Impact of Distance on Mortality in Trauma Patients with an Out-of-Hospital Intubation Attempt

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CERTIFICATE OF APPROVAL

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Abstract

OBJECTIVE: Out-of-hospital endotracheal intubation (OOH-ETI) has been associated with adverse outcomes; whether transport distance changes this relationship is unclear. We sought to determine whether patients injured farther from the hospital benefit more from OOH-ETI than those injured closer.
METHODS: Retrospective cohort analysis of all trauma patients >14 years transported to one of two Level I trauma centers and surviving to admission from January 2000–December 2003 (19 counties). Probabilistically linked geographical data were used to calculate transport distance. To adjust for the nonrandom selection of patients for OOH-ETI, we used a propensity score based on important clinical variables: prehospital physiologic measures, patient demographics, transport mode, mechanism, comorbidities, Abbreviated Injury Scale head injury≥3, injury severity score, blood transfusion, major surgery. A propensity-adjusted multivariable logistic regression (outcome=in-hospital mortality) with mode of transport was used to test the interaction between distance x OOH-ETI. We used fractional polynomials to assess non-linear relationships between distance and outcome and multiple imputation for missing values.
RESULTS: 8,786 patients were included, of which 534 (6%) had OOH-ETI. Patients with OOH-ETI had higher adjusted mortality (OR 2.06, 95%CI 1.33-3.18), and there was a strong interaction between distance x OOH-ETI (p=0.02). Patients with the shortest transport distances had the highest mortality (OR 3.98, 95%CI 2.08-7.60). Probability of mortality was higher with OOH-ETI across all distances and increased for patients closest to the hospital (no change for patients without OOH-ETI)
CONCLUSIONS: Prehospital intubation is associated with an increase in mortality among trauma patients at all distances from the hospital. Patients with the shortest transport distances had the greatest mortality associated with OOH-ETI. The event location and the ensuing distance to the receiving hospital are yet another factor to consider when instituting and modifying OOH airway protocols.

INTRODUCTION

Trauma is the leading cause of death in the United States (U.S.) for those individuals who are 15-44 years of age. In addition to the devastating effect of a young life lost, equally disturbing is the financial impact such a loss could have on society as this age group is potentially the most productive members of society. More deaths and years-of-life are lost to traumatic injuries and events than to cancer and coronary artery disease combined[1]. While prevention of such injuries is likely the most effective means of decreasing these losses, preventing all such events is not feasible. The care of injured patients in both the out-of-hospital (OOH) and hospital setting needs to be optimized in order to prevent further morbidity and mortality from occurring after the inciting event. Recognizing the importance of the OOH setting, the U.S. has developed one of the most advanced emergency medical services (EMS) systems in the world. In 1966, the National Traffic and Motor Vehicle Safety Act was passed[2], ensuring that there would be federal support for the development and maintenance of such care. The National Highway Traffic Safety Administration (NHTSA) has since published and maintained the guidelines of this program. However, since the implementation of the EMS system in this country, there has been very little data which has shown that the system and care that is provided is beneficial to the public it is intended to serve. In light of this, evaluation of the care of the injured patient in the prehospital setting needs to be assessed in order to ensure it is promoting a positive impact.

In the care of the injured patient, management of the patient's airway is the first and most important assessment of all seriously injured individuals. The major reason for this is the detrimental effect that hypoxia has on mortality in the prehospital setting on traumatic brain injured (TBI) patients[3]. Endotracheal intubation (ETI) is practiced in the emergency department and is considered the standard of care in all trauma patients requiring definitive airway intervention. However, the standard is less defined in the prehospital setting; despite this uncertainty, the practice of ETI has been adapted by most EMS systems in the U.S.

Paramedics routinely perform out-of-hospital endotracheal intubation (OOH-ETI) on injured patients with presumed severe traumatic brain injury (TBI). Despite the intended benefit of OOH-ETI, several studies have suggested that OOH-ETI is associated with an increased mortality in injured patients[4-8]. Recommended models of OOH trauma care differ, with some advocating expeditious transport with minimal field interventions[9-11] and others promoting extensive field interventions[12]. In the case of airway management, medical directors and clinicians note that while patients transported over short distances may tolerate non-invasive airway management(-i.e., bag-valve mask [BVM] ventilation), patients transported over long distances may require more definitive invasive airway and ventilatory support[12] (-i.e., ETI).

Despite the body of knowledge suggesting the adverse relationship between OOH-ETI and mortality, the optimal utilization of this procedure remains unclear. Clinicians and EMS medical directors need a better understanding of the tradeoff between performing field interventions and expedient transport to the hospital, particularly when distances and anticipated transport times are long. Despite the debate between "stay and play" versus "scoop and run", there are no prior data identifying optimal transport distance thresholds for each strategy. Insight into such questions is particularly important for ETI, since OOH-ETI is resource intensive and may involve the administration of sedating or paralyzing medications. Even with the growing body of literature on OOH-ETI, to our knowledge, no prior studies have assessed whether different strategies for airway management in trauma patients should be considered based on distance to a receiving hospital.

