# Pre-Hospital Factors Predicting First-Attempt Intubation Success

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**Background:** Effective pre-hospital endotracheal intubation is crucial in management of severe emergencies such as respiratory failure, cardiac arrest, and trauma, where first-pass success (FPS) markedly reduces complications such as hypoxia and cardiovascular instability.

**Objective:** To identify critical predictors of FPS and evaluate the utility and limitations of the HEAVEN criteria within the authors' prehospital setting.

**Materials and Methods:** A retrospective analysis of 90 patients who underwent pre-hospital endotracheal intubation at the Narenthorn EMS Center, Rajavithi Hospital, was conducted between August and November 2023. Demographic data, the HEAVEN criteria, Cormack-Lehane classifications, sedative drugs, laryngoscopic equipment, and types of operator were analyzed using logistic regression to evaluate predictors of FPS.

**Results:** FPS was achieved in 80% of cases. The patients, predominantly male, at 66.7%, had a mean age of 59.30±16.56 years. The primary indication for intubation was cardiac arrest, for 43.3% of the cases. Analysis highlighted the absence of anatomical challenges and a Cormack-Lehane classification Grade I as significant predictors of FPS (OR for Grade I 6.60, 95% CI 1.39 to 31.28, p=0.017). However, in multivariable analysis, no factors remained statistically significant. The HEAVEN criteria showed an AUROC of 0.549 (p=0.519).

**Conclusion:** The present study found that the absence of anatomical challenges in the HEAVEN criteria together with laryngeal visualization grades significantly influenced FPS in pre-hospital endotracheal intubation in univariable analysis. However, in multivariable analysis, no factors remained statistically significant. The poor predictive performance of the HEAVEN criteria suggests the need for improved predictive models and specialized EMS training to effectively manage challenging airways.

**Keywords:** Prehospital; Intubation; First-pass success

Pre-hospital endotracheal intubation is a critical resuscitative skill for treating patients with respiratory failure, cardiac arrest, or severe trauma. High first-pass success (FPS) intubation is associated with lower rates of complications such as severe hypoxia, cardiovascular instability, and increased mortality[1,2].

The HEAVEN criteria, which consider factors such as hypoxemia, extremes of size, anatomic challenges, vomit/blood/fluid, exsanguination, and neck mobility, are discussed in the Prehospital Trauma Life Support (PHTLS) Tenth edition as a rapid assessment tool for pre-hospital use. While these criteria provide a useful framework, some research suggests that their predictive performance in determining intubation difficulty is not highly accurate[3-7], furthermore, the LEMON assessment tool, commonly used in hospitals, has limited applicability in pre-hospital settings due to its reliance on factors that are difficult to assess in the field[8].

The literature highlights the fact that FPS in pre-hospital intubation is influenced by a combination of patient characteristics, environmental conditions, and the experience level of emergency medical services (EMS) personnel[9,10]. However, there is variability in the applicability of these factors across different pre-hospital settings, suggesting the need for more specific research.

The present study aimed to identify significant predictors of FPS in intubation among patients treated by the Narenthorn EMS Center, a hospital-based ambulance service at Rajavithi Hospital. By focusing on this specific pre-hospital setting, the present research aimed to identify predictors tailored to the operational realities faced by EMS personnel, thereby contributing to more effective and improved intubation practices in the field.

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## Materials and Methods

### Study design and population

This single-center, retrospective cohort study focused on pre-hospital patients treated at the Narenthorn EMS Center, which manages an average of 1,300 EMS operations annually. The present research involved a pre-hospital airway record of patients treated between August and November 2023.

### Selection of participants

The study population consisted of all pre-hospital patients who underwent endotracheal intubation during the study period. The inclusion criteria were pre-hospital intubation patients aged 18 years or older. The exclusion criteria included patients who were pregnant or had a "do not resuscitate" order.

