Resuscitation 82 (2011) 378–385

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Out-of-hospital airway management in the United States☆,☆☆

Henry E. Wang[a,*], N. Clay Mann[b], Gregory Mears[c], Karen Jacobson[b], Donald M. Yealy[d]

[a] Department of Emergency Medicine, University of Alabama at Birmingham, Birmingham, AL, United States
[b] Intermountain Injury Control and Research Center, Department of Pediatrics, University of Utah School of Medicine, Salt Lake City, UT, United States
[c] Department of Emergency Medicine, University of North Carolina Chapel Hill, Chapel Hill, NC, United States
[d] Department of Emergency Medicine, University of Pittsburgh, Pittsburgh, PA, United States

ARTICLE INFO

Article history:
Received 18 October 2010
Accepted 10 December 2010

Keywords:
Emergency medical services
Paramedics
Intubation (Intratracheal)

ABSTRACT

Objective: Prior studies describe airway management by single EMS agencies, regions or states. We sought to characterize out-of-hospital airway management interventions, outcomes and complications across the United States.
Methods: Using the 2008 National Emergency Medical Services Information System (NEMSIS) Public-Release Data Set containing data from 16 states, we identified patients receiving advanced airway management, including endotracheal intubation (ETI), alternate airways (Combitube, Laryngeal Mask Airway (LMA), King LT, Esophageal-Obturator Airway (EOA)), and cricothyroidotomy (needle and open). We examined airway management success and complications in the full cohort and in key subsets (cardiac arrest, non-arrest medical, non-arrest injury, children <10 and 10–19 years, rapid-sequence intubation (RSI), population setting and US census region). We analyzed the data using descriptive statistics.
Results: Among 4,383,768 EMS activations, there were 10,356 ETI, 2246 alternate airways, and 88 cricothyroidotomies. ETI success rates were: overall 6482/8418 (77.0%; 95% CI: 76.1–77.9%), cardiac arrest 3494/4482 (78.0%), non-arrest medical 616/846 (72.8%), non-arrest injury 417/505 (82.6%), children <10 years 295/397 (74.3%), children 10–19 years 228/289 (78.9%), adult 5829/7552 (77.2%), and rapid-sequence intubation 289/355 (81.4%). ETI success was success was lowest in the South US census region. Alternate airway success was 1564/1794 (87.2%). Major complications included: bleeding 84 (7.0 per 1000 interventions), vomiting 80 (6.7 per 1000) and esophageal intubation 12 (1.0 per 1000).
Conclusions: In this study characterizing out-of-hospital airway management across the United States, we observed low out-of-hospital ETI success rates. These data may guide national efforts to improve the quality of out-of-hospital airway management.

1. Introduction

1.1. Background

In the United States, airway management is an important intervention performed by Emergency Medical Services (EMS) rescuers. Prior studies highlight the pitfalls of out-of-hospital airway management such as endotracheal tube misplacement or dislodgement, iatrogenic hypoxia and bradycardia, and interruptions in cardiopulmonary resuscitation chest compressions.[1–3] Other studies note the challenges of providing practitioners with adequate airway training and clinical experience.[4–7]

Ample data describe out-of-hospital airway interventions such as endotracheal intubation (ETI), alternate airway insertion (Combitube, laryngeal mask airway or King-LT) and cricothyroidotomy.[8–23] However, these prior reports have been limited to single EMS agencies, systems, regions or states. A broader assessment is vital for understanding the distribution of out-of-hospital airway procedures, their success rates and associated complications across the United States. This information could support and guide national efforts to enhance out-of-hospital airway management training and practice.

In this study, we used a large multi-state data set to characterize out-of-hospital airway management interventions, success rates and complications across the United States.

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2010.12.014.
☆☆ *Presented at*: American Heart Association Resuscitation Science Symposium, November 2010, Chicago, Illinois and the National Association of EMS Physicians Annual Meeting, January 2011, Bonita Springs, Florida.
* Corresponding author at: Department of Emergency Medicine, University of Alabama at Birmingham, 619 19th Street South, OHB 251 Birmingham, AL 35249, United States. Tel.: +1 205 996 6526; fax: +1 205 975 4662.
E-mail address: hwang@uabmc.edu (H.E. Wang).

0300-9572/$ – see front matter © 2011 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.resuscitation.2010.12.014

2. Methods

2.1. Study design

The Institutional Review Board of the University of Alabama at Birmingham approved the study. This descriptive study utilized the 2008 Public-Release Research Data Set available from the National Emergency Medical Services Information Systems (NEMSIS) project.

2.2. Study setting

The NEMSIS project is supported by the Office of Emergency Medical Services of the National Highway Traffic Safety Administration (NHTSA).[24,25] The overall goal of the NEMSIS project is to standardize clinical information collected by EMS rescuers when responding to emergency calls and to develop an aggregate data set encompassing EMS data from every US state and territory. The NEMSIS Technical Assistance Center (University of Utah School of Medicine, Salt Lake City, UT) aggregates and maintains the national EMS dataset.

The NEMSIS project promotes the use of standard definitions and formats for over 400 data elements (version 2.2.1), with 83 of these variables comprising the national repository. States participating in the NEMSIS project coordinate with local EMS providers to promote patient care documentation with standard computer software programs conforming to NEMSIS data element standards. The lead EMS offices in each state aggregate local EMS data into a statewide data set, subsequently exporting the data to the national repository. While each state may collect additional data, only required "national variables" are submitted to the national repository.

The NEMSIS project does not define case inclusion criteria for the national repository; the project accepts all data meeting state inclusion requirements. Additionally, states may submit data with less than 100% of EMS agencies participating in the state registry.

