether IFI, as compared to intubation on ground, can be successfully performed without increases in hypotension or hypoxia and shorten total prehospital time.

Methods

This is a single center retrospective cohort study. Patient data were obtained from April 1st 2010 to March 31st 2017 for 7-year period in Toyooka Hospital. Data sources were hospital medical charts. Ethical committee in Toyooka Hospital approved the study (ID: 137). The requirement for informed consent was waived. Study results are presented according to the STROBE guidelines for observational studies.

HEMS system in japan

The Japanese HEMS system was introduced in 2001. The number of medical helicopters are increasing since then and by October 2019, 53 helicopters had been deployed in 43 prefectures. Each base tertiary medical center corresponds to one helicopter. HEMS system is only available during the day light hours, and night-time flight is prohibited. The system also does not allow to flight during periods of poor visibility or bad weather. Typically, HEMS system receives the dispatch request from a ground Emergency Medical Service (EMS) service, such as the public EMS service, then takes off from the hospital and lands at the predefined place (RP: rendezvous point). At the RP, the HEMS staff makes contact with the patient transported by the ground ambulance, stabilizes the patient, then transports the patient to the hospital. If the HEMS team reaches the RP earlier than ground EMS, the HEMS staff may move from the RP to the scene to contact the patient **(Figure 1)**. The Role of Japanese paramedics (public EMS) has been described in the previous literature[7]. Japanese ground transport is mainly conducted by local public paramedics. The activities of the paramedics are dictated by local protocols. Japanese paramedics are not permitted to perform endotracheal intubation for patients except for patients in cardiac arrest (CA).

Service area and protocol of Toyooka HEMS system

Toyooka HEMS system is responsible for the northern region of Hyogo and Kyoto Prefecture, the eastern region of Tottori Prefecture covering approximately 6,226 km^2 in area with a population of approximately 784 thousand people. This area is rural and mountainous with only a few hospitals. HEMS system was introduced in 2010 with Public Toyooka Hospital serving as the base hospital. The EC145 (BK117C2 Airbus Group SE, The Netherlands) type helicopter is 13.00 m long, 11.00 m wide, and 3.85 m high with a maximum takeoff weight of 3350 kg and an effective payload of 1586 kg. Its cruise range is 550 km with a cruise duration of 2.5 h. It accommodates 7 passengers: a pilot, mechanic, doctor, nurse and patient with room for 2 others. Most severe cases are seen by the HEMS system including the cases with stroke, cardiovascular disease, sepsis, trauma, and CA. Medical crews consist of one or two physicians with one nurse with specialty training in emergency medical care.

Endotracheal intubation is performed in a variety of situations including airway obstruction, regurgitation, respiratory failure (< percutaneous oxygen saturation [SpO_2] 90%), circulatory failure (< systolic blood pressure [sBP] 90mmHg), and coma (< Glasgow Coma Scale 8). Patients are intubated using sedatives (midazolam, or ketamine), analgesics (fentanyl), and neuromuscular blockade (rocuronium or vecuronium). Rapid sequence induction was applied to most of the patients. Video laryngoscope: The Pentax Airway Scope® (AWS-S100®; Pentax Corporation, Tokyo, Japan) is available for the intubation at the discretion of the attending physician.

Patient selection

Patients who were intubated by the Toyooka HEMS physician in the prehospital settings over 18 years of ages were included. Exclusion criteria were as follows: inter-facility transport, ground transport, declaration of death at the scene, not transported by HEMS helicopter. We excluded cases such as intubated on scene during extrications, since the times were confounded by long extrications times or other procedures contributing to total prehospital time.

Measurements

Successful ETI attempt was verified by auscultation and end tidal carbon dioxide (ETCO2) measurement. We divided patients into two groups. In the In-Flight Group (FG), patients were intubated during the flight, after take-off (IFI). In the On-Ground Group (GG), patients were intubated on the ground, usually in the ambulance at RP prior to take-off **(Figure 1)**. The following measured data was collected according to database: age, gender, etiology (endogenous/exogenous). Endogenous/exogenous were decided by HEMS physician in charge: endogenous illness include heart disease, respiratory disease, stroke, sepsis, etc., and exogenous illness include trauma, suffocation, etc. For the ETI procedure, we recorded success rate, number of attempts, use of video laryngoscopy or direct laryngoscopy, training level of the emergency physician who performed the intubation, percentage of patients experiencing hypotension or hypoxia during intubation. We recorded prehospital times including: scene time (the time from HEMS staff arrival at the RP to patient loading onto helicopter) and total prehospital time (the time helicopter dispatch from base hospital to arrive with patient at destination hospital) were recorded.