### Definition of first-attempt intubation

First-attempt intubation was defined as the successful placement of an endotracheal tube into the trachea on the initial attempt, verified by direct visualization of the tube passing through the vocal cords, bilateral breath sounds on auscultation, chest rise, and confirmation via capnography. An attempt was considered continuous from the time the laryngoscope blade was inserted until the endotracheal tube was either correctly positioned or the attempt was abandoned. Any subsequent insertion of the laryngoscope blade or use of different equipment constituted a new attempt.

### Data collection

Clinical characteristics and potential predictors were identified from electronic prehospital medical records, including age, gender, body weight, clinical type of patient, indication for intubation, HEAVEN criteria, Cormack-Lehane classification, sedative drug used such as etomidate, benzodiazepines, or no drugs, laryngoscopic time, and the type of EMS provider such as physician or paramedic who performed the intubation.

### Sample size calculation

Calculation of the sample size was made for a study aiming to estimate a proportion formula. The estimated number of samples (n) was derived from data obtained in a previously published study, which reported that the incidence of first attempt intubation success rate was 75%[9]. To achieve adequate statistical power (80%) and a significance level of 0.05, at least 65 participants were needed.
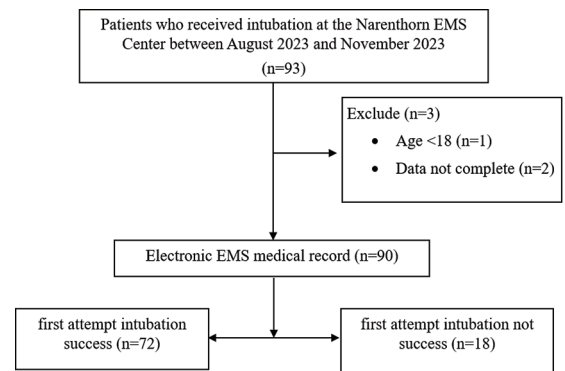


**Figure 1.** Study flow diagram showing the selection of eligible patients for use in predicting first-attempt intubation success.

### Ethical considerations

The present study was conducted in accordance with the principles of the Declaration of Helsinki and Good Clinical Practice Guidelines, and it was approved by the Rajavithi Hospital Ethics Committee for Human Research (approval number 66214). To protect the privacy of the participants, their names were replaced with hospital numbers, and all data used in the study were de-identified.

### Statistical analysis

Continuous variables were summarized as the mean and standard deviation (SD), while categorical variables were represented as frequencies and percentages. Comparisons between categorical variables were performed using chi-square tests or Fisher's exact probability tests, as appropriate. Univariable analysis was conducted to assess the association between potential predictors and the outcome variable, with results presented as odds ratios (ORs) and 95% confidence intervals (CIs). Variables with a p-value less than 0.10 in univariable analysis were included in a multivariate logistic regression model to adjust for potential confounders, with results presented as adjusted ORs and 95% CIs. The predictive performance of the HEAVEN criteria was assessed using the area under the receiver operating characteristic curve (AUROC). A p-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA).

### Results

The present study assessed factors influencing pre-hospital FPS intubation and evaluated the HEAVEN criteria's predictive accuracy. Ninety