For this study, we used data from the 2008 NEMSIS Public-Release Research Data Set version 1.2. This data set contains data on over 4.3 million EMS events from 16 states (Alabama, Colorado, Florida, Hawaii, Iowa, Maine, Minnesota, Missouri, North Carolina, North Dakota, Nebraska, New Hampshire, New Jersey, New Mexico, Nevada, and Oklahoma) for the one-year period January 1, 2008–December 31, 2008. (Fig. 1, Appendix A) These states were the first to participate in the NEMSIS project. There are no estimates of the numbers of EMS agencies or EMS responses that are not included in NEMSIS. Hawaii, New Jersey, New Mexico and Oklahoma provided only partial data for the study period because of their implementation of NEMSIS during 2008.

2.3. Selection of participants

We studied patients receiving NEMSIS-defined airway interventions as well as subgroups receiving invasive airways (endotracheal intubation, alternate airway insertion, cricothyroidotomy) or ventilatory support (BiPAP/CPAP, bag-valve-mask or other ventilation) (Appendix B).

2.4. Outcomes

The primary outcomes of this study were the frequency, success rates and complications of each airway intervention.

The NEMSIS data set identifies airway interventions through a "procedures" variable (NEMSIS variable #E19_03). We defined endotracheal intubation (ETI) as direct laryngoscopy, video laryngoscopy, nasotracheal intubation, orotracheal intubation, and rapid sequence intubation. Alternate airways included Esophageal-Obturator airway, Combitube, Laryngeal Mask Airway and King LT Airway. We combined needle and surgical cricothyroidotomy into a single category. We defined "Bagged (via BVMask)" as bag-valve-mask ventilation. We combined "Bagged (via tube)," Respirator Operation (BLS)" and "Ventilator Operation" into the single category "other ventilation." We combined continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP) into a single category.

If a procedure appeared more than once for a single patient, we counted the procedure only once; for example, a patient coded with two cases of orotracheal intubation was classified as receiving a single orotracheal intubation. In contrast, we tallied related procedures separately; for example, a patient coded with both orotracheal and rapid sequence intubations was classified as receiving two different interventions.

NEMSIS contains information on the age, sex, race and ethnicity of patients receiving airway interventions. The data set indicates cardiac arrests through the variable "cardiac arrest" (NEMSIS variable #E11_01). The NEMSIS public release data set does not contain electrocardiographic data which could be used to confirm cardiac arrest status. The data set also identifies injury through the variable "possible injury" (NEMSIS variable #E09_04). Injury severity measures were not available in the data set. NEMSIS listed the provider's primary clinical impression for each case (NEMSIS variable #E09_15) and well as the reported cause of injury (NEMSIS variable #E10_01).

The NEMSIS data contains information on the success of each airway intervention effort (NEMSIS variable #E19_06). Procedural success should be reported in the NEMSIS data set on a "per procedure" basis. The data set, however, often does not indicate the success of each individual attempt. Thus, if there were duplicate procedures listed for a single patient (for example, three orotracheal intubations), we considered the overall effort successful if any of the individual procedures were successful.

Among complications for each intervention (NEMSIS variable #E19_07), we focused on events customarily associated with airway management: (i.e., bleeding, bradycardia, esophageal intubation-immediately detected, esophageal intubation-other, hypotension, hypoxia, injury, vomiting and other).

The NEMSIS Project classified population setting (urbanicity) using United States Department of Agriculture (USDA) and Office of Management and Budget (OMB) definitions: Urban (Urban Influence Codes 1, 2), counties with large (1 + million residents) or small (less than 1 million residents) metropolitan areas; Suburban (Urban Influence Codes 3 and 5), micropolitan (with an urban core of at least 10,000 residents) counties adjacent to a large of small metropolitan county; Rural (Urban Influence Codes 4, 6, 8, 9), non-urban core counties adjacent to a large metropolitan area or a small metropolitan area (with or without a town); Wilderness (Urban Influence Codes 7, 10, 11, 12), non-core counties that are adjacent to micropolitan counties (with or without own town).[24]

To evaluate regional differences, we stratified the data according to states in each nationally defined US census regions (Northeast, South, Midwest and West)[26] (Fig. 1). NEMSIS Data Use Agreements with each state precluded the identification of individual EMS providers, EMS agencies or states.

2.5. Primary data analysis

We analyzed the data using descriptive statistics, expressing the results using binomial proportions and exact 95% confidence intervals.

We determined the number and proportion of EMS episodes involving airway management interventions. Some EMS agencies did not report procedures data to NEMSIS. Therefore, to accurately estimate the prevalence of each airway interventions, we counted

