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A comparison of invasive airway management and rates of pneumonia in prehospital and hospital

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Abstract

Introduction—Infection is a major cause of morbidity and mortality in trauma. Infection in trauma is poorly understood. The impact of prehospital invasive airway management (IAM) on the

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incidence of pneumonia and health services utilization is unknown. We hypothesized that trauma patients exposed to prehospital IAM will suffer higher rates of pneumonia compared to no IAM or exposure to IAM performed in the hospital. We hypothesized that patients who develop pneumonia subsequent to prehospital IAM will have longer ICU and hospital LOS compared to patients who acquired pneumonia after IAM performed in the hospital.

Methods—This is an observational cohort study of data previously collected for the ROC hypertonic resuscitation randomized trial. Patients were included if traumatic injury resulted in shock, traumatic brain injury or both. Patients were excluded if they died 24 hours after injury, or pneumonia data were missing. Adjusted and unadjusted logistic regression was used to calculate the odds ratio of pneumonia if exposed in the prehospital setting compared to no exposure or exposure in the hospital.

Results—Of 2222 patients enrolled in HS, 1676 patients met enrolment criteria for this study. Four and a half percent of patients suffered pneumonia. IAM in the prehospital setting resulted in 6.8 fold increase (C.I. 2.0, 23.0, $p=0.003$) in the adjusted odds of developing pneumonia compared to not being intubated, while in hospital intubation resulted in 4.8 fold increase (C.I. 1.4, 16.6, $p=0.01$), which was not statistically significantly different to the odds ratio of prehospital IAM. There were no statistically significant increases in health services utilization resulting from pneumonia incurred after IAM.

Conclusion—Exposure to IAM in prehospital and in hospital setting results in an increase in pneumonia, however, there does not appear to be a link between the source of pneumonia and an increase in ICU or hospital LOS.

Levels of Evidence—Level III, therapeutic

Keywords

emergency medical services; endotracheal intubation; pneumonia; infection; health services utilization

Introduction

Traumatic injury is the leading cause of death and disability for North Americans in the first four decades of life [1, 2] While improvements to trauma systems have been attributed to reductions in late traumatic mortality [3, 4], infection remains one of the main non-immediate causes of trauma mortality[5, 6].

Out of hospital care is provided in an uncontrolled environment, generally with very minimal opportunity to exercise thorough control procedures. Lack of infection control procedures, the uncontrolled environment or both, may contribute to increases in infection in traumatically injured patients. This is particularly true for invasive airway management (IAM) procedures, raising questions about the relationship between the out of hospital environment and incidence of pneumonia. Additionally, increased incidence of pneumonia may result in additional health service utilization, increasing health care delivery costs, and potentially contribute to patient morbidity and mortality.

The purpose of this study is twofold. First we sought to compare rates of pneumonia attributable to IAM performed in the out of hospital vs. in the hospital environment. We hypothesize that exposure to prehospital IAM compared to hospital IAM is associated with increased incidence of pneumonia.

Second we sought to compare the differences in intensive care unit (ICU) length of stay (LOS) and hospital LOS between patients who had experienced prehospital IAM vs. in hospital IAM. We hypothesized that patients who developed a pneumonia subsequent to exposure to prehospital IAM would have longer ICU and hospital LOS compared to patients who developed pneumonia after IAM performed in the hospital environment.

Methods

Study Design

This is a secondary analysis of data that were collected for the Resuscitation Outcomes Consortium study of hypertonic resuscitation of traumatically injured patients [7–9] (ClinicalTrials.gov Identifier: NCT00316017, and 00316004). The Resuscitation Outcomes Consortium is a multicenter research consortium consisting of university, hospital, and emergency medical services collaborators that conduct resuscitation research of cardiac arrest and major trauma. [10] The hypertonic resuscitation trial had 10 contributing sites consisting of 89 EMS agencies, approximately 7000 EMS providers, and 32 hospitals. The study enrolled patients from May 9, 2006 to May 5, 2009, with six-month follow-up. Two thousand two hundred and twenty-two (2,222) patients were enrolled after suffering systemic trauma, traumatic brain injury or both. Ethical approval for the hypertonic resuscitation trials, and subsequent use of the data collected was provided.

Population and setting

Patients were enrolled in the hypertonic resuscitation trial if they suffered a traumatic injury and were greater than 14 years of age, had a systolic blood pressure of less than 70 mm Hg or between 71 and 90 mm Hg in conjunction with HR $\geq$ 108 bpm or suffered blunt trauma to the head with a prehospital Glasgow Coma Scale of less than 9.

