RESUSCITATION 173 (2022) 124–133

Available online at ScienceDirect

Resuscitation

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

Clinical paper

Epidemiology of out-of-hospital pediatric airway management in the 2019 national emergency medical services information system data set

Erin R. Hanlin[a,1], *Hei Kit Chan*[a], *Matt Hansen*[b], *Barbara Wendelberger*[c], *Manish I. Shah*[d], *Nichole Bosson*[e,f,g], *Marianne Gausche-Hill*[e,f,g,h], *John M. VanBuren*[i], *Henry E. Wang*[j,*]

[a] *Department of Emergency Medicine, The University of Texas Health Science Center at Houston, Houston, TX, United States*
[b] *Department of Emergency Medicine, Oregon Health & Science University, Portland, OR, United States*
[c] *Berry Consultants, LLC, Austin, TX, United States*
[d] *Department of Pediatrics, Division of Emergency Medicine, Baylor College of Medicine, Houston, TX, United States*
[e] *Los Angeles County Emergency Medical Services Agency, Los Angeles, CA, United States*
[f] *Department of Emergency Medicine, Harbor-UCLA Medical Center, Torrance, CA, United States*
[g] *David Geffen School of Medicine at UCLA, Los Angeles, CA, United States*
[h] *Department of Pediatrics, Harbor-UCLA Medical Center, Torrance, CA, United States*
[i] *Department of Pediatrics, University of Utah, Salt Lake City, UT, United States*
[j] *Department of Emergency Medicine, The Ohio State University, Columbus, OH, United States*

Abstract

Objective: Airway management is an important priority in the care of critically ill children. We sought to provide updated estimates of the epidemiology of pediatric out-of-hospital airway management and ventilation interventions in the United States.

Methods: We used data from the 2019 National Emergency Medical Services Information System (NEMSIS) data set. We performed a descriptive analysis of all patients < 18 years receiving one or more of the following: bag-valve-mask ventilation (BVM), tracheal intubation (TI), supraglottic airway (SGA) insertion, continuous positive airway pressure (CPAP), bilevel positive airway pressure (BiPAP) and surgical airway placement. We determined success and complication rates for each airway procedure.

Results: Among 1,148,943 pediatric patient care encounters, airway and ventilation interventions occurred in 22,637 (1,970 per 100,000 pediatric Emergency Medical Services (EMS) activations), including 64% <11 years old, 56.1% male, 16.9% cardiac arrest, 16.6% injured, and 83.9% in urban areas. Airway interventions included: BVM 3,997 (17.7% of pediatric airway encounters), TI 3,165 (14.0%), SGA 582 (2.6%), CPAP/BiPAP 331 (1.5%) and surgical airway 29 (0.1%). TI success was 75.2% (95% CI 73.7–76.7%) and lowest for the 0–1 month age group (56.8%; 49.2–64.2%). SGA success was 88.0% (95% CI 85.1–90.6%). Vomiting was the most common airway complication (n = 223, 1%).

Conclusions: BVM and advanced airway management occur in 1 of every 51 pediatric EMS encounters. BVM is the most commonly prehospital pediatric airway management technique, followed by TI and SGA insertion. These data provide contemporary perspectives of pediatric prehospital airway management.

Keywords: Cardiopulmonary arrest, Airway management, Intubation, Emergency medical service

* Corresponding author at: Department of Emergency Medicine, The Ohio State University, 376 W. 10th Ave, 760 Prior Hall, Columbus, OH 43210, United States.
E-mail address: henry.wang@osumc.edu (H.E. Wang).
[1] Dr. Hanlin is now affiliated with the Division of Emergency Medicine, Department of Surgery, Duke University School of Medicine, United States.

https://doi.org/10.1016/j.resuscitation.2022.01.008
Received 27 September 2021; Received in Revised form 8 January 2022; Accepted 11 January 2022