The objective of this study was to assess whether transport distance modifies the relationship between OOH-ETI and mortality among a heterogeneous group of adult trauma patients. We hypothesized that OOH-ETI would be beneficial for those patients intubated at greater distances from the hospital despite a detrimental effect to those intubated closer to the hospital.

METHODS

Study Design

This was a retrospective cohort analysis of consecutively injured adult trauma patients meeting Oregon State Trauma System criteria. The primary outcome of interest was in-hospital mortality. This study was approved by Oregon Health and Science University's institutional review board.

Study Setting and Population

The Oregon State Trauma Registry is a statewide registry that includes patients of all ages meeting standardized state trauma criteria (physiologic, anatomic, mechanism, and risk factors). The trauma system in Oregon was initiated in 1985 with Oregon being the second state to develop a state trauma program in the United States[13]. To this day, Oregon continues to be recognized as one of the leaders in trauma systems development. In the state of Oregon, there are only two Level I trauma centers, both of which are located in Portland, Oregon. The city of Portland has an estimated population of 562,690, with the Portland metropolitan region having a population of 2,095,861[14]. Portland is Oregon's most densely populated area, with approximately 60% of the total population living in 600 of the 96,000 square miles of land which make up the state[15]. The main goals of the registry are to evaluate the outcomes of trauma patients, to provide data for research and education, and to promote injury prevention in the state of Oregon.

Inclusion into the registry can be prospective, either at the time of field evaluation or during the emergency department assessment at the receiving hospital, or retrospective, after admission to the hospital (i.e. if a significant injury is found). Data for the registry is collected from all statewide hospitals participating in the trauma system

(48) via structured review of patient care records by trained, trauma data abstractors at each hospital. The data are submitted at regular intervals to the Emergency Medical Services & Trauma Systems section of the Department of Human Services for Oregon for central processing. Data submission is a legislated mandatory requirement for all hospitals participating in the state trauma system and there are standard procedures in place to ensure reliable and consistent chart abstraction.

The majority of patients (~70-75%) entered into the Oregon State Trauma System are done so based on clinical characteristics of the patient in the field (Table 1). All trauma patients transported by ground are to be taken to a Level I center directly from the field unless transport time to the Level I hospital is anticipated to be greater than 30 minutes (with a closer hospital available) or instructed by online medical command (OLMC). All trauma patients transported by air from the scene are taken to a Level I trauma center. Air transport in our system is recommended for those patients in whom transport time may be reduced by 10 minutes or more via the air ambulance response zone map in our region. Based on this map, trauma patients that are injured outside of a 15-mile radius from the Level I trauma centers could be transported by air.

The decision to intubate a patient in the field in our system is approached in a systematic fashion. Trauma patients eligible for OOH-ETI include those with a Glasgow Coma Scale (GCS) ≤8, airway compromise, agitation or combativeness, or those that require air medical transport. In our system, only the lead paramedics in the urban and suburban regions (average of 3-5 years of experience) are allowed to perform OOH-ETI with the use of RSI. The paramedics in the urban/suburban regions are all career paramedics whereas those in the rural setting tend to be volunteers with a lower level of training (i.e. intermediate, basic). Prehospital providers in the rural setting are not allowed to use RSI for OOH-ETI.

Study Protocol

In this study, we included consecutive adult (>14 years) injured patients meeting the Oregon trauma criteria and having field EMS evaluation in 19 counties in the northwest portion of Oregon (including the greater Portland Metropolitan region) (Figure 1). We included all such patients entered into the state trauma system by EMS providers from January 2000 through December 2003. To minimize the outcome effect of varying levels of hospital-based care, we restricted our sample to trauma patients transported directly from the scene to one of the two Level I trauma centers that are present in the state of Oregon. This restriction was implemented because the majority of injured patients in this region are directly transported to a Level I center. Such a restriction was also necessary to capture the exact field scene location (latitude/longitude coordinates), as such information is routinely obtained by our regional Trauma Communications Center for all injured patients being transported directly to a Level I hospital but not for those that are transferred from referring facilities. Therefore, interhospital transfers were excluded. To reduce potential selection bias we also excluded patients who were dead on arrival to the emergency department (ED) and patients who died in the ED, as inclusion of such patients may falsely inflate the association between OOH-ETI and mortality (i.e. most of these patients are intubated and all had fatal outcomes).

Measures

The primary intervention was OOH-ETI, defined as a dichotomous variable. We considered the OOH-ETI term to represent the "intent" to intubate, and thus included:

endotracheal intubation (ETI), endotracheal intubation with rapid sequence induction (ETI-RSI), Combitube insertion (CTI), Combitube insertion with RSI (CTI-RSI), cricothyrotomy, and failed intubations.

We used additional clinical covariates included in the trauma registry database for risk adjustment and the propensity score development, including: gender, race, transport mode (air medical versus ground), mechanism of injury (motor vehicle crashes, penetrating injuries, assaults/falls, machinery, burns/suffocations/drowning), comorbidities (diabetes mellitus, cardiac disease, pulmonary disease, renal disease, liver disease), GCS, systolic blood pressure, respiratory rate, age, OOH-ETI, Abbreviated Injury Scale (AIS) Head Injury $\geq$3, blood transfusion in the ED, major surgery within 3 days of admission, and Injury Severity Score (ISS). GCS, systolic blood pressure, respiratory rate, and age were included as continuous variables in the analysis. The remainder of the covariates were coded as categorical terms.