For this study, patients were included if they were alive for 24 hours after initial injury and had pneumonia data collected. Patients were excluded if they died in the first 24 hours after injury or had missing pneumonia data.

Measurement

We sought to compare the same or similar IAM performed in three different environments, with no IAM as a reference group. The environments were: prehospital, in-hospital (including the emergency department), and both prehospital and in-hospital. Patients who developed pneumonia were considered to have experienced the outcome of interest. To reduce misclassification, only pneumonia diagnoses made in the first 2 to 4 days after IAM were considered attributable to that exposure environment.

In the prehospital environment, patients could have their airways managed by endotracheal intubation or supraglottic airway, cryothyrotomy or prehospital surgical airway. In the

hospital patients could have their airway managed by endotracheal intubation, tracheostomy, or surgical airway. Determination of specific IAM procedure was based on review of clinical records from the hospital or prehospital agencies.

A pneumonia diagnosis was confirmed by one of the following methods: bronchoalveolar lavage (BAL), protected specimen brushing, or positive sputum gram stain. The treating hospital was guided by their own protocols and resource availability in making decisions about which method of confirmation they would use.

In the second part of our study, we investigated if a relationship exists between IAM, development of pneumonia and differences in health service utilization. ICU LOS and hospital LOS were used as proxy measures of health services utilization. The investigators deemed *a priori* that attribution of health services utilization needed to flow directly from the exposure/pneumonia relationship. To attribute ICU or hospital LOS to the pneumonia, the pneumonia that developed in the first 2 to 4 days was considered the start of the LOS, upon which the follow up period was calculated. To account for potential bias resulting from different rates of mortality, ICU LOS was calculated as the number of ICU free days in the first 28 days following diagnosis of pneumonia with patients who die while in ICU as having 0 days of ICU free days. Hospital free days are defined similarly as number of hospital free days in the first 28 days following pneumonia diagnosis.

Covariables

Covariables were identified *a priori* and were based on hypothesized relationships between IAM and development of pneumonia. We included an indication of the severity of chest injuries, measured as chest region abbreviated injury score (AIS) of two or less, and greater than two, in an effort to more directly control for bias associated with differences in chest injury severity. The New Injury Severity Score (NISS) and the Revised Trauma Score were used to account for injury severity anatomically and at the time of treatment. Injury types included were blunt systemic trauma, traumatic brain injury or both blunt trauma and traumatic brain injury.

Data Management

All exposure and outcomes measures were collected prospectively as part of the hypertonic resuscitation randomized controlled trials, and abstracted by trained research staff who were blind to the hypotheses being tested in this study. All patients who were eligible and included in the hypertonic saline trial were eligible for this study if they survived at least 24 hours.

Analytic Methods

Descriptive statistics were provided as mean and standard deviation or frequency and percentages. To assess the relationship between airway management and incidence of pneumonia, the outcome was coded as either yes or no regarding whether pneumonia had been identified in the 48 hours following IAM. Multivariable logistic regression models were used to estimate the differences in odds. The analysis of the relationship between airway management procedure and the resulting lengths of stay (continuous variable) was

performed using multivariable linear regression models (using robust standard errors) for only those patients who experienced pneumonia. Patients who experienced IAM in both prehospital and in-hospital environments were included in the analysis as a fourth exposure group, but no results are presented for this group because of small numbers and resulting wide confidence intervals. A p-value of 0.05 was considered significant and ninety-five percent confidence intervals were provided. P-values are not adjusted for multiple comparisons.

Results

Two thousand two hundred and twenty-two (2222) patients were enrolled in the hypertonic saline study. Twenty-four patients were excluded because they did not meet eligibility criteria, leaving 2198 patients who were injured and suffered systemic trauma, traumatic brain injury or both. Four hundred and twenty-two (422) patients died in the first 24 hours after injury and were excluded from this study, and a further 95 patients had missing pneumonia information, leaving 1681 patients eligible for inclusion in this study. An additional five patients were missing covariate data, resulting in a final analytic cohort of 1676 patients. (Figure 1)

Overall, 344 (21%) patients had no form of IAM performed, while 786 (47%) experienced IAM in the prehospital environment, 498 (30%) in the hospital environment, and 48 (2%) received IAM in both the prehospital and in hospital environment. Incidence of pneumonia diagnoses at anytime during hospitalization was 21.7% (363) for the entire cohort, 28% (221) for patients who received prehospital IAM, and 22.7% (113) for patients who received in hospital IAM. The unadjusted relative risk of developing pneumonia if the patient received IAM in the prehospital setting compared to in the hospital was 1.24 for all diagnosed cases of pneumonia.