Introduction

Emergency medical services (EMS) providers must be prepared to render care to patients of all ages. Children may present with critical illness including cardiac arrest, trauma, respiratory failure and sepsis. Airway management is a key step in the stabilization and resuscitation of these critical conditions.[1,2] The best approach to pediatric out-of-hospital airway management is unknown. Pediatric airway management is challenging due to the distinctions of airway anatomy and respiratory physiology in children. Intubation success rates are lower for younger children.[3] Prior studies underscore the unclear associations between out-of-hospital tracheal intubation (TI) and outcomes in children.[4–7] Despite these factors, many EMS personnel still prefer intubation over bag-valve-mask ventilation (BVM).[8] Compared with intubation, newer supraglottic airways (SGA) suggest potentially better outcomes in adults, but these devices have not been studied compared to BVM or TI in children.[9,10]

To help identify optimal clinical approaches, new information is needed characterizing current pediatric out-of-hospital airway practices. The National Emergency Medical Services Information System (NEMSIS) is the United States' largest repository of EMS clinical encounters. In this study we used NEMSIS to characterize the current epidemiology of pediatric out-of-hospital airway management interventions, success rates and complications in the United States.

Methods

Study design

The Committee for Protection of Human Subjects of the University of Texas Health Science Center at Houston reviewed and approved the study. In this descriptive cohort study, we analyzed the data from the 2019 NEMSIS data set.

Study Setting

NEMSIS is a national database that has standardized the collection and aggregation of information on EMS care in the United States.[11] The goal of NEMSIS is to establish a uniform method for EMS providers to document patient care and to aggregate these data for analysis at local, state and national levels in order to inform EMS care nationwide. A product of the National Highway Traffic Safety Administration Office of Emergency Medical Services, the NEMSIS database is maintained by the NEMSIS Technical Assistance Center (TAC) at the University of Utah School of Medicine.

The lead EMS offices in each individual state or territory are responsible for the coordination of data collection from their local EMS agencies for submission to NEMSIS. The lead EMS offices collect clinical data from EMS agencies in the state. The data collected by these offices are then exported to the NEMSIS TAC. Of the 400 data elements in NEMSIS, 83 are standard national variables collected from all encounters. NEMSIS itself has no specific inclusion or exclusion criteria but instead takes all data meeting the state inclusion criteria. Currently, all states except Idaho and Delaware are contributing to NEMSIS. While reporting to NEMSIS is voluntary, the majority of EMS events are captured across participating states. NEMSIS is considered a public health project, and consent is not obtained from patients for inclusion of data in the national data set. State, agency and provider information are not included in the NEMSIS public use data set.

The most current iteration of the NEMSIS data set (version 3) records data using SNOMED CT, an international standard for health terminology.[12] SNOMED CT is highly granular with many procedure codes characterizing a given procedure. We broadly defined various airway and ventilatory management procedures for this study, identifying the SNOMED CT procedure codes corresponding with each intervention. (Appendix 1)

Selection of participants

For this study, we identified EMS activations for patients less than 18 years of age from the NEMSIS 2019 Public Release Data set. We included ground and air EMS "911" activations, regardless of whether the patient was transported. We excluded interfacility transports.

Interventions

We included all patients receiving at least one of the following airway management interventions: BVM, TI, SGA, surgical airway placement, continuous/bilevel positive airway pressure (CPAP/BiPAP), or ventilation via a tracheal tube (TT) or SGA. (Fig. 1) We further sub-categorized TI as orotracheal intubation, nasotracheal intubation and rapid sequence intubation (RSI). SGAs specified in NEMSIS included laryngeal mask airways (LMA), laryngeal tube (LT), Combitube and esophageal-obturator airway. Surgical airways included needle, percutaneous, or surgical cricothyroidotomy. Post-airway insertion ventilation procedures included mechanical ventilator operation and bag ventilation via a TT or SGA.

We reported additional airway interventions reported in NEMSIS including oropharyngeal and nasopharyngeal airway insertion, the use of continuous capnography, treatment with nebulized medications, the use of positive end-expiratory pressure (PEEP), airway foreign body removal and airway suctioning. Several SNOMED CT airway or ventilatory procedure codes were not specific enough to identify the exact procedure performed. Examples of unspecified airway or ventilation intervention codes included respiratory assist, procedure on respiratory system, airway procedure, assisted breathing, artificial airway management, etc.[12] We categorized these procedure codes as "unspecified" and included them in the total number of airway or ventilation procedures. We excluded patients with reported existing tracheostomy tubes or home ventilator use as their care does not typically entail acute airway management interventions.