Transport distance was calculated as shortest driving distance (in miles) to the destination hospital from the latitude/longitude coordinates of the injury site recorded in the Trauma Communications Center database using Geographical Information Systems (GIS) software (ArcGis version 9.1 Environmental Systems Research Institute, Redland CA). Distance was calculated based on the theoretical computed shortest travel time which was then calculated to theoretical travel distance via the Dijkstra shortest path algorithm[16]. Distance was then rounded to the nearest mile for the final analysis. We used transport distance rather than transport time because distance offers a fixed data point that could be used by EMS medical directors to generate paramedic airway management protocols, based on distance to a receiving hospital, within a region.

Additionally, prior work has evaluated the impact of total OOH time on mortality in trauma patients and found no association with mortality[17]. Furthermore, we have previously assessed the relationship between transport distance and total OOH time among intubated and non-intubated patients and found an increase in total OOH time in those patients who had an OOH-ETI attempt largely due to the use of RSI[18]. This increase in time was most apparent as the distance from the receiving hospital increased for those intubated with RSI. However, we did assess the relationship between total OOH time (time from 9-1-1 call to hospital arrival), intubation, and mortality separately using identical methodology to assess whether OOH time serves as a better effect modifier than distance.

The primary outcome of this study was in-hospital mortality. We also looked at a secondary combined outcome of death and/or medical complications as reported in the registry. The registry has data on a total of 36 different medical complications with the four most common being: pneumonia, sepsis/infections, deep venous thrombosis, and acute respiratory distress syndrome.

Data Analysis

We used a combination of deterministic and probabilistic linkage[19-21] (LinkSolv v.5.0, Strategic Matching, Inc., Morrisonville, NY) to match trauma registry records (i.e. clinical information and outcomes) to records from the Trauma Communication Center database (GIS information). The use of probabilistic linkage in similar datasets has been validated previously[22]. To avoid the potential bias associated with complete case analysis, we used multiple imputation to impute missing data for patients included in the sample[23-24]. Multiple imputation has been previously validated for handling missing out-of-hospital values in our state trauma registry[25]. The amount of missing data in the variables used from the trauma registry varied from 0% to 20% (Table 2).

To reduce the strong selection bias inherent in deciding which patients should undergo OOH-ETI, we used propensity score adjustment in the model[26-28]. The propensity score was generated from available variables identified as confounders (i.e., associated with both OOH-ETI and mortality) and those associated only with outcome[29]. Such an approach is recommended in order to reduce the potential variance of the propensity score that would be present using only those variables associated with the exposure as well as to minimize bias and increase the statistical efficiency of the propensity score [29]. These covariates included: GCS, systolic blood pressure, respiratory rate, age, gender, ground versus air transport, race, mechanism of injury, ISS, Head AIS, major surgery, blood transfusion in the ED, and comorbidities. All potential interaction terms were tested in the model generating the propensity score, with interactions having $p<0.10$ level of significance retained for the final non-parsimonious model. The variables that were included in the development of the propensity score are seen in Table 3.

Multivariable logistic regression analysis was used to evaluate both the association between OOH-ETI and death, as well as the potential effect modification (i.e. interaction) of transport distance × OOH-ETI. The final model included the following variables to evaluate the effect of OOH-ETI on mortality: intubation status, mode of transport, distance, and propensity score. Hosmer-Lemeshow goodness-of-fit statistic was used to assess goodness of fit for all models.

Because we believed many of the continuous covariates (including distance) to have a non-linear relationship with OOH-ETI and mortality, we assessed all such variables as fractional polynomials using a standard algorithm for selecting the best fit term[30]("fracpoly" in STATA v.9 StataCorp LP, College Station, TX). Based on previous research suggesting the use of fractional polynomials as an effective means of testing interactions between continuous predictors (with a non-linear relationship to outcome) and categorical interventions[31] we used the fractional polynomial distance term to interact with OOH-ETI.

We assessed the ability of the propensity score to create comparability between the two groups by regressing each covariate in a univariate regression model on OOH-ETI (the main "intervention") with and without the propensity score on intubation status . to ensure that the propensity score correctly compensated for any potential differences between the two group (i.e., OOH-ETI versus no OOH-ETI) and checked the distribution of propensity scores between the two groups to ensure adequate overlap throughout the full range of the score. In addition, to further assure the comparability between the groups and to assess an alternative method for handling the propensity score, we repeated the above analyses using a propensity-matched analysis using a greedy matching algorithm[32]. Sensitivity analyses were done including those patients who were dead on arrival (DOA) or who had died in the ED and identical analyses were performed to evaluate the impact of total OOH time, rather than distance, on mortality. Additionally, we repeated the primary analysis by adding potential confounders to the final model (EMS GCS, ISS, Head AIS $\geq$3, Blood Transfusion in the ED, Age) to assess their potential impact.