Seventy-two (4.3%) of patients developed pneumonia in the surveillance period of 2 to 4 days; while, three (1%) of patients who did not have any form of IAM developed pneumonia. Forty-seven (6%) of those treated in the prehospital environment developed pneumonia. Twenty-one (4%) of those treated in the hospital only developed pneumonia. (Table 1) The unadjusted relative risk of developing pneumonia for patients who received prehospital IAM compared to those who received IAM in the hospital was 1.41 in patients whose pneumonia diagnosis was within the 2 to 4 day surveillance period. Only one (2%) patient developed pneumonia after IAM in the prehospital and in hospital setting. (results not shown).

Environment/Pneumonia Relationship

Seven hundred and eighty-six of the 1676 (45%) patients were treated with an IAM in the prehospital environment, compared to 344 (20%) not receiving any advance airway management, 498 (29%) in the hospital only. Patients treated in the prehospital environment only were more likely to suffer traumatic brain injury (77%) and a blunt force injury (95%). (Table 1) Patients who did not have their airway managed had less severe chest injuries, were more frequently enrolled in the shock cohort, and had higher revised trauma scores. Six

percent of those treated in the prehospital environment only and 4.2% if treated in the hospital only developed pneumonia. (Table 2)

After adjusting for age, sex, chest injury score, injury type, and treatment group, presence of an airway procedure was significantly associated with risk of developing pneumonia, with patients receiving pre-hospital airways only most likely to become infected (OR=6.8, 95% CI: 2.0 – 23.0) and followed by in-hospital airway only (OR=4.8, 95% CI: 1.4 – 16.6). (Table 3) The difference between the odds ratios for those receiving pre-hospital airways only and those receiving in-hospital airways only was not significant ($p = 0.22$).

Environment/Resource Utilization relationship among patients who experienced pneumonia

One of the main concerns of increased incidence of iatrogenic pneumonia is that it may lead to increases in the use of health services. In this part of the study, we sought to determine if patients who developed pneumonia secondary to airway management, incurred increases in ICU or hospital LOS.

In our analysis, we attempted to determine if there were differences in either ICU or in hospital LOS based on the source of the pneumonia. We monitored patients for the first 28 of hospital admission. Overall, patients stayed in hospital for 16.6 days (SD=10.5), while those who had a pneumonia diagnosis stayed on average 25.1 days (SD=5.3) and those without pneumonia stayed in hospital only 14.2 days (SD=2.7). In this study we found no statistically significant difference in ICU LOS among patients who develop pneumonia after prehospital, in hospital or no IAM, as measured by differences in ICU free days in the first 28 days of post pneumonia diagnosis. (Table 4) There were statistically significant more in-hospital free days in the USA compared to Canada and there were statistically significant fewer in-hospital free days for shock patients compared to TBI patients. (Table 5)

Functional outcome related to pneumonia

Patients were assessed with the Extended Glasgow Outcome Scale (GOS-E) at 6 months. Overall GOS-E for this patient cohort was 4.5 (SD=2.6), and 3.8 (SD=2.1) among those with a pneumonia diagnosis, and 4.8 (SD=2.7) among those without a pneumonia diagnosis. The percent of patients with a GOS-E less than 4 was greater in the pneumonia group (68.1%) than in the group non-pneumonia group (42.7%).

Discussion

In this study of a mixed population of systemic trauma and traumatically brain injured patients, patients whose airways were treated invasively in the prehospital or hospital setting were more likely to develop a pneumonia than those who did not have their airway managed. The difference in the odds of developing pneumonia between prehospital exposure and in hospital exposure was not statistically significant. Regardless of the source of the pneumonia, there does not appear to be any increase in ICU or hospital LOS.

The International Sepsis Forum Consensus Conference on Definitions of Infection in the Intensive Care Unit [11] lists pneumonia as one of the six sources of septic infection. In this

study, we examined the role of various environments in both the incidence of infection and health services utilization when trauma patients develop pneumonia.

The epidemiologic triad [12] is commonly used to isolate the source of infectious diseases. In this study, we hypothesized that the differences in environment rather than the airway management procedure is responsible for the incidence of pneumonia in traumatically injured patients. We were unable to establish a statistically significance difference between prehospital and in hospital rates of pneumonia. We consider the use of both a mixed patient cohort and a heterogeneous treatment modality as an advantage for this particular study in that it provided us with a larger sample size that has been previously studied, and particularly suited to addressing our question which emphasizes the treatment environment rather than the treatment itself. Two of three previous studies comparing intubation performed in the prehospital vs. in hospital setting [4, 5, 13] demonstrated a statistically significant increase in pneumonia in patients treated in the out of hospital setting, while one study established a non significant increase in pneumonia subsequent to prehospital intubation. It should be noted that the risk of developing pneumonia may be associated with the type of IAM used. Since in hospital IAM tends to include far more invasive and potentially pneumonia prone procedures (rapid sequence intubation, surgical airway), it is possible that in hospital IAM would be associated with greater odds of pneumonia than prehospital IAM. Our inability to detect a statistically significant difference in the odds ratios of pneumonia between the prehospital and in hospital IAM may be due to residual confounding, which is difficult to control outside of a randomized control trial setting.