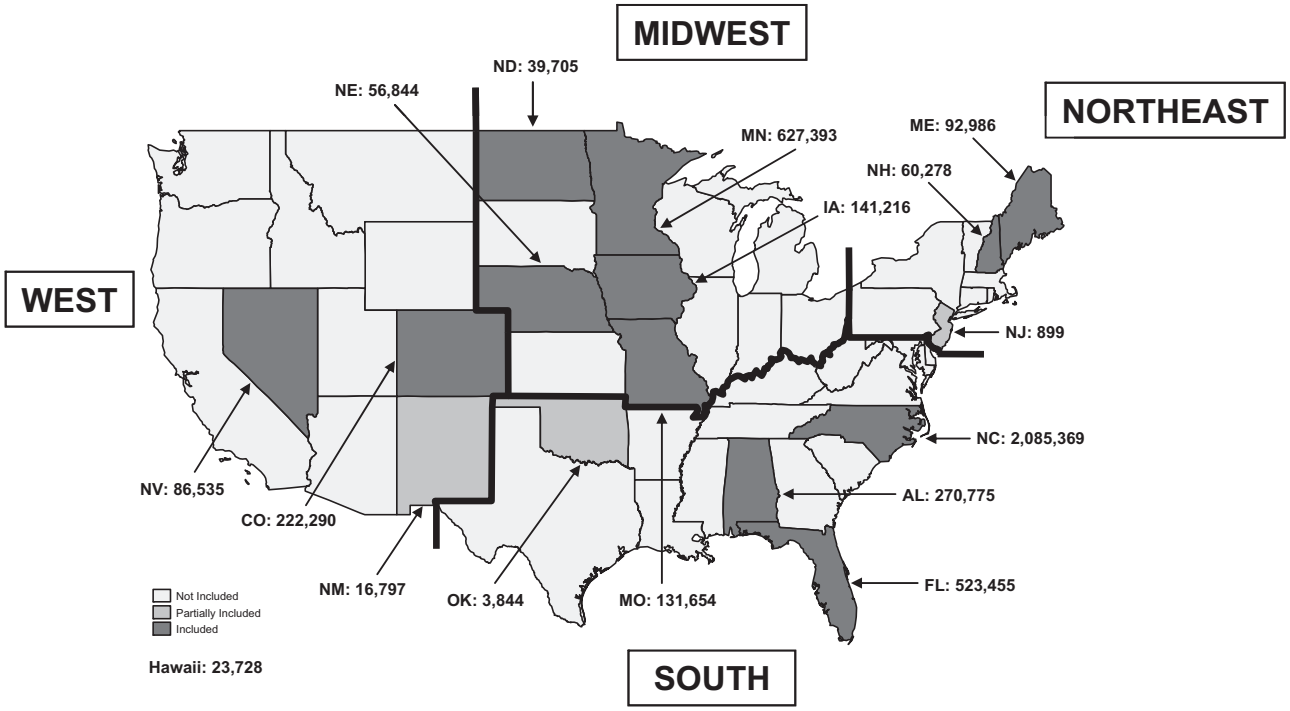

Fig. 1. States and numbers of EMS episodes included in the 2008 NEMSIS public-use data set. Hawaii is included in the data set. Alaska is not included. Numbers next to state abbreviations indicate number of EMS activations included in the data set. Light grey states and Hawaii contributed data for only a portion of 2008. Bold lines and boxed text indicate United States census regions.

only patient care episodes from EMS agencies reporting at least one clinical procedure in the master data set.

We characterized the demographics of the population receiving airway interventions, including age, sex, race, ethnicity, cardiac arrest status, major injury, clinical impression, cause of injury, population setting and US census region.

We calculated ETI success rates for the entire cohort, for key subsets (cardiac arrest, non-arrest medical, non-arrest injury, pediatric and rapid-sequence intubation), for alternate airway insertion and cricothyroidotomy, as well as for each population setting and US census region.[27] We compared airway management success between population and US census regions using univariable odds ratios. Because of NEMSIS policies precluding identification of individual states, we did not perform a multivariable adjusted analysis.

We determined the prevalence of key adverse events, including bleeding, bradycardia, esophageal intubation, hypotension, hypoxia, injury and vomiting. We analyzed the data using Stata 11.2 (Stata, Inc., College Station, Texas).

3. Results

During the study period, participating states submitted data to the NEMSIS national data set on 4,383,768 EMS activations encompassing 3,173,361 patient care events (Fig. 2). North Carolina, Minnesota and Florida contributed the largest number of events, collectively accounting for 74% of the data (Appendix A). Hawaii, New Jersey, New Mexico and Oklahoma began submitting data to NEMSIS during 2008 and did not report events for the entire year.

Among EMS agencies that reported at least one valid procedure, there were 2,333,254 patient care events, including 88,180 with airway management interventions (3.78%; 95% CI: 3.75–3.80%). (Fig. 2 and Table 1) The most common interventions were nasopharyngeal airways, nebulizer treatments and other ventilation.

Invasive airway management (ETI, alternate airway, cricothyroidotomy) or ventilatory support (BiPAP/CPAP, bag-valve-mask or other ventilation) occurred in 32,592 of 2,333,254 (1.40%; 95% CI 1.38–1.41%) patient care events. Most patients receiving invasive airway or ventilatory interventions (ETI, alternate airway, cricothyroidotomy, BiPAP/CPAP, bag-valve-mask or other ventilation), were elderly, male, or White, and originated from urban population settings (Table 2).

Table 1
Prevalence of airway management interventions. Table includes only EMS agencies reporting at least one procedure in the NEMSIS 2008 data set. Percentages reflect portion of 2,333,254 total patient care events. Prevalence estimates not calculated for King LT and foreign body removal due to the small numbers of events. BiPAP = bilevel positive airway pressure. CPAP = continuous positive airway pressure. PEEP = positive end expiratory pressure.