**Table 1.** Clinical characteristics

| Variables | All patients (n=90) | First-attempt intubation success | | p-value |
|---|---|---|---|---|
| | | Yes (n=72) | No (n=18) | |
| Sex; n (%) | | | | 0.094 |
| Male | 60 (66.7) | 51 (85.0) | 9 (15.0) | |
| Female | 30 (33.3) | 21 (70.0) | 9 (30.0) | |
| Age (years); mean±SD | 59.30±16.56 | 58.82±16.52 | 61.22±17.05 | 0.585 |
| Body weight (kg); mean±SD | 63.31±14.82 | 62.96±15.23 | 64.72±13.34 | 0.654 |
| Clinical types; n (%) | | | | 0.658 |
| Medical | 82 (91.1) | 66 (80.5) | 16 (19.5) | |
| Trauma | 8 (8.9) | 6 (75.0) | 2 (25.0) | |
| Indication; n (%) | | | | 0.174 |
| Cardiac arrest | 39 (43.3) | 28 (71.8) | 11 (28.2) | |
| Respiratory failure | 28 (31.1) | 24 (85.7) | 4 (14.3) | |
| Alteration of consciousness | 21 (23.3) | 19 (90.5) | 2 (9.5) | |
| Trauma | 2 (2.2) | 1 (50.0) | 1 (50.0) | |
| HEAVEN criteria; n (%) | | | | |
| Hypoxia | 57 (63.3) | 47 (65.3) | 10 (55.6) | 0.444 |
| Extreme size | 6 (6.7) | 5 (6.9) | 1 (5.6) | 1.000 |
| Anatomical challenge | 11 (12.2) | 6 (8.3) | 5 (27.8) | 0.039 |
| Vomit/blood/fluid | 30 (33.3) | 23 (31.9) | 7 (38.9) | 0.576 |
| Exsanguinous/anemia | 2 (2.2) | 1 (1.4) | 1 (5.6) | 0.362 |
| Neck mobility | 7 (7.8) | 5 (6.9) | 2 (11.1) | 0.624 |
| Total criteria number; mean±SD | 1.26±0.94 | 1.21±0.90 | 1.44±1.10 | 0.345 |
| Cormack-Lehane classification; n (%) | | | | 0.032 |
| Grade I | 38 (42.2) | 33 (86.8) | 5 (13.2) | |
| Grade II | 42 (46.7) | 34 (81.0) | 8 (19.0) | |
| Grade III | 4 (4.4) | 3 (75.0) | 1 (25.0) | |
| Grade IV | 6 (6.7) | 2 (33.3) | 4 (66.7) | |
| Laryngoscopy; n (%) | | | | 0.362 |
| Video | 88 (97.8) | 71 (80.7) | 17 (19.3) | |
| Direct | 2 (2.2) | 1 (50.0) | 1 (50.0) | |
| Sedative drugs; n (%) | 44 (48.9) | 38 (86.36) | 6 (13.64) | 0.115 |
| Laryngoscopic time (second); median (IQR) | 20 (14 to 40) | 20 (10 to 30) | 60 (30 to 100) | <0.001 |
| Intubator; n (%) | | | | 0.624 |
| Physician | 83 (92.2) | 67 (80.7) | 16 (19.3) | |
| Paramedic | 7 (7.8) | 5 (71.4) | 2 (28.6) | |

SD=standard deviation; IQR=interquartile range

patients who underwent pre-hospital intubation by the staff at Narenthorn EMS Center, Rajavithi Hospital, between August 1 and November 30, 2023, were analyzed after three patients were excluded due to being under 18 or having incomplete data. The first attempt intubation was successful in 72 patients (80%), while 18 (20%) required more than one attempt (Figure 1).

The majority of patients were male at 66.7% with a mean age of 59.30±16.56 years and a mean weight of 63.31±14.82 kg. Most intubations (91.1%) were performed in response to medical emergencies, with 43.3% related to cardiac arrest. The HEAVEN criteria assessment revealed hypoxia in 63.3% of cases, vomit/blood/fluid in 33.3%, and anatomical challenges in 12.2%. The total number of HEAVEN criteria averaged 1.26±0.94, with a mean of 1.21±0.90 in the FPS group. The Cormack-Lehane classification indicated that 42.2% of intubations were Grade I, and 46.7% were Grade II. Video laryngoscopy was utilized in 97.8% of cases, and sedative drugs were administered in 48.9%. Regarding the sedative drugs, 34.4% were etomidate and 14.4% were benzodiazepines. The median laryngoscopic time was