We defined hypoxia and hypotension during intubation as the patient's SpO_2 dropping below 90% or sBP below 90mmHg during the procedure[8][9][10][11]. The primary outcome was the proportion of successful ETI. The secondary outcomes included scene time, total prehospital time and incidence of complications such as hypoxia or hypotension.

Data Analysis

Continuous variables were described as medians with Inter Quartile Range (IQR) and compared using the Mann–Whitney U-test. Categorical variables were described as numbers or percentages using Fisher's exact test. All statistical analyses were performed with EZR version 1.40 (Saitama Medical Center, Jichi Medical University; http://www.jichi.ac.jp/saitama-sct/SaitamaHP.files/statmed.html; Kanda, 2012), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria, version 2.13.0). More precisely, it is a modified version of R commander (version 1.6-3) that was designed to add statistical functions frequently used in biostatistics[12]. All *p*-values were two sided and *p*-values of less than 0.05 were considered statistically significant.

Results

Seven-thousand-four-hundred-fifty-two cases were treated by Toyooka HEMS during the period, 671 cases were intubated. We included 648 cases, excluding 23 cases for age (under 18: 18 cases) and intubation prior to HEMS arrival (5 cases). We further excluded 272 cases in which the prehospital times were disturbed for comparison (inter-facility transport: 20 cases; HEMS provider landing at the scene: 54 cases; HEMS provider responding to the scene: 153 cases; ground transport: 35 cases; Declaration of death at scene: 6 cases; not transported by HEMS helicopter: 3 cases). We excluded one case as the patient's airway was secured through a wound and not via traditional ETI. Finally, 376 cases were analyzed. FG included 192 cases and GG included 184 cases **(Figure 2)**. The characteristics of two group are summarized in **Table 1**. The populations did not differ with respect to age, male, injury type, and vital signs at the scene had no significant differences between the groups. however, the proportion of respiratory disease were higher in the GG group. The median age of the all cases was 74 (60 - 82) years, and proportion of CA was 39.1% (75/192 cases) in FG and 48.4% (89/184 cases) in GG.

ETI success rate, complications, and mortality

ETI success rate, characteristics, and complications are shown in **Table 2**. Overall intubation success rate was not different between two groups (FG 98.4% [189/192] vs GG 97.3% [179/184], $p = 0.50$). First pass success rate tends to be higher in the GG, but there was no significant difference (FG 88.5% [170/192] vs GG 93.5% [172/184], $p = 0.11$). Overall success rate at the second pass was not different between groups (FG 98.4% [189/192] vs GG 96.7% [178/184], $p = 0.33$). There were five cases of failed intubation requiring cricothyrotomy (FG [1 case], GG [4 cases]) and bag-valve-mask ventilation was performed in 2 cases in the FG and 1 case in the GG. There was no difference in physician emergency services experience (FG 4.0 years vs GG 4.0 years, $p = 0.38$). Use of video laryngoscope was higher in FG than GG (FG 83.3% [160/192] vs GG 19.0% [35/184], $p < 0.001$). Following the exclusion of patient in cardiac arrest, there were no differences in the incidence of hypoxia (FG 3.4% [4/117] vs GG 4.2% [4/95], $p = 1.00$) or hypotension (FG 5.1% [6/117] vs GG 5.3% [5/95], $p = 1.00$). Mortality was higher in the GG (FG 45.7% [86/192] vs GG: 64.5% [109/184], $p = 0.01$) (**Table 2**).

Time in the prehospital scene

There was no difference in the time from taking off the hospital to arriving RP (FG 13 min vs GG 13 min, $p = 0.43$). Scene time was approximately 7 min shorter in FG (FG 7 min vs GG 14 min, $p < 0.001$). Total prehospital time was shorter for the FG (FG 33.5 min vs GG 40.0 min, $p < 0.001$) (**Table 3**).