Outcomes

The primary outcomes were frequency, success and complication rates of pediatric active airway interventions. NEMSIS data include the success status of each procedure attempted. Rescuers reported the success of each attempt. If a specific procedure was attempted more than once within the same EMS activation, and if any of the attempts were reported as successful, we classified that procedure as successful. If an EMS activation included multiple airway management and ventilatory support procedures, each type of procedure was counted in the analysis and were not exclusive of each other. Procedural complications included bleeding, bradycardia, esophageal intubation, hypotension, hypoxia, injury, vomiting and other as defined by the EMS provider completing the record.

Clinical impressions reported by EMS personnel were recorded in NEMSIS using the International Classification of Diseases v.10 (ICD-10). Patient demographic variables include age, gender, race and ethnicity. Illness specific variables included cardiac arrest and injury status as reported by the EMS provider. We classified population

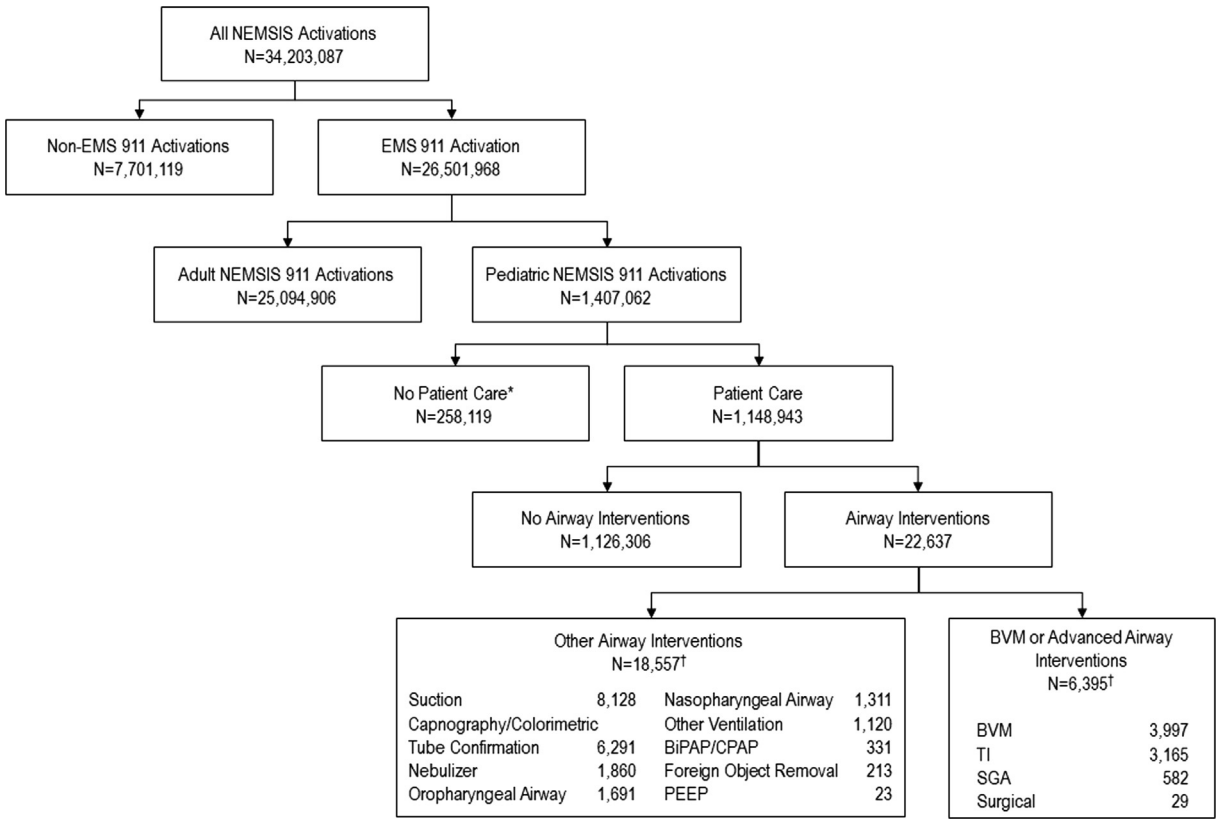

Fig. 1 – NEMSIS emergency medical services events involving airway management. *Includes 117,217 no treatment, 131,421 refusal of care, 5,497 no patient, 3,094 dead at scene, 890 cancelled call. †Multiple airway interventions may have occurred for a single activation.