**Table 2.** Univariable analysis of prehospital factors for predicting first-attempt intubation success

| Variables | Odds ratio | 95% CI | p-value |
|---|---|---|---|
| Sex | | | |
| Female | 1.00 | Reference | |
| Male | 2.43 | 0.85 to 6.97 | 0.099 |
| Age (years) | | | |
| <65 | 1.33 | 0.47 to 3.79 | 0.589 |
| ≥65 | 1.00 | Reference | |
| Body weight (kg) | | | |
| <60 | 3.29 | 0.70 to 15.60 | 0.133 |
| ≥60 | 1.00 | Reference | |
| Clinical types | | | |
| Medical | 1.38 | 0.25 to 7.46 | 0.712 |
| Trauma | 1.00 | Reference | |
| Indication | | | |
| Cardiac arrest | 2.36 | 0.66 to 8.37 | 0.185 |
| Respiratory failure | 2.62 | 0.64 to 10.61 | 0.178 |
| Alteration of consciousness and trauma | 1.00 | Reference | |
| HEAVEN Criteria | | | |
| Hypoxia | 1.50 | 0.53 to 4.29 | 0.446 |
| Extreme size | 1.27 | 0.14 to 11.59 | 0.833 |
| Anatomical challenge | 0.24 | 0.06 to 0.89 | 0.033 |
| Vomit/blood/fluid | 0.74 | 0.25 to 2.15 | 0.577 |
| Exsanguinous/anemia | 0.24 | 0.01 to 4.02 | 0.321 |
| Neck mobility | 0.60 | 0.11 to 3.36 | 0.559 |
| Cormack-Lehane classification | | | |
| Grade I | 6.60 | 1.39 to 31.28 | 0.017 |
| Grade II | 4.25 | 0.99 to 18.29 | 0.052 |
| Grade III-IV | 1.00 | Reference | |
| Laryngoscopy | | | |
| Video | 4.18 | 0.25 to 70.20 | 0.321 |
| Direct | 1.00 | Reference | |
| Sedative drugs | 2.24 | 0.76 to 6.61 | 0.146 |
| Laryngoscopic time (second) | 0.97 | 0.95 to 0.99 | 0.001 |
| Intubator | | | |
| Physician | 1.00 | Reference | |
| Paramedic | 0.60 | 0.11 to 3.36 | 0.559 |

CI=confidence interval

**Table 3.** Multivariable analysis of prehospital factors for predicting first-attempt intubation success

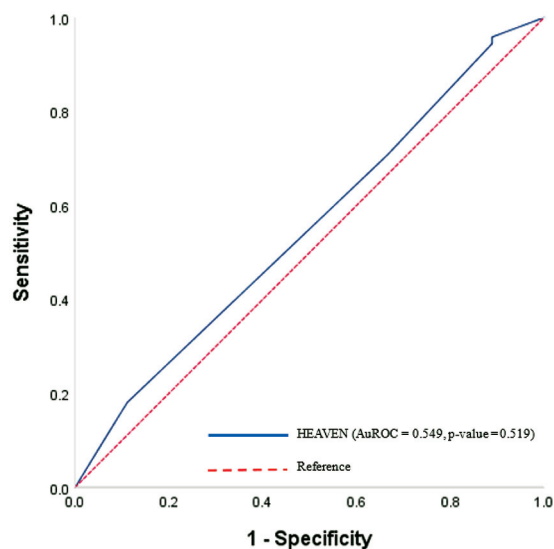| Variables | Adjusted OR | 95% CI | p-value |
|---|---|---|---|
| Sex | | | |
| Male | 2.42 | 0.81 to 7.25 | 0.113 |
| HEAVEN criteria | | | |
| Anatomical challenge | 0.26 | 0.07 to 1.04 | 0.057 |
| Cormack-Lehane classification | | | |
| Grade I | 1.77 | 0.54 to 5.78 | 0.343 |

OR=odds ratio; CI=confidence interval



**Figure 2.** Area under receiver operating characteristic curve (AUROC) of HEAVEN criteria for predicting first-attempt intubation success.

20 seconds (IQR 14 to 40), with 92.2% of intubations performed by doctors (Table 1).

Univariable analysis revealed significant correlations between successful and unsuccessful intubations in terms of anatomical challenges, Cormack-Lehane classification, and laryngoscopic time. Anatomical challenges were more prevalent in unsuccessful intubations at 8.3% versus 27.8% (p=0.039). Successful intubations were more likely to have Cormack-Lehane classification Grade I with OR of 6.60 (95% CI 1.39 to 31.28, p=0.017), showing 6.6 times higher odds of success compared to Grade III-IV (Table 2). In the multivariable analysis, gender, anatomical challenges, and Cormack-Lehane classification Grade I were included in the model. None of the variables remained statistically significant after adjustment (Table 3). The average number of HEAVEN criteria did not significantly differ between groups. The HEAVEN criteria's predictive value for FPS showed AUROC of 0.549 (p=0.519) (Figure 2).