A randomized controlled trial [14] comparing six month neurological outcomes between prehospital rapid sequence intubation versus in hospital intubation for traumatically brain injured patients found a 28% increase in the likelihood of a patient having a good neurological outcome at 6 months, suggesting that well managed prehospital IAM can improve some patient outcomes.

Vadeboncoeur and colleagues [15] determined that paramedics performed intubation as a result of identifying aspiration prior to making any efforts to secure an airway, suggesting that there are potentially confounding differences in patient populations that result in increases in pneumonia in the population that is intubated in the prehospital setting.

We established a pneumonia surveillance period of 2 to 4 days post IAM in an effort to limit the introduction of contaminating our exposure groups. Patients who have their airways managed in the prehospital environment are at greatest risk of this form of bias, due to the fact that prehospital care occurs prior to all other care. Our calculation of the unadjusted risk ratios for all cases of pneumonia and for cases that developed during the 2 to 4 day surveillance period (1.24 vs 1.41) suggests that our choice of surveillance period may have increased this bias, rather than decrease it. More robust methods are required if valid disease attribution is to be established.

Minshall et al [16] studied the use of bronchoalveolar lavage (BAL) as a means of improving identification of patients at risk for VAP. They were able to identify nine different pathogens with the use of BAL, and we believe that this diagnostic technique could potentially be used

to further differentiate between sources of pneumonia introduced in the prehospital as opposed to the hospital environments.

While this is a relatively large cohort study, our analysis of the differences in LOS resulting from differences in the source of the pneumonia may have been impacted by reduced statistical power. A larger follow-up study, which focuses on the health services utilization impacts of the source of pneumonia may help to quantify the extent to which pneumonia resulting from prehospital intubation is producing patient hardship. While we hypothesize that a small study sample could have impacted on our ability to detect a true difference between these groups, our study does appear to have been sufficiently powered to detect well established differences, such as differences in LOS between US vs. Canadian hospitals, and longer LOS for TBI patients compared to shock patients.

This is the first published study that attempts to compare the incidence of pneumonia resulting from IAM performed in the prehospital environment compared to those performed in the hospital. There are several limitations to this study. This investigation is an observational study making secondary use of data collected during two randomized controlled trials. The observational nature of this study makes causal attribution impossible. For the second part of our study, we established temporality by selecting patients who developed pneumonia after having their airways managed. Studies that are based on secondary use of data are susceptible to misclassification bias. In this study, outcome, exposure and covariate data were collected prospectively, and all data collection personnel were blinded to the hypothesis we have tested, reducing the risk for this type of bias.

Despite using all of the patients enrolled in the original trial, the rare occurrence of the outcome measure appears to have limited the power of our study. At the outset we considered this investigation a hypothesis generating study, and encourage a prospectively designed study as part of a larger infection control effort to help establish the role of the prehospital environment in the incidence of infectious complications in injured patients.

Conclusion

We have established that patients intubated in the prehospital or in the in hospital setting are at higher risk of developing pneumonia than those patients who do not receive advanced airway management. Despite being at greater risk for developing pneumonia, patients who experience IAM in the prehospital or in the hospital setting and do develop pneumonia, do not experience either longer ICU or hospital LOS than those who develop pneumonia and who were not intubated. Further investigation to better understand the underlying mechanism of the pneumonia is warranted.

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Figure 1.
Participant inclusion flow chart