setting according to U.S. Department of Agriculture and the Office of Management and Budget definitions: 1) urban areas with large (≥1 million residents) or small (<1 million residents) metropolitan areas; 2) suburban areas with micropolitan (urban core of at least 10,000 residents) counties adjacent to large or small metropolitan areas; 3) rural areas that have non-urban core counties adjacent to a large or small metropolitan area; and 4) wilderness that are considered non-core counties adjacent to micropolitan counties. Geographic areas included U.S. defined census regions: northeast, south, midwest and west.

Primary data analysis

We analyzed the data with descriptive statistics. For frequencies we determined binomial proportions with exact 95% confidence intervals. For associations with event and patient characteristics we determined univariate odds ratios and associated 95% confidence intervals. We characterized the demographics of patients undergoing airway management, including age, sex, race, ethnicity, urbanicity and U.S. census region. We used the age groups previously defined by Hansen, et al.; newborn 0–0.9 month, infant 1–11.9 months, toddler 1–4.9 years, child 5–10.9 years, adolescent 11–17.9 years, unknown.[13] We identified disease groups associated with pediatric airway management. We calculated the success and complication rates for TI, surgical airway and alternate airways for patients within each age group and stratified by cardiac arrest status, injury status, urbanicity and region. Because their respective skills and available resources may vary, we stratified the analysis between ground and air medical settings. We conducted the analysis using Stata v. 16.0 (Stata, Inc, College Station, TX).

Results

During the 2019 study period, there were 34,203,087 EMS activations submitted by 9,993 EMS agencies serving 47 states and territories. Of these, there were 1,148,943 pediatric EMS activations that resulted in patient care. (Fig. 1) Airway management or ventilation support procedures occurred in 22,637 encounters (1,970 per 100,000 pediatric EMS patient care events).

BVM, intubation or supraglottic airway insertion occurred in 643.0 per 100,000 pediatric patient care events. (Table 1) TI occurred in 3,165 pediatric EMS patient care encounters (276 per 100,000 patient care encounters). Orotracheal intubation was the most common TI technique. Supraglottic airway insertion occurred in 582 patient encounters (50.7 per 100,000 patient care encounters). LMA was the most commonly used SGA. Surgical airway occurred in 29 encounters. Of the 3,562 events involving TI, SGA or surgical airway, BVM also occurred in 1,164 (32.7%). The incidence of airway interventions was higher for air medical than ground events. Other reported airway interventions include suctioning, capnography and colorimetric tube confirmation, nebulizer, oropharyngeal and nasopharyngeal airway, foreign body removal and PEEP. Of encounters with TI, SGA or surgical airway, capnography use was reported in 13.1%. CPAP/BiPAP occurred in 331 cases.

Table 1 – Incidence of EMS pediatric airway procedures. Stratified by EMS unit type (ground vs. air). Total of n = 1,148,943 EMS events. *Includes boat (n = 15) and non-specified EMS activations (n = 210,150).