Intervention	*N*	(*N* per 100,000 patient care events; 95% CI)
Bag-valve-mask ventilation	8809	(378; 370–386)
Other ventilation (bag-valve, mechanical, unspecified)	12,241	(525; 516–534)
Endotracheal intubation	10,356	(444; 436–453)
Orotracheal intubation	9130	(392; 384–400)
Nasotracheal intuabtion	1064	(46; 43–48)
Rapid sequence intubation	371	(16; 14–18)
Alternate airway	2246	(96; 92–100)
Combitube	1521	(65; 62–69)
Esophageal-Obturator Airway (EOA)	175	(8; 6–9)
Laryngeal Mask Airway	571	(24; 23–27)
King LT	4	(Not calculated)
Cricothyroidotomy	88	(4; 3–5)
BiPAP/CPAP	4456	(191; 186–197)
Oropharyngeal airway	4623	(198; 193–204)
Nasopharyngeal airway	37,298	(160; 158–161)
Colorimetric tube confirmation	7007	(300; 294–308)
Bulb tube confirmation	646	(28; 26–30)
Nebulizer	12,796	(549; 539–558)
PEEP	2614	(112; 108–117)
Suction	8115	(348; 341–356)
Foreign body removal	1	(Not calculated)

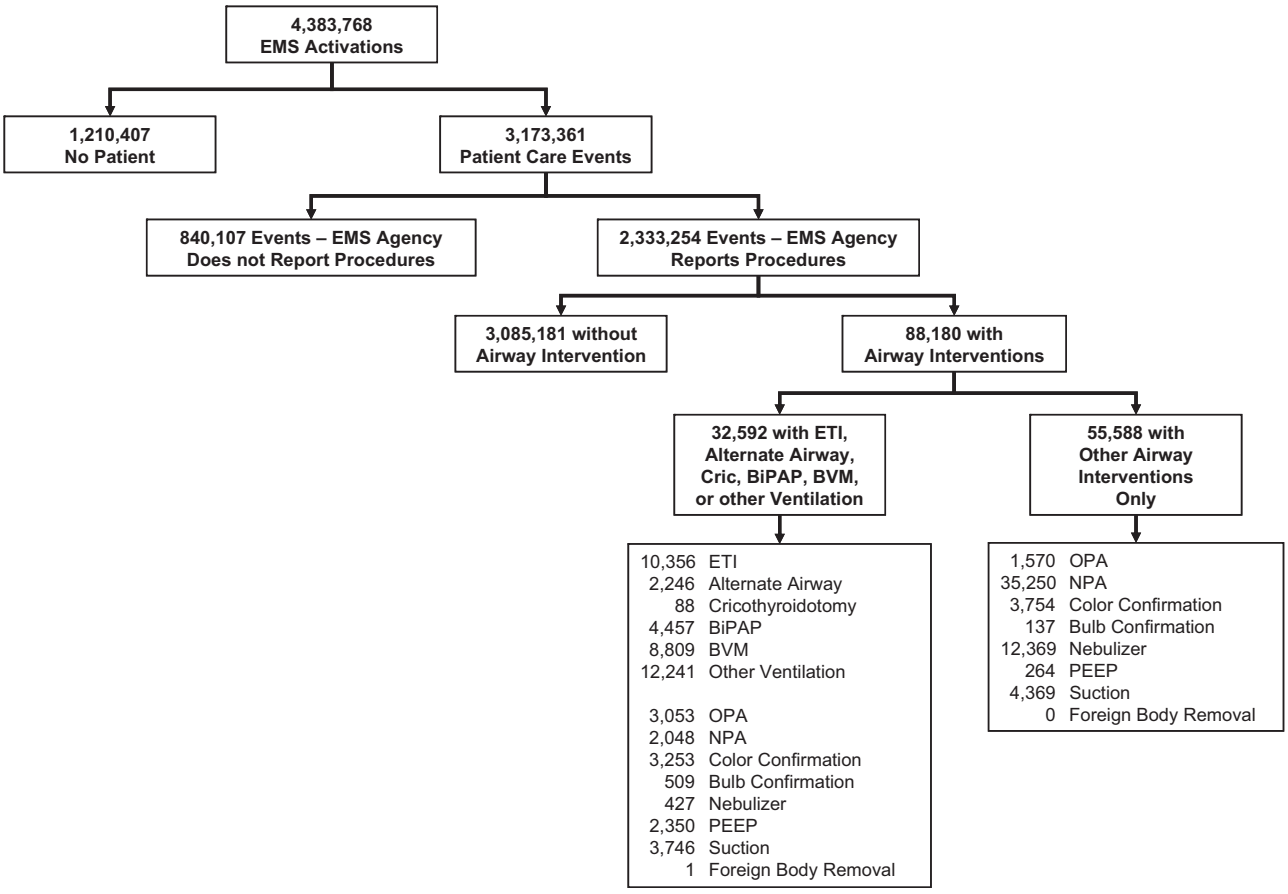

Fig. 2. Airway management events in the NEMSIS data set. EMS = emergency medical services, Cric = cricothyroidotomy, ETI = endotracheal intubation, BiPAP = bilevel positive airway pressure, BVM = bag-valve-mask ventilation, OPA = oropharyngeal airway, NPA = nasopharyngeal airway, PEEP = positive end-expiratory pressure.

Of the 20,690 cases where rescuers provided a clinical impression, respiratory arrest (30.0%), cardiac arrest (20.9%), injury (11.2%), and altered level of consciousness (7.6%) were the most common conditions associated with invasive airway or ventilatory support. Among the 2908 cases where rescuers indicated a cause of injury, motor vehicle incidents (including motor vehicle, motorcycle and pedestrian traffic accidents – 41.6%) and falls (26.3%) were the most common events associated with invasive airway or ventilatory support.

ETI occurred in 10,356 of 2,333,254 (444 per 100,000; 95% CI: 436–453) patient care events. (Table 1) Overall ETI success was 77.0% (95% CI: 76.1–77.9%) (Table 3). ETI success was lower for non-arrest medical than cardiac arrest cases. ETI success was higher for non-arrest injury than non-arrest medical and cardiac arrest ETI. ETI success was similar between age groups. ETI success was lower in suburban than rural population settings. ETI success was higher in the Midwest, Northeast and West than the South US census region.