To provide a different analytic strategy for determining the effect of intubation at different distance intervals from the receiving hospitals, we created a dummy variable for intubation at different distances combining the distance variable and the intubation variable into one term (reference group: non-intubated patients at any distance). The dummy variable was created by combining those patients intubated in the field and the distance variable at predetermined mileage ranges into the following groups: OOH-ETI and 0-<10 miles, OOH-ETI and 10-<20 miles, OOH-ETI and 20-<30 miles, OOH-ETI and 30-<40 miles, OOH-ETI and 40-<50 miles, and OOH-ETI and 50 or > miles. These groups were then compared to non-intubated patients at any distance in the previously mentioned model without inclusion of any interaction terms. Finally, in order to assess the impact of helicopter transport, we stratified the primary analysis by mode of transport.

SAS version 9.1 (SAS Institute, Inc., Cary, NC) was used for database management and analyses. SAS-callable IVEware (University of Michigan, Ann Arbor, MI) was used for multiple imputation and for the final multivariable models.

RESULTS

Of 9875 trauma patients, 1026 patients were excluded based on age (less than 15 years) or interhospital transfer. An additional 63 patients were excluded due to death on arrival or in the ED leaving 8,786 persons in the final analysis. Of these patients, 534 (6%) underwent OOH-ETI with 307 (57.5%) undergoing OOH-ETI with RSI and 227 (42.5%) without RSI. Demographics of all patients included in the analysis are included in Table 2.

After adjusting for potential confounders and the propensity to be intubated, OOH-ETI was associated with an increased odds of mortality (OR 2.06; 95% confidence interval [CI] 1.33-3.18) compared to non-intubated controls (Table 4) as well as an increased odds of complications (OR 2.08; 95% CI 1.50-2.89). Patients intubated closest to the hospital (i.e., those with a theoretical distance of zero miles), had the highest odds of death compared to the non-intubated patients (OR 3.98; 95% CI 2.08-7.60). An increase in the odds of complications was also seen in those with the shortest transport distances (OR 4.14; 95% CI 2.42-7.10). Distance was found to be a strong effect modifier of the association between OOH-ETI and mortality (interaction term p=0.02) as well as for OOH-ETI and complications (p=0.004). Qualitatively similar results were found with the matched-propensity analysis (n=552) for those with OOH-ETI (OR 1.61; 95% CI 0.94-2.74, p=0.06) and for those with OOH-ETI closest to the hospital (OR 2.15; 95% CI 0.57-8.09).

Based on a geographical plot assessing the adjusted probability of mortality versus distance to the receiving hospital (Figure 2), the probability of mortality of intubated patients was higher than that of non-intubated patients at all distances.

Mortality increased with shorter distances starting within 30 miles from the receiving hospital, with the largest increase seen within 10 miles from the receiving facility. There was no relationship between distance and outcome among patients without OOH-ETI. The distribution of the mode of transport of the OOH-ETI patients by distance is included in Figure 3. Patients with longer transport distances tended to have a higher number of transports via helicopter while those closest to the hospitals were often transported by ground.

Total OOH time had no association with mortality for those patients with OOH-ETI ($p=0.18$) and did not modify the effect of OOH-ETI on mortality (interaction term $p=0.74$). Inclusion of those patients who were dead on arrival or who died in the ED revealed similar results as the primary analysis (OR for OOH-ETI 2.59; 95% CI 1.74-3.87), with a similar increase in the mortality for those patients injured closest to the hospital (OR 5.41; 95% CI 2.88-10.16). Similar results were found when additional confounders were added to the primary model (OR 1.78; 95% CI 1.08-2.93).

When analyzed by distance category, those patients who were intubated in the field and had a travel distance of less than 10 miles were found to have the highest odds of mortality (Table 5).

The propensity score was able to create balance on many of the background characteristics of both groups of patients (Table 6). It improved, but did not completely balance, the differences in injury severity of the two groups of patients via the GCS, ISS, and Head AIS ≥ 3. There was adequate overlap of the distribution of the propensity scores on the lower two-thirds of the scores. This distribution was less than optimal in the highest one-third of the propensity score.

As seen in Table 7, when stratified by mode of transport, those who were transported by ground had similar findings as those in the primary analysis (OR 2.10; 95% CI 1.29-3.40).

DISCUSSION

In this study, we demonstrate that OOH-ETI patients had a higher risk of mortality than non-intubated controls at all distances. Patients injured closest to the hospital had the highest risk of mortality. There was no similar relationship among injured persons not requiring OOH-ETI. These results suggest that the highest increase in mortality is seen within 10 miles from a Level 1 trauma center among patients with OOH-ETI. These findings continue to call into question the utility of OOH-ETI at all distances, but particularly for trauma patients injured relatively close to the receiving hospital.