Intervention	Ground EMS Unit (N = 933,090 events)		Air EMS Unit (N = 5,688 events)		All EMS Units* (N = 1,148,943 events)	
	N	Incidence N per 100,000 events (95% CI)	N	Incidence N per 100,000 events (95% CI)	N*	Incidence N per 100,000 events (95% CI)
Bag-Valve-Mask (BVM) Ventilation	3,679	394.3 (381.7–407.2)	104	1,828.4 (1,496.3–2,211.1)	3,997	347.9 (337.2–358.8)
Tracheal Intubation (TI)	2,643	283.3 (272.6–294.3)	401	7,049.9 (6,398.1–7,746.3)	3,165	275.5 (266.0–285.2)
Orotracheal Intubation	2,165	232.0 (222.4–242.0)	212	3,727.1 (3,249.9–4,252.5)	2,464	214.5 (206.1–223.1)
Rapid Sequence Intubation	122	13.1 (10.9–15.6)	96	1,687.8 (1,369.2–2,057.2)	231	20.1 (17.6–22.9)
Nasotracheal Intubation	37	4.0 (2.8–5.5)	3	52.7 (10.9–154.1)	40	3.5 (2.5–4.7)
Other Intubation	407	43.6 (39.5–48.1)	108	1,898.7 (1,560.1–2,287.9)	543	47.3 (43.4–51.4)
Supraglottic Airway (SGA)	519	55.6 (50.9–60.6)	30	527.4 (356.1–752.1)	582	50.7 (46.6–54.9)
Laryngeal Mask Airway	266	28.5 (25.2–32.2)	18	316.5 (187.7–499.7)	304	26.5 (23.6–29.6)
Laryngeal Tube	238	25.5 (22.4–29.0)	12	211.0 (109.1–368.2)	263	22.9 (20.2–25.8)
Combitube	15	1.6 (0.9–2.7)	0	0.0 (0.0–0.0)	15	1.3 (0.7–2.2)
Esophageal Obturator Airway	1	0.1 (0.0–0.6)	0	0.0 (0.0–0.0)	1	0.1 (0.0–0.5)
Surgical Airway	24	2.6 (1.7–3.8)	4	70.3 (19.2–179.9)	29	2.5 (1.7–3.6)
Other Ventilation	983	105.3 (98.9–112.1)	97	1,705.3 (1,385.0–2,076.5)	1,120	97.5 (91.9–103.4)
Bag Ventilation via Tracheal Tube or SGA	514	55.1 (50.4–60.1)	28	492.3 (327.4–710.7)	563	49.0 (45.0–53.2)
Mechanical Ventilation	477	51.1 (46.6–55.9)	75	1,318.6 (1,038.5–1,650.1)	571	49.7 (45.7–54.0)
Suction	7,536	807.6 (789.6–826.0)	198	3,481.0 (3,019.9–3,990.6)	8,128	707.4 (692.2–722.9)
Capnography and Colorimetric Tube Confirmation	5,639	604.3 (588.7–620.3)	116	2,039.4 (1,688.0–2,441.1)	6,291	547.5 (534.1–561.2)
Nebulizer	1,758	188.4 (179.7–197.4)	0	0.0 (0.0–0.0)	1,860	161.9 (154.6–169.4)
Oropharyngeal Airway	1,555	166.7 (158.5–175.1)	45	791.1 (577.6–1,057.2)	1,691	147.2 (140.3–154.4)
Nasopharyngeal Airway	1,239	132.8 (125.5–140.4)	25	439.5 (284.6–648.1)	1,311	114.1 (108.0–120.5)
CPAP/BiPAP	320	34.3 (30.6–38.3)	3	52.7 (10.9–154.1)	331	28.8 (25.8–32.1)
Foreign Body Removal	169	18.1 (15.5–21.1)	6	105.5 (38.7–229.5)	213	18.5 (16.1–21.2)
Positive End Expiratory Pressure	21	2.3 (1.4–3.4)	2	35.2 (4.3–127.0)	23	2.0 (1.3–3.0)

Table 2 – Characteristics of children undergoing EMS airway management.