Alternate airway insertions occurred in 2246 (96 per 100,000; 92–100) patient care events, mostly involving Combitube insertion. Alternate airway insertion success was 87.2% (85.5–88.7%). LMA insertion success was higher than Combitube. Commonly reported ETI complications included bleeding, vomiting and immediately detected esophageal intubation (Table 4). There were 12 "other" esophageal intubations (1.0 per 1000 ETI; 95% CI: 0.5–1.7).

4. Discussion

While numerous studies describe out-of-hospital airway interventions, these reports have been limited to single EMS agencies, regions or states.[8–23] While limited to data from 16 states, our study presents one of the first large-scale perspectives of out-of-hospital airway management in the US, drawing upon the scale and heterogeneity offered by the NEMSIS data set.

While ETI success is a common measure of out-of-hospital airway management quality, the ETI success rates in this series are lower than prior reports.[8,9,13–15,27] Our observed overall ETI success of 77.0% differs from Hubble, et al.'s meta-analytic estimate of 86.3% across 30 studies.[11] The cardiac arrest and rapid-sequence ETI success rates of 78.0% and 81.4% in our study also differ from Hubble's estimates of 91.2% and 96.1%. In contrast, our observed Combitube success of 83.6% was similar to a Hubble's meta-analytic observation of 85.4%.[28] While individual reports or data set aggregation errors may have biased ETI success estimates, one would expect practitioners to under-report ETI failures. Therefore, our observed ETI success rates may represent "best-case" estimates. Also, since out-of-hospital ETI has not been described in most of the 16 states of the current analysis, lower success rates are plausible in these previously unstudied areas.

Regional health variations are important, suggesting potential differences in disease incidence, population characteristics, education or approaches to medical care.[7,29–33] While our study alludes to regional variations in ETI success, we could not verify these differences due to NEMSIS policies precluding state level data analysis. However, regional ETI performance variations are plausible. We have previously identified regional variations in Pennsylvania out-of-hospital ETI incidence.[4] In an examination of out-of-hospital trauma care at 16 metropolitan regions, Bulger et al. observed intubation success rates ranging from 33% to 100%.[32] If verified with a larger, more representative data set, regional

Table 2
Characteristics of patients receiving airway management interventions.

Characteristic	All invasive airway or ventilatory support[a] (*n* = 32,592)		ETI, alternate airway, cricothyroidotomy, BiPAP only (*n* = 16,379)		ETI only (*n* = 10,356)	
	N	(%)	*N*	(%)	*N*	(%)
Age group (years)						
0–9	1838	(5.6)	574	(3.5)	461	(4.5)
10–19	1065	(3.3)	417	(2.6)	357	(3.4)
20–29	2033	(6.2)	854	(5.2)	734	(7.1)
30–39	1924	(5.9)	865	(5.3)	716	(6.9)
40–49	3425	(10.5)	1599	(9.8)	1212	(11.7)
50–59	4799	(14.7)	2456	(15.0)	1666	(16.1)
60–69	5673	(17.4)	3084	(18.8)	1776	(17.1)
70–79	5501	(16.9)	2996	(18.3)	1574	(15.2)
80–89	4566	(14.0)	2496	(15.2)	1269	(12.3)
90–99	1152	(3.5)	674	(4.1)	303	(2.9)
>100	43	(0.1)	21	(0.1)	9	(0.1)
Unknown	573	(1.8)	343	(2.1)	279	(2.7)
Sex						
Male	18,043	(55.4)	9347	(57.1)	6313	(61.0)
Female	14,173	(43.5)	6854	(41.9)	3903	(37.7)
Unknown	376	(1.2)	178	(1.1)	140	(1.4)
Race						
American Indian	225	(0.7)	119	(0.7)	93	(0.9)
Asian	641	(2.0)	283	(1.7)	51	(0.5)
African American	4550	(14.0)	2293	(14.0)	1373	(13.3)
Pacific Islander	35	(0.1)	14	(0.1)	4	(0.0)
White	17,504	(53.7)	8840	(54.0)	5702	(55.1)
Other	633	(1.9)	388	(2.4)	212	(2.0)
Unknown	225	(0.7)	4442	(27.1)	2921	(28.2)
Ethnicity						
Hispanic	856	(2.6)	344	(2.1)	272	(2.6)
Not hispanic	20,301	(62.3)	9757	(59.6)	5934	(57.3)
Unknown	11,435	(35.1)	6278	(38.3)	4150	(40.1)
Cardiac arrest						
Yes	14,154	(43.4)	6189	(37.8)	5265	(50.8)
No	8470	(26.0)	4946	(30.2)	2592	(25.0)
Unknown	9968	(30.6)	5244	(32.0)	2499	(24.1)
Injury						
Yes	3990	(12.2)	1833	(11.2)	1528	(14.8)
No	18,686	(57.3)	8719	(52.2)	4704	(45.4)
Unknown	9968	(30.6)	5827	(35.6)	4124	(39.8)
Population setting						
Rural	3787	(11.6)	2103	(12.8)	1394	(13.5)
Suburban	3626	(11.1)	2351	(14.4)	1558	(15.0)
Urban	24,137	(74.1)	11,386	(69.5)	6993	(67.5)
Wilderness	967	(3.0)	522	(3.2)	395	(3.8)
Unknown	75	(0.2)	17	(0.1)	16	(0.2)
US census region						
Midwest	12,049	(37.0)	4565	(27.9)	2775	(26.8)
Northeast	2086	(6.4)	1342	(8.2)	984	(9.5)
South	14,441	(44.3)	8071	(49.3)	4806	(46.4)
West	4016	(12.3)	2401	(14.7)	1791	(17.3)

ETI = endotracheal intubation, CPAP = continuous positive airway pressure, BiPAP = bi-level positive airway pressure.
[a] Includes endotracheal intubation, alternate airway, cricothyroidotomy, BiPAP/CPAP, bag-valve-mask and other ventilation.

variations could indicate disparities in EMS practitioner skill or training.