Discussion

Two previous reports demonstrate the safety of IFI [4][5], however, this is the first report to describe the safety of IFI in the context of associated complications (hypoxia and hypotension) and the impact on total prehospital time. The success rate for intubation in the helicopter (FG) was high (98.4%), similar to the success rates of prehospital ETI performed by physicians in other studies. (**Table 4**)[9][13][14][15][16] First pass success rate in the FG group was lower than the GG group, potentially showing the difficulty of IFI, however, overall success rate did not differ between FG and GG[17]. Moreover, the incidences of hypoxia and hypotension were also similar between the groups and consistent with the complication rates in previously published data[9][13][15][18]. Our data indicate that ETI can be safely conducted by experienced providers during flight.

Prehospital intervention such as ETI may decrease mortality in some life-threatening cases in the field[19]. However, prehospital ETI may prolong the prehospital time leading to a delay in definitive care [20]. Nakstad et al. reported that the scene time was prolonged for approximately 8 min when ETI was performed[21]. Similarly, Lansom et al. reported for prehospital intubation prolonged total prehospital time by 25 min, meanwhile, they also reported 11 min shortened time from arrival at ED to initiation of Computerized Tomography imaging[22]. In our study, intubating patients in the helicopter decreased scene time by 7 min. Patients arriving intubated in the Emergency department may further facilitate the critical examination or intervention. Due to the diversity of patients and retrospective nature of the study, we could not show improved mortality in the current study. Further research is needed to elucidate the effect of this shortened time on mortality.

In the current study, approximately half of patients were intubated with video laryngoscope, with significantly larger proportion in the FG. Past studies describing IFI were conducted in 1990s before the invention of video laryngoscope[5][6], therefore these studies did not address the use of the device. Due to the environmental limitations of space and limitations in patient positioning, this newly introduced tool may have provided clinicians with an improved laryngoscopic view which may have contributed to the observed success rates. In the helicopter, video laryngoscopy allowed providers to share the view with each other and improved the communication with the assisting provider. Communication in the aircraft is typically done only through headsets given the noisy environment. Finally, the ergonomics and thicker blade of the video laryngoscope may have made improved the intubation conditions given the vibration from the aircraft. In spite of the difficultly associated with ETI confirmation by auscultation, use of this video laryngoscope to provide direct visualization in additional to capnography, allows safe confirmation of airway management even in the flight condition.

Intubation success generally depends on the experience of the provider[23][24]. Compared with paramedical or nurse providers, ETI success rates are higher when the physician performs the procedure[25][26][27], which may partly explain our high IFI success rate in the study. However, the past 2 studies for IFI were conducted by experienced paramedics with success rates exceeding 95% indicating the feasibility of IFI by the “experienced” providers **(table 5)**. Careful considerations of provider’s experience and air medical education programs should be considered before the introduction of IFI in the HEMS system. Moreover, patient selection should be limited to patients with time dependent conditions to justify intubating in the aircraft. Hypoxia and hypotension do not differ from previous reports [9][13][15]. When intubation is performed by an experienced provider the success rate and safety will be maintained. We believe that IFI's adaptation to flight crews with different provider compositions needs further study and subsequent verification.

Our investigation has several limitations. The study was performed in a single HEMS system with ETI performed only by highly trained physicians; therefore, the results may not be generalizable to other emergency medical services. We could not obtain intubation time of both groups, however, assessment of transportation time may be a surrogate for estimating procedure time. We did not adjust for the patient mortality between groups, due to the diversity of patients making severity of the patients not comparable: more severe patients may have been intubated before flight (in GG). In fact, proportion of cardiac arrest patients were higher in the GG.

Conclusions

In-flight-intubation was safely performed with high success rates compared to intubation on ground. In-flight-intubation by experienced providers decreased total prehospital time by an average of 7 minutes. Further studies are needed to determine if this strategy is associated with improved patient outcomes.

Abbreviations

CA: Cardiac arrest

EMS: Emergency medical service

$ETCO_2$: End tidal carbon dioxide

ETI: Endotracheal intubation

FG: Flight group

GG: Ground group

HEMS: Helicopter emergency medical service

IFI: In-flight-intubation

IQR: Inter Quartile Range

sBP: Systolic blood pressure

SpO2: Percutaneous oxygen saturation

RP: Rendezvous point

Declarations

1. Ethics approval and consent to participate- project proposal authorized by Ethical committee in Toyooka Hospital, consent of participation was waived.
2. Consent for publication- not applicable.
3. Availability of data and materials- the datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
4. Competing interests- the authors declare that they have no competing interests.
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6. Authors' contributions- HM planed this retrospective study, analyzed data, and drafted the manuscript. HN participated in designing this study, analyzing data, and

revising the manuscript. FXG participated in designing this study, analyzing data, and revising the manuscript. TY participated in designing this study, analyzing data, and revising the manuscript. YB participated in designing this study, collecting data, and revising the manuscript. DM participated in designing this study, collecting data, and revising the manuscript. TY participated in designing this study, analyzing data, and revising the manuscript. AN participated in designing this study, analyzing data, and revising the manuscript. MK participated in designing this study, collecting data, and revising the manuscript. All authors have read and approved the final manuscript.