One potential explanation for these findings may be that patients intubated further from the hospital are more likely to be transported by air medical providers and intubated by field providers with more airway experience and training than patients injured closer to the hospital. As distance from a receiving hospital increases in our system, it is more likely that air medical transport is summoned to assist and assume care (including airway management) of the patient. Air medical crews often have more experience with intubation, more training with intubation and RSI. Patients with TBI transported by air medical crews have shown improved outcome after intubation in the prehospital setting[33]. Although we did not have data on which individual (i.e., ground versus air crew) performed the intubation when air medical crews were summoned to a scene, it is possible that more experienced prehospital teams offer a potential survival benefit to OOH-ETI patients injured further from the hospital (though we found no similar finding among non-intubated patients). Such a benefit of paramedic experience and training with improved results has been suggested in patients with TBI[34] as well as cardiac arrest[35]. In addition, there was an independent survival benefit among patients transported by helicopter in our study (Table 4), as well as an associated increase in mortality in patients transported by ground (Table 7) that was not seen in patients transported by helicopter, a finding that has been seen in prior studies as well[36, 37], suggesting that such an effect may have been present.

Another potential reason for our findings is that distance from a receiving trauma center may serve as a marker for selection bias among patients transported to a trauma hospital. That is, patients injured closer to a trauma center with short response and transport times may not have survived to be transported if injured farther from the hospital. There was a small number of patients with OOH-ETI at further distances (>60 miles) that had increased mortality comparable to those closest to the hospital. These patients (n=12) represent a small cohort with high injury severity and long transport distances (>60 miles) who managed to survive to the hospital. These patients had high predicted mortality and appeared as outlier points in Figure 2, though otherwise the trend was for increasing probability of mortality with closer distances to the hospital for OOH-ETI patients.

A final reason for these findings may be a lack of complete correlation between transport distance and total OOH time. Patients injured closer to a hospital are often transported by ground via main roads and side streets, requiring many turns and high volumes of traffic. Patients injured further away who are transported by ground are often transported via highways, which allows for faster travel and often a more direct route[38]. Such a discrepancy in roadways may allow for patients with longer transport distances to have equal or shorter OOH times than those with shorter distances. This, in addition to road conditions and travel conditions, may lead to a poor correlation between distance and time. However, we did look at time separately and found an increase in OOH time with increasing distance from a hospital when patients had an intubation attempt compared to non-intubated controls[18]. This suggests that patients intubated further from the hospital had the largest increase in OOH time compared to non-intubated patients, while the largest increase in mortality is seen in those patients intubated closest to the hospital, where the discrepancy in OOH time is less. These findings suggest that increased OOH time is not the main reason for the observed results, a finding that has been observed elsewhere[17]. Furthermore, in the sensitivity analysis, we found no association between OOH time and mortality, nor any significant interaction between time and OOH-ETI, suggesting that OOH time is not the reason for the observed association.

The clinical implications of this project coincide with the findings of previous endeavors. Given the growing body of literature observing a detrimental association of OOH-ETI and mortality in trauma patients, one must continue to question the utility of OOH-ETI in all trauma patients, in particular in those patients who are injured closest to a Level I trauma center. We found no distance at which OOH-ETI demonstrated a mortality benefit for injured patients.

LIMITATIONS

The major limitation of this study is its retrospective design and all of the inherent restrictions with such methodology. In order to balance this limitation, we used statistical methods (e.g., propensity scores and multiple imputation) plus integration of known confounders to reduce bias and other anticipated deficiencies. Despite these efforts, it is possible that we were not able to fully adjust for the potential confounders nor able to create comparability between the two groups, potentially biasing our results, a finding that is suggested when evaluating the distribution of the propensity scores and the lack of complete balance of the markers of injury severity. However, on the propensity-matched analysis, qualitatively similar findings were achieved, despite reaching statistical significance. This was likely the result of a reduction in the sample size of >90%. Future endeavors should prospectively randomize such patients to evaluate and compare the outcomes of patients with OOH-ETI in order to help reduce such bias and further validate these findings.

In addition to the known confounders, there may have been unmeasured confounders that we were unable to adjust for in the analysis (e.g., C02 level and 02 levels). Prior studies have shown these two variables to be important factors affecting outcome in trauma patients[39, 40]. Davis et al identified that those patients with prehospital intubation had a significantly increased incidence of hyperventilation compared to non-intubated controls and that this hyperventilation was associated with an increased mortality in intubated patients[40]. However, after adjusting for the hyperventilation, the increased odds of mortality in intubated patients persisted compared to non-intubated controls[33]. Future projects should attempt to measure and control the ventilation rates and episodes of hyperventilation in intubated patients in order to reduce potential confounding effects.

We combined patients who were intubated with and without the use of RSI, though some studies consider these two groups as different classes of patients[41]. In our system, the use of RSI may depend on provider comfort with the medication, anticipated difficulty of intubation, and clinical factors (e.g., GCS), among other factors. Given this variability in use of RSI, we felt that analyzing the two groups together would be more representative of actual pre-hospital practice. Moreover, this study was not designed to assess potential outcome differences between patients intubated with or without RSI.

We also excluded those patients who were transferred from other hospitals. While this may have resulted in selection bias, it is more likely that this 25-30% of missed patients from the trauma registry likely represents a different population of trauma patients. This population is likely less severely injured with a less serious mechanism of injury that do not need immediate care and stabilization at a Level I trauma center but whom may need the expertise and resources of such a center after a non-life threatening injury was found.