Assuming the validity of the observations, our study hints at the need for organized national efforts to improve out-of-hospital airway management quality. Individual EMS agencies often improve ETI performance through enhanced training such as supplemental operating room training or human simulation-based curricula.[34] Others have modified clinical technique such as limiting the number of larygnoscopies or substituting ETI with alternate airway insertion on cardiopulmonary arrests.[35,36] These and other strategies could potentially improve US ETI performance if organized on a national scale. If geographic ETI performance variation were verified, this observation would indicate the additional need for regionally tailored approaches to improving airway management.

ETI success is only one dimension of airway management quality. Procedure specific errors in ETI may include tube misplacement or dislodgement, airway injury, iatrogenic hypoxemia and bradycardia, and interruption of concurrent cardiopulmonary resuscitation chest compressions.[1–3,8,10] Although we studied some of these endpoints, we observed small numbers of events. Of note, prior studies describe paramedic endotracheal tube misplacement rates ranging from 5 to 25%, figures that exceed the 0.1% observed in the current series.[1,37,38] Some experts believe that self-reports result in low estimates of airway adverse events.[27] Our study underscores that while clinical data may offer important insights of airway management, complementary data may be needed to accurately gauge the frequency and magnitude of airway adverse events.

5. Limitations

The 2008 NEMSIS data set contained data on only 16 states. Four states began submitting data during 2008 and therefore did not report data for the entire year. Furthermore, approximately 75%

Table 3
Airway intervention success. Includes only orotracheal, nasotracheal and rapid sequence intubation and alternate airway insertions where procedural success was reported. ETI success was reported for only 8418 of 10,356 ETI.

Procedure	Successful/subgroup total	(% Successful; 95% CI)	Univariable odds ratio (95% CI)
Endotracheal intubation	6482/8418	(77.0; 76.1–77.9)	Referent
Cardiac arrests[a]	3494/4482	(78.0; 76.7–79.2)	0.8 (0.6–0.9)
Non-arrest medical[a]	616/846	(72.8; 69.7–75.8)	1.3 (1.1–1.7)
Non-arrest injury[a]	417/505	(82.6; 79.0–85.8)	Referent
Pediatric age < 10 years	295/397	(74.3; 69.7–78.5)	1.3 (0.9–1.9)
Pediatric age 10–19 years	228/289	(78.9; 73.7–83.5)	1.2 (0.9–1.5)
Adult age > 19 years	5829/7552	(77.2; 76.2–78.1)	N/A
Rapid-sequence intubation	289/355	(81.4; 77.0–85.3)	
Population setting			
Rural	945/1228	(77.0; 74.6–79.3)	Referent
Suburban	1094/1490	(73.4; 71.2–75.7)	0.8 (0.7–0.99)
Urban	4153/5301	(78.3; 77.2–79.5)	1.1 (0.9–1.3)
Wilderness	278/383	(72.6; 68.1–77.1)	0.8 (0.6–1.03)
US census region			
Midwest	1604/1920	(83.5; 81.9–85.2)	2.1 (1.8–2.4)
Northeast	779/917	(85.0; 82.6–87.3)	2.3 (1.9–2.8)
South	2801/3952	(70.9; 69.5–72.3)	Referent
West	1298/1629	(79.7; 77.7–81.6)	1.6 (1.4–1.9)
Alternate airways	1564/1794	(87.2; 85.5–88.7)	–
Combitube	971/1162	(83.6; 81.3–85.6)	Referent
Esophageal Obturator Airway	88/104	(84.6; 76.2–90.9)	1.1 (0.6–2.0)
Laryngeal Mask Airway	505/530	(95.3; 93.1–96.9)	4.0 (2.6–6.4)
King	4/4	(100.0; 40.0–100.0)	N/A
Cricothyroidotomy (needle and open)	61/70	(87.1; 77.0–93.9)	N/A

ETI = endotracheal intubation. US = United States.
[a] Subgroups do not add up to total because of unknown cardiac arrest status for 5244 cases. Univariable odds ratios presented for selected comparisons only.

of the data originated from North Carolina, Minnesota and Florida. The use of more current data with inclusion of a larger number of states may result in different observations. Unbalanced sampling of cases may also have biased baseline and regional ETI success estimates. Regionally organized sampling (as is the case with other national data sets such as the National Hospital Ambulatory Care Survey) may provide an alternate analytic strategy.[39] However, the NEMSIS data represent the largest and most heterogeneous EMS data currently available.

Although envisioned as a national data set, NEMSIS is not currently a population-based sample. NEMSIS does not include data from agencies whose data collection efforts are not NEMSIS compliant or where agency data are not aggregated to a state data set. Incomplete event capture may also introduce bias. The portion of each state's EMS cases not included in the data set is unknown.

The NEMSIS data are clinical out-of-hospital patient care records and reflect self-reports without independent confirmation. Missing data or observations may bias the inferences. Additional bias may occur from errors or data incompatibility during local, state, or national-level data aggregation. These errors may be due to incorrect mapping or storage within a local EMS software product or errors in storage or export from the state and national repositories.

Table 4
Airway management complications. Includes 16,379 events with endotracheal intubation, alternate airway insertion or cricothyroidotomy.