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Tables

Table 1. Patient characteristics for two groups

	Flight group	Ground group	*p*-value
Age, median (IQR), y	74 (60 - 82)	73 (59 – 83)	0.91
Male, No. (%)	135 (70.3)	115 (62.5)	0.13
Endogenous, No. (%)	108 (56.3)	105 (57.1)	0.92
Heart disease	45 (23.4)	40 (21.7)	0.71
Respiratory disease	3 (1.6)	11 (6.0)	0.03
Stroke	35 (18.2)	37 (20.1)	0.70
Sepsis	2 (1.0)	0 (0)	0.50
Others	23 (12.0)	17 (9.2)	0.41
Extrinsic, No. (%)	84 (43.7)	79 (42.9)	0.92

Trauma	55 (28.6)	48 (26.1)	0.64
Suffocation	11 (5.7)	5 (2.7)	0.20
Others	18 (9.4)	26 (14.1)	0.20
Vital signs, median (IQR)			
Respiratory rate	22 (18 - 30)	22 (16 - 28)	0.56
Heart rate	100 (80 - 126)	89 (70 - 120)	0.08
systolic blood pressure	130 (80- 180)	129 (83 - 189)	0.80
Glasgow Coma Scale	6 (3 - 11)	6 (3 - 7)	0.19
CA, No. (%)	75 (39.1)	89 (48.4)	0.08

Flight group (FG) consists of 192 patients; Ground group (GG) consists of 184 patients. Vital signs are measured in patients excluding cardiac arrest (CA) patients. FG: 117 patients; GG 95 patients. IQR: inter quartile range.

Table2. ETI Success Rate, Characteristics, Complications, and Death

	Flight group	Ground group	*p*-value
Successful case, No. (%)	189/192 (98.4)	179/184 (97.3)	0.50
Number of ETI attempts, No. (%)			
First pass	170/192 (88.5)	172/184 (93.5)	0.11
Second pass	189/192 (98.4)	178/184 (96.7)	0.33
Third pass		179/184 (97.3)	
Video laryngoscope, No. (%)	160/192 (83.3)	35/184 (19.0)	< 0.001
Cricothyroidotomy, No. (%)	1/192 (0.5)	4/184 (2.2)	0.21
Physician’s years specialized in emergency services, median (IQR), years	4 (3 - 6)	4 (3 - 5)	0.38
Complications excluding CA cases, No. (%)			
Hypoxia	4/117 (3.4)	4/95 (4.2)	1.00
Hypotension	6/117 (5.1)	5/95 (5.3)	1.00
Death, No. (%)	86/192 (45.7)	109/184 (64.5)	0.01

ETI: Endotracheal intubation, CA: cardiac arrest, IQR: inter quartile ranges.

Table3. Prehospital Time

	Flight group (n = 192)	Ground group (n = 184)	*p*-value
Take off to RP arrival, median (IQR), min	13 (10 - 16)	13 (9 - 17)	0.43
Prehospital activity time, median (IQR), min	7 (5 - 9)	14 (11 - 17)	<
Total prehospital time, median (IQR), min	33.5 (28 - 40)	40 (33- 47)	<

Abbreviations: RP rendezvous point, IQR inter quartile range.

Table4 Comparative Data of Intubation in Prehospital Settings by Physician (Present and Previous Studies).

	Geir Arne Sunde et al. 13 (2015)	Tobias Piegeler et al.14 (2016)	Emmanuel Ca (20
Number	2144	988	12
Age,y	53 (0 - 95)[a]	49.7 (25.7 - 65.9)[a b] 52.7 (34.5 - 66.5) [a c]	60.3
Medical.(%)	55.0	NA	N
Trauma.(%)	44.0	NA	N
CA.(%)	42.0	46.4	57
success rate.(%)			
total	98.7	99.5	99
first pass	85.5	96.4	63
second or more pass	13.2	3.1	35
hypoxia exclude CA.(%)	2.1	NA	10
hypotension exclude CA.(%)	3.0	NA	1

Abbreviations: CA: cardiac arrest, IQR inter quartile range. [a] median (range) [b] first attempt success [c] two or more attemp

Table5 Comparative Data of In-Flight-Intubation (Present and Previous Studies).