CONCLUSIONS

Prehospital intubation is associated with an increase in mortality among trauma patients at all distances from Level I trauma centers. The greatest increase in mortality appears to occur in patients who are injured closest to the hospital, particularly within 10 miles of the receiving facility. These findings suggest that injured patients may benefit from alternative, less aggressive airway management in the prehospital setting, particularly when close to a receiving hospital. Additionally, these findings suggest that EMS systems who have not adapted OOH-ETI as the standard of care in seriously injured patients should consider alternative airway management procedures.

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Table 1 Prehospital Criteria for Trauma System Entry from the Field

Prehospital Physiologic criteria:
Systolic blood pressure < 90 mmHg
Respiratory rate < 10, >29, or need for airway management
Glasgow Coma Scale score ≤ 12
Anatomic criteria:
Flail chest
2 or more long bone (humerus/femur) fractures
Penetrating injury to the head, neck, torso, or groin
Amputation proximal to the wrist or ankle
Suspected spinal cord injury with paralysis
Mechanism of injury:
Extrication time > 20 minutes
Death of occupant in same vehicle
Ejection from vehicle
Discretionary criteria:
High energy mechanism (fall > 20 feet, pedestrian versus auto, motorcycle/ATV/bicycle crash, rollover, passenger space intrusion)
Comorbid conditions (age < 5 or > 55 years, anticoagulation, medical illness, pregnancy, intoxication)

Table 2 Demographics of injured patients ≥15 years transported to the Level I Trauma centers in Oregon

	All Subjects (n=8786)	OOH-ETI (n=534) RSI: 307(57.5%) Non-RSI: 227(42.5%)	Non-ETI (n=8252)	% of Missing Data in Registry
Mean age (years)	39.7	38.6	39.8	0
Mean distance (miles)	14.5	18.1	14.2	0
Mean EMS GCS	13	6	14	14.9
Mean EMS Respirations/minute	20	17	20	13.1
Mean EMS SBP	132	128	132	16.9
Mean ISS	9.1	25	8	0.6
Mean OOH Time (minutes)	44.9	49.6	44.5	20.3
Blood in ED	359 (4%)	132 (25%)	227 (2.7%)	0
Alcohol	2302 (26.2%)	172 (32.3%)	2130 (25.8%)	0.1
Male	5974 (68%)	403 (75.5%)	5571 (67.5%)	0
AIS Head >=3	1295 (14.7%)	382 (72%)	913 (11.1%)	2.8
Helicopter Transport	962 (10.9%)	211 (39.6%)	751 (9.1%)	0
Mechanism of Injury:				0.8
MVC	4207 (47.9%)	233 (43.6%)	3974 (48.2%)	
Fall	3299 (37.6%)	202 (37.9%)	3097 (37.5%)	
Penetrating	739 (8.4%)	53 (9.9%)	686 (8.3%)	
Burns, Drownings	426 (4.8%)	43 (8.0%)	383 (4.6%)	
Machinery	115 (1.3%)	3 (0.6%)	112 (1.4%)	
Comorbidities:				5.6
None	7147 (81.4%)	471 (88.3%)	6676 (80.9%)	
1 Comorbidity	1397 (15.9%)	50 (9.4%)	1347 (16.3%)	
2 or > Comorbidities	241 (2.7%)	12 (2.3%)	229 (2.8%)	
Surgery within 3 days	776 (8.8%)	180 (33.7%)	596 (7.2%)	0.02
Mortality	313 (3.5%)	170 (32%)	143 (1.7%)	0

EMS=emergency medical services; GCS=Glasgow Coma Scale; SBP=systolic blood pressure; ISS=Injury Severity Scale score; AIS=Abbreviated Injury Scale score; MVC=motor vehicle crash

Table 3 Variables Included in Final Propensity Score Model

ISS[a]	EMS[b] GCS[c]
EMS SBP[d] Fractional Polynomial 1[†]	EMS SBP Fractional Polynomial 2[‡]
Age Fractional Polynomial[††]	Past Medical History
Alcohol	Mode of Transport
Mechanism of Injury	Blood Transfusion in ED[e]
AIS[f] Head Injury ≥3	Major Surgery within 3 days of Admission
AIS Head Injury ≥3*Mechanism of Injury	Past Medical History*Age
Alcohol*GCS	Mode of Transport*GCS
Mechanism of Injury*GCS	Blood Transfusion in ED*GCS
AIS Head Injury ≥3* ISS	

a = Injury Severity Score
b = Emergency Medical Services
c = Glasgow Coma Scale
d = Systolic blood pressure
e = Emergency Department
f = Abbreviated Injury Score
† = EMS SBP*EMS SBP
‡ = (EMS SBP*EMS SBP)*Log of EMS SBP
†† = Age*Age

Table 4 Multivariable Adjusted Odds of Mortality

Model 1 (Primary Model) OR (95% CI)	
OOH-ETI	2.06 (1.33-3.18) p=0.001
Helicopter	0.34 (0.22-0.53) p<0.000001
Propensity	11.64 (6.41-21.14) p<0.000001
Distance 1†	0.97 (0.95-0.99) p=0.014
Distance 2†	1.00 (1.00-1.01) p=0.019