Complication	*N* (of 16,379)	(*n* per 1000 interventions, 95% CI)
Bleeding	84	(7.0; 5.5–8.5)
Bradycardia	4	(0.3; 0.0–0.7)
Esophageal intubation – immediately detected	64	(5.3; 4.0–6.6)
Esophageal intubation – other	12	(1.0; 0.4–1.6)
Hypotension	6	(0.5; 0.1–0.9)
Hypoxia	10	(0.8; 0.3–1.3)
Injury	13	(1.1; 0.5–1.7)
Vomiting	80	(6.7; 5.2–8.1)
Other	402	(34.9; 31.7–38.2)

Although NEMSIS has standard definitions for each data element, EMS practitioners may not have followed these standards during documentation.

Some procedures exhibited low frequencies (for example, King LT airway) because they were not initially incorporated into the NEMSIS data set. Given the broadening use of the King LT and other procedures, these estimates are clearly underestimates.[20] The frequency of these and other events may increase with the wider application of the NEMSIS standards.

We identified key subsets (cardiac arrest, injured) through single variables in the NEMSIS Public Use data set. This data set did not contain related variables such as electrocardiogram rhythm or injury severity that could be used to confirm these classifications. Future analyses using additional NEMSIS data elements may improve these estimates.

6. Conclusion

In this study characterizing out-of-hospital airway management across the United States, we observed low out-of-hospital ETI success rates. These data may guide national efforts to improve the quality of out-of-hospital airway management.

Conflict of interest statement

The authors declare no financial or other conflicts of interest.

Role of the funding source

None.

Appendix A.

Number of EMS episodes included in the 2008 National Emergency Medical Services Information System (NEMSIS) data set.[24] Total of 4,383,768 episodes.

State	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
Alabama	58,120	63,143	72,595	76,917	270,775
Colorado	54,312	51,074	56,880	60,024	222,290
Florida	94,137	126,441	151,622	151,255	523,455
Hawaii		793	3,233	19,702	23,728
Iowa	34,721	35,711	34,792	35,992	141,216
Maine	17,836	17,027	27,764	30,359	92,986
Minnesota	147,309	151,576	166,208	162,300	627,393
Missouri	32,053	33,035	35,419	31,147	131,654
North Carolina	278,754	585,269	602,821	618,525	2,085,369
North Dakota	11,603	11,485	8305	8312	39,705
Nebraska	13,814	13,754	14,699	14,577	56,844
New Hampshire	20,000	15,580	3215	21,483	60,278
New Jersey	7	13	26	853	899
New Mexico	3	2	7554	9238	16,797
Nevada	13,002	12,858	33,018	27,657	86,535
Oklahoma				3844	3844
Total					4,383,768

Appendix B.

Airway interventions in the NEMSIS data set.

NEMSIS Procedural Code	Intervention
93.931	Bagged (via BVMask) [bag-valve-mask]
93.930	Bagged (via tube)
96.702	BiPAP [bilevel positive airway pressure][a]
97.230	Change tracheostomy tube
98.130	Cleared, opened, or heimlich
96.051	Combitube Blind Insertion Airway Device
93.900	CPAP [continuous positive airway pressure]
31.420	Direct laryngoscopy[a]
96.030	EOA/EGTA [esophageal obturator airway/esophageal gastric tube airway]
96.993	Extubation[a]
98.131	Foreign body removal[a]
96.703	Impedance threshold device[a]
96.991	Intubation confirm colorimetric ETCO2 [end-tidal carbon dioxide]
96.992	Intubation confirm esophageal bulb
97.231	Intubation of existing tracheostomy stoma[a]
96.053	King LT Blind Insertion Airway Device[a]
96.052	Laryngeal Mask Blind Insertion Airway Device
96.010	Nasal airway
96.041	Nasotracheal intubation
93.940	Nebulizer treatment
31.110	Needle cricothyrotomy
96.020	Oral airway
96.040	Orotracheal intubation
96.790	PEEP [positive end-expiratory pressure]
96.042	Rapid sequence intubation
93.910	Respirator operation (BLS) [basic life support]
98.150	Suctioning
31.120	Surgical cricothyrotomy
96.700	Ventilator operation
96.701	Ventilator with PEEP
31.421	Video laryngoscopy[a]

[a] Interventions that were not specified in the original NEMSIS data set but were later added by individual states.