## Discussion

The present study assessed factors influencing FPS in pre-hospital endotracheal intubation, which an 80% success rate was found. Univariable analysis identified anatomical challenges and a Cormack-Lehane Grade I view as significant predictors of FPS. However, in multivariable analysis, no factors remained statistically significant, due to

the small sample size, which may have limited the statistical power to detect independent associations. This limitation highlights the need for caution in interpreting the adjusted results. Despite the lack of statistical significance in the multivariable analysis, these results underscore the importance of precise anatomical assessments and optimal glottic visualization in achieving successful intubations in pre-hospital settings[9-11]. The results showed no significant differences in FPS intubation outcomes between physicians and paramedics. The findings also highlight the necessity for advanced training programs for EMS personnel to enable them to effectively manage these challenges.

As the HEAVEN criteria did not demonstrate high predictive value (AUROC of 0.549, p=0.519), they should not be used as standalone predictors, which is partially consistent with the findings of a previous study[12]. The present study prospective collection of pre-hospital airway parameters ensured that the data were both accurate and reflective of real-world conditions, underscoring the strength of the present study. Nonetheless, the limitations of the HEAVEN criteria emphasize the need for tailored predictive models for pre-hospital intubation.

Repeated intubation attempts significantly increase the risk of adverse outcomes compared to the achievement of FPS[1,2]. A deep understanding of the barriers and influential factors in pre-hospital intubation is vital for enhancing clinical management and refining patient assessment protocols. To enhance the relevance and applicability of the present study findings, future research should evaluate the influence of provider experience levels on FPS rates and the impact of specific environmental factors, such as scene conditions or the type of drug-assisted intubation. Further studies should focus on developing more accurate predictive models that incorporate a broader range of patient and situational factors. Additionally, larger, multi-center studies are essential to validate these findings across diverse healthcare settings.

## Limitation

The present study had limitations. First, the authors identified predictors associated with FPS, including anatomical challenges as defined by the HEAVEN criteria and a Cormack-Lehane Grade I view. However, since the HEAVEN criteria demonstrated poor predictive value for FPS, they are not suitable as standalone predictors, highlighting the need for more comprehensive predictive models.

Second, the generalizability of findings may be limited due to the specific cohort and the small sample size. Although multivariable analysis was performed, the limited sample size may have led to unreliable estimates and reduced the ability to detect true associations. Future studies with larger sample sizes are needed to validate our findings and enable a more reliable multivariable analysis. Additionally, multi-center studies are necessary to confirm the applicability of these results across different healthcare settings. Third, the retrospective design of the present study may have introduced selection and information biases, potentially affecting the accuracy and reliability of the data.

## Conclusion

The present study supports the view that the pre-hospital factors affecting FPS were the absence of anatomical challenges as defined by the HEAVEN criteria and the presence of a Cormack-Lehane Grade I view in univariable analysis. However, in multivariable analysis, no factors remained statistically significant. As the HEAVEN criteria demonstrated poor predictive value with an AUROC of 0.549, p=0.519, their limitations underscore the need for more tailored predictive models for pre-hospital intubation. Recognizing these predictors should help to alert pre-hospital providers to the potential need for multiple intubation attempts or the presence of a difficult airway. The present study findings also highlight the necessity for advanced training programs to enable EMS personnel to effectively manage these challenges.

## What is already known about this topic?

The pre-hospital factors affecting FPS included the absence of anatomical challenges, as defined by the HEAVEN criteria, and the presence of a Cormack-Lehane grade I view.

## What does this study add?

The HEAVEN criteria demonstrated moderate predictive value with an AUROC of 0.549. However, their limitations highlight the need for more tailored predictive models for prehospital intubation.

## Acknowledgment

## Conflicts of interest

The authors report no conflicts of interest.

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