	Timothy Harrison et al. (1997)	Thomas SH et al.
Number	120	246
Age,y	27(2-75)[a]	NA
Medical.(%)	23.0	NA
Trauma.(%)	77.0	NA
CA.(%)	42.0	NA
Success rate.(%)		
Total	94.2	95.5
First pass	75.0	71.9
Second or more pass	19.2	23.6
Hypoxia excluding CA.(%)	NA	NA
Hypotension excluding CA.(%)	NA	NA

Abbreviations: CA cardiac arrest, IQR inter quartile range. [a] median (range) [b] median (IQR)

Figures

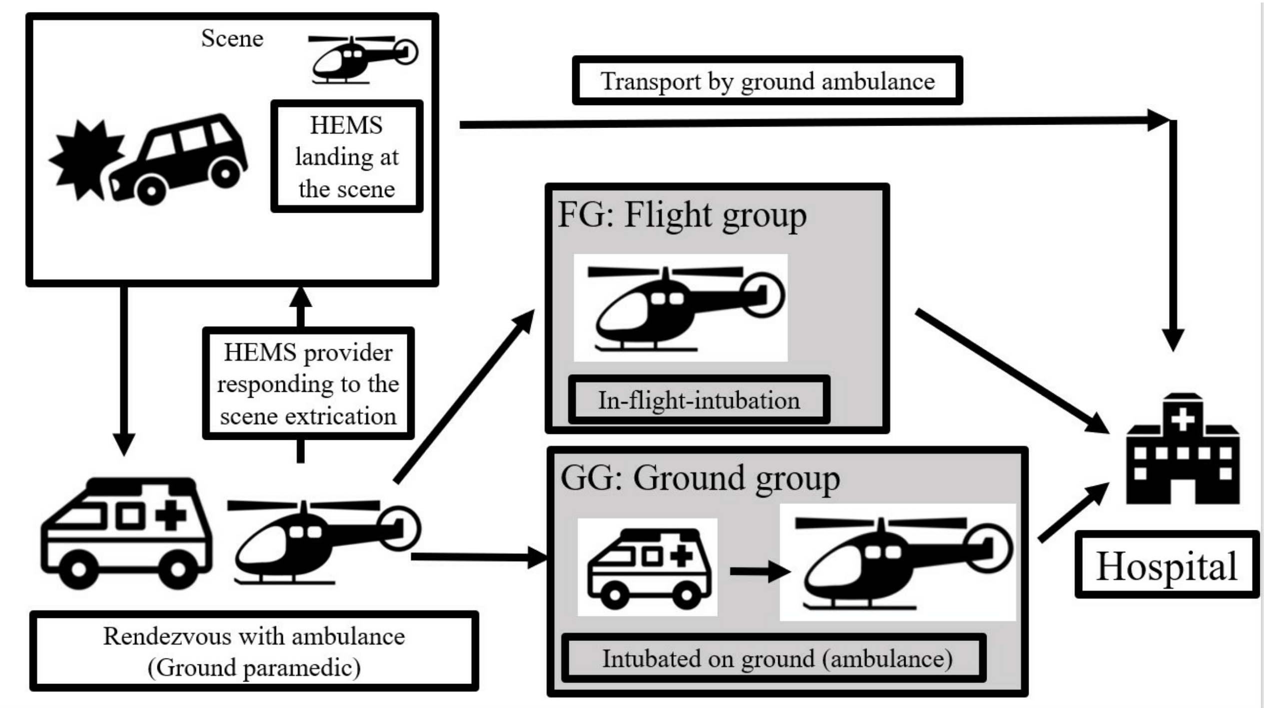
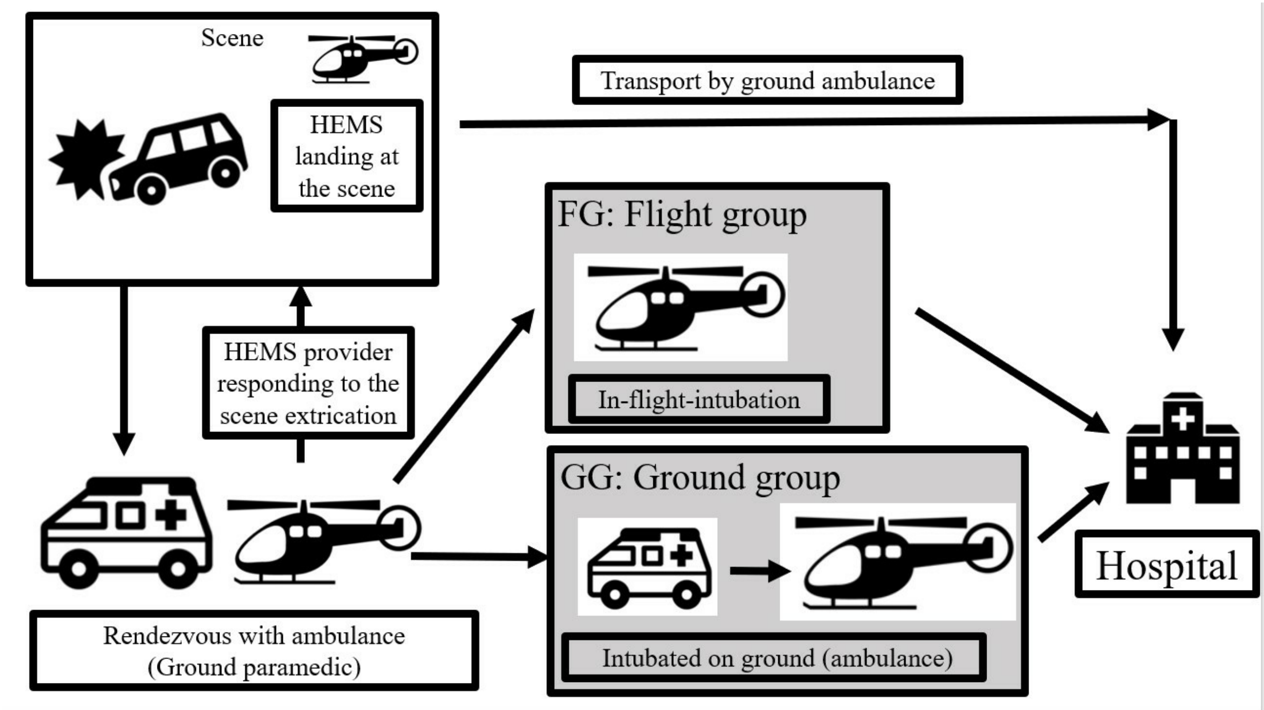