Table 1

Cohort characteristics by intubation exposure status

Pneumonia			
	No Exposure (n=344)	Prehospital Exposure only (n=786)	In-hospital only (n=498)
AIS chest category			
0–2 (%)	229 (66.6%)	415 (52.8%)	288 (57.8%)
3+ (%)	115 (33.4%)	371 (47.2%)	210 (42.2%)
Cohort			
Shock (%)	243 (70.6%)	179 (22.8%)	191 (38.4%)
TBI (%)	101 (29.4%)	607 (77.2%)	307 (61.6%)
Age			
<45 (%)	242 (70.3%)	564 (71.8%)	342 (68.7%)
45–65 (%)	70 (20.3%)	171 (21.8%)	120 (24.1%)
65 (%)	32 (9.3%)	51 (6.5%)	36 (7.2%)
Injury type			
Blunt (%)	214 (62.2%)	747 (95.0%)	415 (83.3%)
Penetrating (%)	124 (36.0%)	38 (4.8%)	83 (16.7%)
Treatment group			
HSD (%)	85 (24.7%)	212 (27.0%)	134 (26.9%)
HS (%)	100 (29.1%)	223 (28.4%)	131 (26.3%)
NS (%)	159 (46.2%)	351 (44.7%)	233 (46.8%)
Sex, male (%)	266 (77.3%)	601 (76.5%)	393 (78.9%)
NISS category			
0–8 (%)	69 (20.3%)	57 (7.3%)	52 (10.6%)
9–15 (%)	64 (18.8%)	45 (5.8%)	37 (7.5%)
16–24 (%)	84 (24.7%)	97 (12.5%)	78 (15.9%)
25+ (%)	123 (36.2%)	578 (74.4%)	325 (66.1%)
RTS (SD)	6.4 (1.2)	4.8 (1.4)	5.4 (1.3)

Note: results of the population that experienced both prehospital and in-hospital airway management have been excluded.

Table 2

Univariable analyses relating exposure to pneumonia

Pneumonia			
Exposure	Pneumonia (%)	No Pneumonia (%)	Total
None	3 (1)	341 (99)	344
PH only	47 (6)	739 (94)	786
In-hospital only	21 (4)	477 (96)	498
Both prehospital and in hospital	1 (2)	47 (98)	48

Table 3

Adjusted Odds of Pneumonia

Pneumonia			
	OR	95% CI	<i>p</i>
No exposure	Referent		
PH exposure only	6.79	(2.00, 23.03)	0.00
In-hosp. exp. Only	4.83	(1.40, 16.63)	0.01
Both PH and in-hosp. exp.	2.34	(0.23, 23.63)	0.47
AIS chest 3+	1.77	(1.08, 2.90)	0.02
Shock cohort	0.90	(0.49, 1.65)	0.74
Age 45–65	0.72	(0.38, 1.34)	0.30
Age 65+	0.80	(0.28, 2.27)	0.67
Blunt injury	0.86	(0.36, 2.09)	0.75
HSD treatment group	0.63	(0.33, 1.18)	0.15
HS treatment group	1.00	(0.58, 1.74)	0.99

Note: results of the population that experienced both prehospital and in-hospital airway management have been excluded.

Table 4

Multivariable Linear Regression Results for ICU free days (out of 28 days)

Pneumonia, ICU free days			
	ICU free days	95% CI	p-value
No exposure†	Referent		
PH exposure only	0.98	(−8.83, 10.79)	0.84
In-hosp. exp. Only	0.18	(−9.40, 9.77)	0.97
Ventilated			
USA[17]	−0.07	(−5.59, 5.45)	0.98
AIS chest 3+	−2.25	(−6.20, 1.71)	0.26
Shock cohort	−3.78	(−8.97, 1.41)	0.15
Age 45–65	−3.15	(−8.34, 2.04)	0.23
Age 65+	−8.54	(−20.00, 2.92)	0.14
Blunt injury	−4.60	(−15.40, 6.20)	0.40
HSD treatment group	1.47	(−3.36, 6.29)	0.55
HS treatment group	−0.44	(−5.62, 4.74)	0.86
Male	0.74	(−7.08, 8.57)	0.85

Note: results of the population that experienced both prehospital and in-hospital airway management have been excluded.

Table 5

Multivariable Linear Regression Results for Hospital free days (out of 28 days)

Pneumonia, Hospital free days			
	Hospital free Days	95% CI	p-value
No exposure [†]	Referent		
PH exposure only	−3.10	(−11.34, 5.14)	0.46
In-hosp. exp. Only	−5.39	(−13.90, 3.12)	0.21
Ventilated			
USA	4.09	(0.29, 7.89)	0.04
AIS chest 3+	−1.20	(−4.50, 2.10)	0.47
Shock cohort	−3.70	(−7.18, −0.22)	0.04
Age 45–65	−2.12	(−6.58, 2.33)	0.35
Age 65+	−4.12	(−9.72, 1.48)	0.15
Blunt injury	−1.47	(−9.34, 6.39)	0.71
HSD treatment group	−0.09	(−4.09, 3.92)	0.97
HS treatment group	−1.76	(−5.95, 2.43)	0.40
Male	2.02	(−3.72, 7.76)	0.48

[†]Note that only 3 subjects had no exposure

Note: results of the population that experienced both prehospital and in-hospital airway management have been excluded.