References

1. Katz SH, Falk JL. Misplaced endotracheal tubes by paramedics in an urban emergency medical services system. Ann Emerg Med 2001;37:32–7.
2. Dunford JV, Davis DP, Ochs M, Doney M, Hoyt DB. Incidence of transient hypoxia and pulse rate reactivity during paramedic rapid sequence intubation. Ann Emerg Med 2003;42:721–8.
3. Wang HE, Simeone SJ, Weaver MD, Callaway CW. Interruptions in cardiopulmonary resuscitation from paramedic endotracheal intubation. Ann Emerg Med 2009;54:645–52, e1.
4. Wang HE, Abo BN, Lave JR, Yealy DM. How would minimum experience standards affect the distribution of out-of-hospital endotracheal intubations? Ann Emerg Med 2007;50:246–52.
5. Johnston BD, Seitz SR, Wang HE. Limited opportunities for paramedic student endotracheal intubation training in the operating room. Acad Emerg Med 2006;13:1051–5.
6. Wang HE, Kupas DF, Hostler D, Cooney R, Yealy DM, Lave JR. Procedural experience with out-of-hospital endotracheal intubation. Crit Care Med 2005;33:1718–21.
7. Wang HE, Balasubramani GK, Cook LJ, Lave JR, Yealy DM. Out-of-hospital endotracheal intubation experience and patient outcomes. Ann Emerg Med 2010;55:527–37, e6.
8. Wang HE, Kupas DF, Paris PM, Bates RR, Yealy DM. Preliminary experience with a prospective, multi-centered evaluation of out-of-hospital endotracheal intubation. Resuscitation 2003;58:49–58.
9. Wang HE, O'Connor RE, Schnyder ME, Barnes TA, Megargel RE. Patient status and time to intubation in the assessment of prehospital intubation performance. Prehosp Emerg Care 2001;5:10–8.
10. Wang HE, Lave JR, Sirio CA, Yealy DM. Paramedic intubation errors: isolated events or symptoms of larger problems? Health Aff (Millwood) 2006;25:501–9.
11. Hubble MW, Brown L, Wilfong DA, Hertelendy A, Benner RW, Richards ME. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates. Prehosp Emerg Care 2010;14:377–401.
12. Jensen JL, Cheung KW, Tallon JM, Travers AH. Comparison of tracheal intubation and alternative airway techniques performed in the prehospital setting by paramedics: a systematic review. CJEM 2010;12:135–40.
13. Jacobs LM, Berrizbeitia LD, Bennett B, Madigan C. Endotracheal intubation in the prehospital phase of emergency medical care. JAMA 1983;250:2175–7.
14. Stewart RD, Paris PM, Winter PM, Pelton GH, Cannon GM. Field endotracheal intubation by paramedical personnel. Success rates and complications. Chest 1984;85:341–5.
15. De Leo BC. Training of rescue squads in endotracheal intubation. In: National conference on standards for cardiopulmonary resuscitation and emergency cardiac care Dallas. American Heart Assoc; 1975. p. 39–41.
16. Rumball CJ, MacDonald D, The PTL. Combitube, laryngeal mask, and oral airway: a randomized prehospital comparative study of ventilatory device effectiveness and cost-effectiveness in 470 cases of cardiorespiratory arrest. Prehosp Emerg Care 1997;1:1–10.
17. Davis DP, Valentine C, Ochs M, Vilke GM, Hoyt DB. The Combitube as a salvage airway device for paramedic rapid sequence intubation. Ann Emerg Med 2003;42:697–704.
18. Tumpach EA, Lutes M, Ford D, Lerner EB. The King LT versus the Combitube: flight crew performance and preference. Prehosp Emerg Care 2009;13:324–8.
19. Russi CS, Hartley MJ, Buresh CT. A pilot study of the King LT supralaryngeal airway use in a rural Iowa EMS system. Int J Emerg Med 2008;1:135–8.
20. Guyette FX, Wang H, Cole JS. King airway use by air medical providers. Prehosp Emerg Care 2007;11:473–6.
21. Gerich TG, Schmidt U, Hubrich V, Lobenhoffer HP, Tscherne H. Prehospital airway management in the acutely injured patient: the role of surgical cricothyrotomy revisited. J Trauma 1998;45:312–4.
22. Xeropotamos NS, Coats TJ, Wilson AW. Prehospital surgical airway management: 1 year's experience from the Helicopter Emergency Medical Service. Injury 1993;24:222–4.
23. Guss DA, Posluszny M. Paramedic orotracheal intubation: a feasibility study. Am J Emerg Med 1984;2:399–401.
24. National Emergency Medical Service Information System. www.nemsis.org [accessed 16.07.2010].
25. Dawson DE. National emergency medical services information system (NEMSIS). Prehosp Emerg Care 2006;10:314–6.
26. U.S. Census Bureau. Census Regions and Divisions of the United States. http://www.census.gov/geo/www/us_regdiv.pdf [accessed July 18, 2010].
27. Wang HE, Domeier RM, Kupas DF, Greenwood MJ, O'Connor RE. Recommended guidelines for uniform reporting of data from out-of-hospital airway management: position statement of the National Association of EMS Physicians. Prehosp Emerg Care 2004;8:58–72.
28. Hubble MW, Wilfong DA, Brown LH, Hertelendy A, Benner RW. A meta-analysis of prehospital airway control techniques. Part II. Alternative airway devices and cricothyrotomy success rates. Prehosp Emerg Care 2010;14:515–30.

29. Borhani NO. Changes geographic distribution of mortality from cerebrovascular disease. Am J Public Health Nations Health 1965;55:673–81.
30. Howard G. Why do we have a stroke belt in the southeastern United States? A review of unlikely and uninvestigated potential causes. Am J Med Sci 1999;317:160–7.
31. Nichol G, Thomas E, Callaway CW, et al. Regional variation in out-of-hospital cardiac arrest incidence and outcome. JAMA 2008;300:1423–31.
32. Bulger EM, Nathens AB, Rivara FP, MacKenzie E, Sabath DR, Jurkovich GJ. National variability in out-of-hospital treatment after traumatic injury. Ann Emerg Med 2007;49:293–301.
33. Callaway CW, Schmicker R, Kampmeyer M, et al. Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. Resuscitation 2010;81:524–9.
34. Davis DP, Buono C, Ford J, Paulson L, Koenig W, Carrison D. The effectiveness of a novel, algorithm-based difficult airway curriculum for air medical crews using human patient simulators. Prehosp Emerg Care 2007;11:72–9.
35. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation 2009;119:2597–605.
36. Bobrow BJ, Clark LL, Ewy GA, et al. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA 2008;299:1158–65.
37. Jones JH, Murphy MP, Dickson RL, Somerville GG, Brizendine EJ. Emergency physician-verified out-of-hospital intubation: miss rates by paramedics. Acad Emerg Med 2004;11:707–9.
38. Jemmett ME, Kendal KM, Fourre MW, Burton JH. Unrecognized misplacement of endotracheal tubes in a mixed urban to rural emergency medical services setting. Acad Emerg Med 2003;10:961–5.
39. Pitts SR, Niska RW, Xu J, Burt CW. National hospital ambulatory medical care survey: 2006 emergency department summary. Natl Health Stat Report 2008: 1–38.