Figure 1

Patient flow chart and grouping. Patients from the two groups were included in the study. Flight group (FG): patients were intubated during the flight, after take-off; ground group (GG), patients were intubated on the ground. HEMS system receives the dispatch request from public EMS, then takes off the hospital and land at the predefined place (RP: rendezvous point). In some cases, the HEMS land at scene. Generally, in RP, HEMS staff contact with the patient transported by the ground ambulance, treat the patient (divided into two groups), then transport to the hospital. If the HEMS team reaches the RP earlier than ground EMS, the HEMS staff may respond to the scene to contact the patient. EMS: emergency medical service, HEMS: helicopter emergency medical service.



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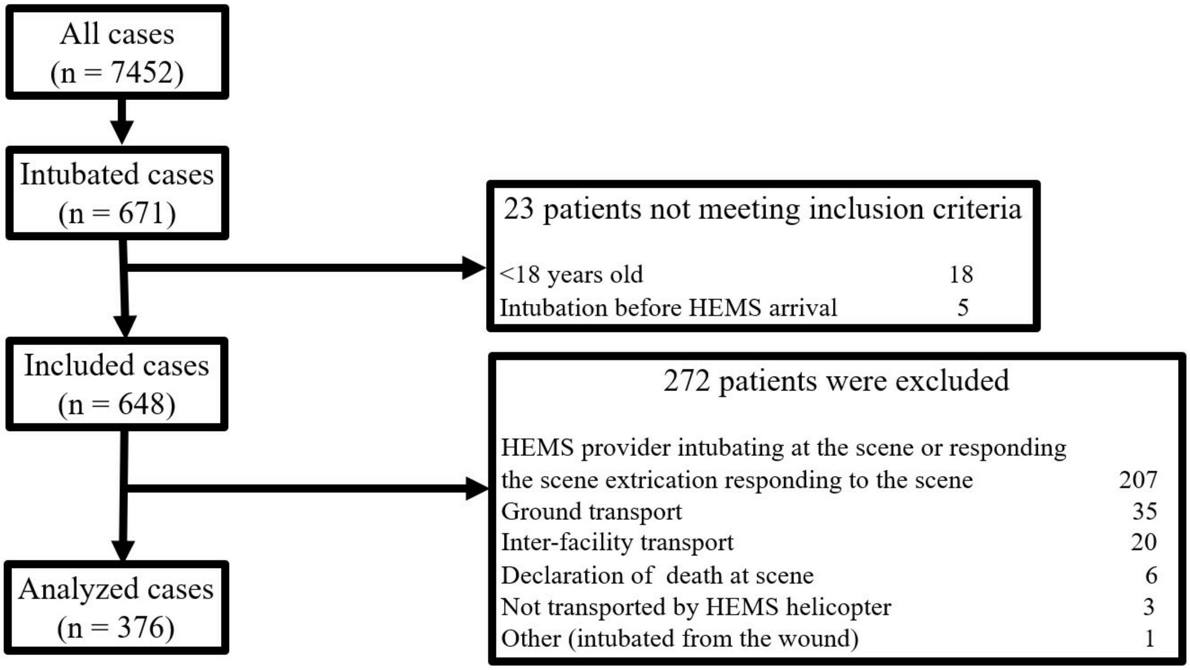
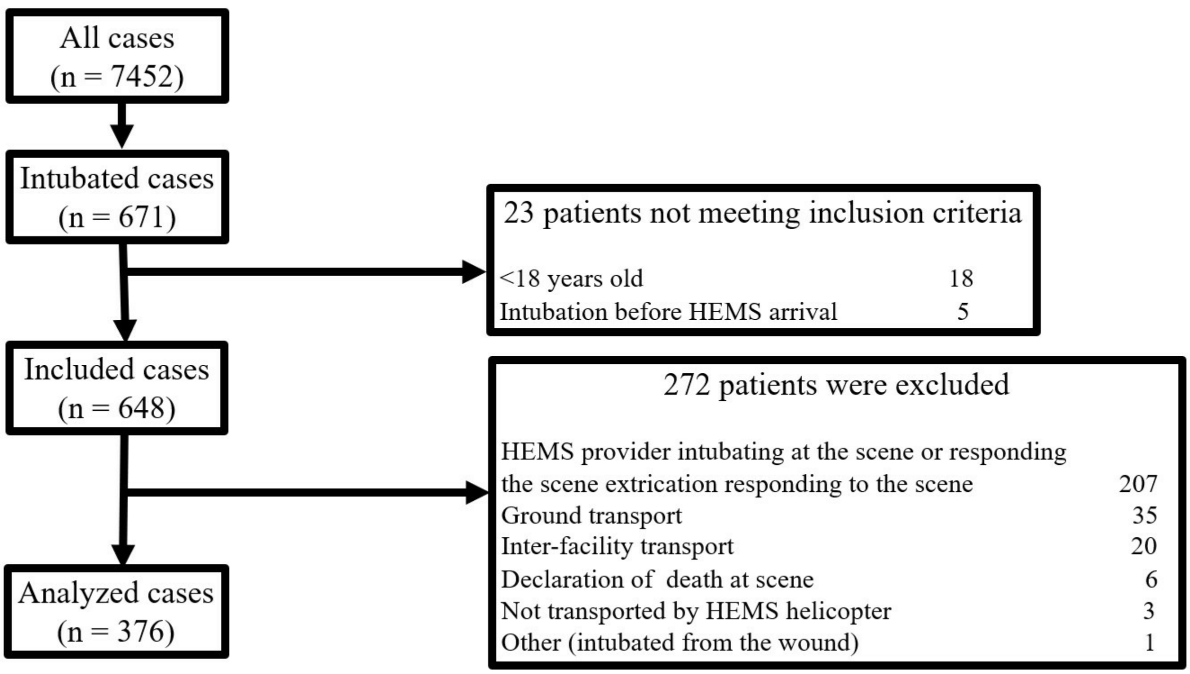


Figure 2

STROBE diagram detailing the inclusion and exclusion criteria.



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STROBE diagram detailing the inclusion and exclusion criteria.