OOH-ETI: Out-of-hospital endotracheal intubation
Model 1 represents primary model without interaction terms
†= Represents Best Fit Fractional Polynomials of Distance with OOH-ETI and Mortality
Distance 1= distance (linear)
Distance 2= distance*distance

Model 2 (Secondary Model with Interaction Terms) OR (95% CI)	
OOH-ETI	3.98 (2.08-7.60) p=0.00002
Helicopter	0.38 (0.24-0.58) p=0.00001
Propensity	11.88 (6.57-21.50) p<0.000001
Distance 1	0.99 (0.97-1.03) p=0.90
Distance 2	1.00 (0.99-1.01) p=0.76
Distance 1*OOH-ETI †	0.94 (0.89-0.98) p=0.009
Distance 2*OOH-ETI †	1.00 (1.00-1.01) p=0.045

Model 2 represents secondary model with interaction terms representing those with an OOH-ETI and the shortest transport distance
†= Represents interaction term of fractional polynomial distance term with OOH-ETI

Table 5 Multivariable Adjusted Odds of Mortality of OOH-ETI by Distance Categories

Model 3 (Mortality by Distance Category)	OR (95% CI)
Non-Intubated Patient at Any Distance	(REFERENCE)
OOH-ETI and distance <10 miles from Hospital	2.70 (1.63-4.46) p=0.00009
OOH-ETI and 10-<20 miles from Hospital	1.87 (1.09-3.21) p=0.020
OOH-ETI and 20-<30 miles from Hospital	1.80 (0.92-3.52) p=0.08
OOH-ETI and 30-<40 miles from Hospital	0.90 (0.38-2.16) p=0.81
OOH-ETI and 40-<50 miles from Hospital	0.20 (0.02-1.65) p=0.13
OOH-ETI and 50 or >miles from Hospital	1.83 (0.61-5.46) p=0.27
Helicopter	0.36 (0.24-0.56) p<0.000001
Propensity	11.20 (6.56-21.80) p<0.000001

OOH-ETI: Out-of-hospital endotracheal intubation

Table 6 Characteristics Adequately Controlled for by Propensity Score

Blood Transfusion in the Emergency Department
Age
Past Medical History
Mode of Transport
Mechanism of Injury
EMS Systolic Blood Pressure

Table 7 Primary Model, Ground Only Transported Patients

	OR (95% CI)
OOH-ETI	2.10 (1.29-3.40) $p=0.003$
Propensity	17.05 (8.80-33.02) $p<0.000001$
Distance 1†	0.97 (0.94-0.99) $p=0.046$
Distance 2†	1.00 (1.00-1.01) $p=0.039$

OOH-ETI: Out-of-hospital endotracheal intubation
†= Represents Best Fit Fractional Polynomials of Distance with OOH-ETI and Mortality
Distance 1= distance (linear)
Distance 2= distance*distance

Figure 1 Geographic Region of NW Oregon, Including Portland Metropolitan

(Data points represent location of all included trauma patients).

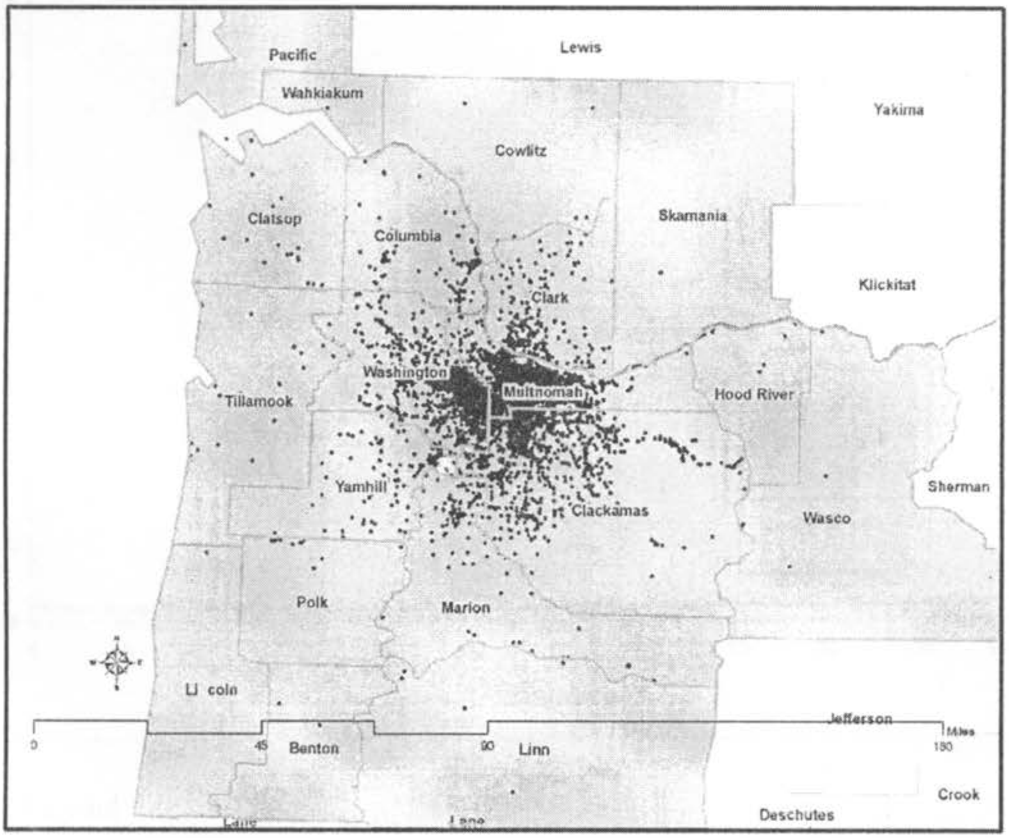

Figure 2 Distance vs. Probability of Mortality in OOH-ETI vs. Non-Intubated Patients.*†

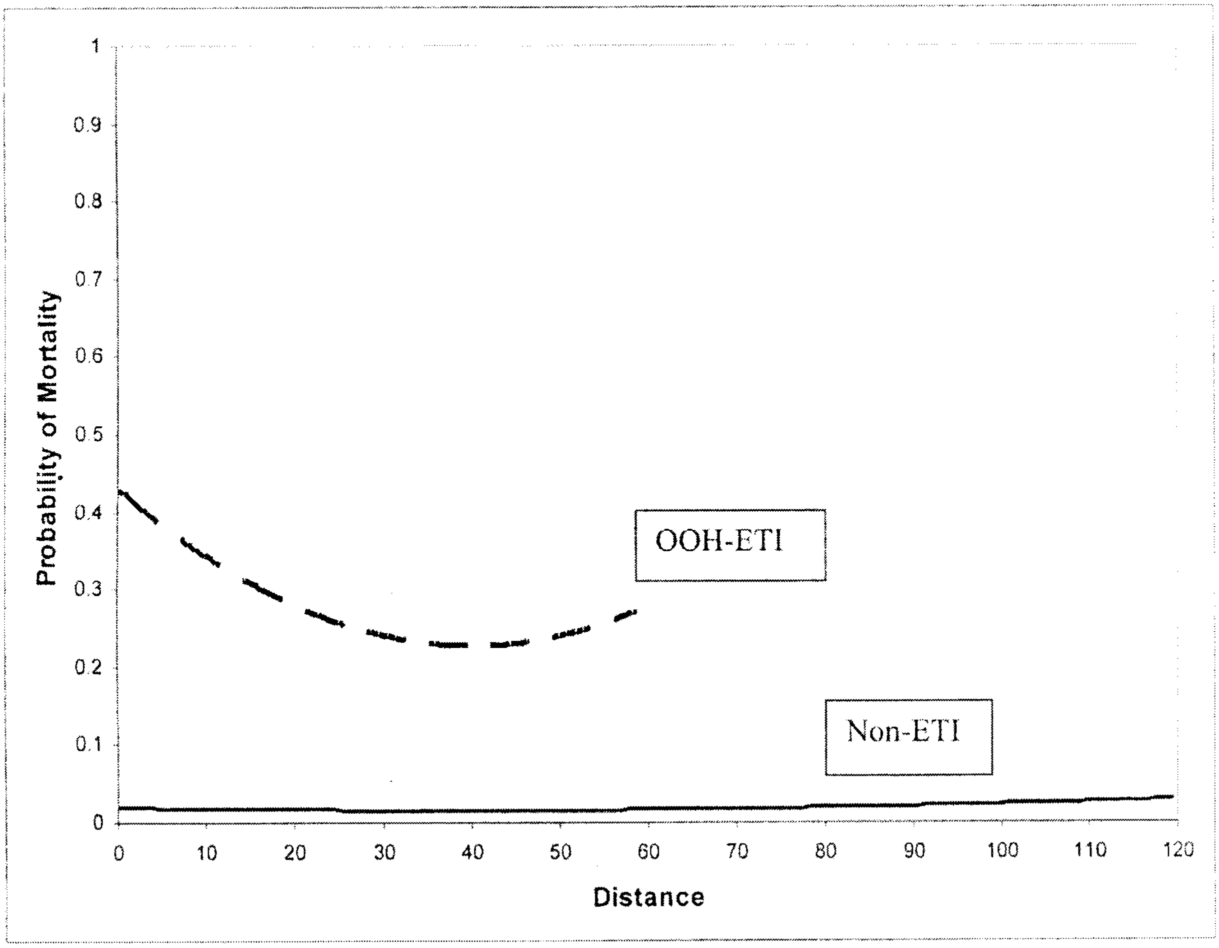

Figure 2 Legend

*Adjusted probability of mortality of trauma patients based on the final model with distance from hospital in miles. Solid line represents probability of mortality in non-intubated patients. Dashed line represents intubated patients. "Distance" is the shortest distance (in miles) from the event site to the Level I receiving trauma center.
† Twelve outlier observations for OOH-ETI with distance greater than 60 miles were omitted from this graph to prevent the fractional polynomial curve from being inappropriately influenced by a small number of outlier observations[36].

Figure 3. Distribution of Transport Distance by Mode of Transport in Intubated Patients