Characteristic	TI Only (n = 3,165 events) n (%)	TI, SGA, Surgical Airway Only (n = 3,562 events) n (%)	BVM, TI, SGA, Surgical Airway Only (n = 6,395 events) n (%)	All Airway or Ventilatory Interventions (n = 22,637 events) n (%)
Age Group				
Newborn (0–0.9 month)	177 (5.6)	201 (5.6)	443 (6.9)	1,664 (7.4)
Infant (1–11.9 months)	787 (24.9)	888 (24.9)	1,522 (23.8)	3,605 (15.9)
Toddler (1–4.9 years)	619 (19.6)	685 (19.2)	1,456 (22.8)	5,401 (23.9)
Child (5–10.9 years)	419 (13.2)	484 (13.6)	900 (14.1)	3,802 (16.8)
Adolescent (11–17 years)	1,163 (36.7)	1,304 (36.6)	2,074 (32.4)	8,165 (36.1)
Sex				
Female	1,264 (39.9)	1,413 (39.7)	2,656 (41.5)	9,859 (43.6)
Male	1,878 (59.3)	2,125 (59.7)	3,702 (57.9)	12,689 (56.1)
Unknown	23 (0.7)	24 (0.7)	37 (0.6)	89 (0.4)
Race/Ethnicity				
American Indian	10 (0.3)	10 (0.3)	17 (0.3)	88 (0.4)
Asian	12 (0.4)	14 (0.4)	21 (0.3)	94 (0.4)
African American	289 (9.1)	316 (8.9)	556 (8.7)	1,834 (8.1)
Hispanic	110 (3.5)	128 (3.6)	249 (3.9)	979 (4.3)
Pacific Islander	4 (0.1)	4 (0.1)	9 (0.1)	37 (0.2)
White	596 (18.8)	672 (18.9)	1,080 (16.9)	3,256 (14.4)
Other	2,150 (67.9)	2,425 (68.1)	4,479 (70.0)	16,417 (72.5)
Activation Type				
Ground Activation	2,643 (83.5)	3,001 (84.3)	5,630 (88.0)	20,526 (90.7)
Air Activation	401 (12.7)	418 (11.7)	460 (7.2)	783 (3.5)
Cardiac Arrest				
Yes, Prior to EMS Arrival	1,793 (56.7)	2,061 (57.9)	2,448 (38.3)	3,423 (15.1)
Yes, After EMS Arrival	200 (6.3)	226 (6.3)	2,792 (43.7)	405 (1.8)
No	823 (26.0)	904 (25.4)	330 (5.2)	14,992 (66.2)
Unknown	349 (11.0)	371 (10.4)	825 (12.9)	3,817 (16.9)
Injury				
Yes	1,108 (35.0)	1,228 (34.5)	3,879 (60.7)	3,756 (16.6)
No	1,718 (54.3)	1,936 (54.4)	1,671 (26.1)	16,770 (74.1)
Unknown	339 (10.7)	398 (11.2)	845 (13.2)	2,016 (8.9)
Population Setting				
Urban	2,482 (78.4)	2,824 (79.3)	518 (8.1)	18,995 (83.9)
Suburban	231 (7.3)	238 (6.7)	379 (5.9)	1,198 (5.3)
Rural	285 (9.0)	313 (8.8)	5,186 (81.1)	1,497 (6.6)
Wilderness	61 (1.9)	70 (2.0)	518 (8.1)	344 (1.5)
Unknown	106 (3.3)	117 (3.3)	379 (5.9)	603 (2.7)
US Census Region				
Midwest	509 (16.1)	578 (16.2)	1,093 (17.1)	3,384 (14.9)
Northeast	297 (9.4)	305 (8.6)	661 (10.3)	1,850 (8.2)
South	1,771 (56.0)	1,969 (55.3)	3,189 (49.9)	11,417 (50.4)
West	588 (18.6)	710 (19.9)	1,448 (22.6)	5,957 (26.3)

Of EMS events involving active airway interventions, most entailed patients who were male, in the oldest age group, in urban settings, in the South census region and in cardiac arrest prior to EMS arrival. (Table 2) Primary clinical impressions associated with airway encounters included signs and symptoms, and diseases of the respiratory, circulatory and nervous system, and injuries. (Appendix 2)

Overall TI success was 75.2%. (Table 3) RSI success was 90.7%. Overall SGA success was 88.0%. TI success was higher for air than ground units, and for traumas than non-trauma cases. (Table 4) TI success decreased with age. Compared with adolescents, SGA insertion success was lower with younger age. There was no difference in overall TI or SGA success rates between population settings.

Vomiting and bleeding were the most common airway complications, occurring in 0.99% and 0.74% of pediatric airway cases. (Table 5) Immediately detected esophageal intubations occurred in 60 of 3,168 intubations (1.9%). Hypotension was rarely reported (0.01%).

Discussion

Airway management is an essential element in the resuscitation of critically ill children. In this updated analysis of the large NEMSIS data set, we found that BVM, intubation and SGA insertion occurred in 1 of every 51 pediatric EMS patient care encounters. Approximately 49% of pediatric airway cases received TI. This study offers important observations of current prehospital pediatric airway practices and key perspectives to guide future practice, education and research.

Hansen et al. performed a similar analysis of pediatric out-of-hospital airway management using the 2012 NEMSIS data set.[12]

Table 3 – Pediatric tracheal intubation and supraglottic airway success rates.

Procedure	n successful/N events	% Success (95% CI)
Tracheal intubation	2,351/3,126	75.2 (73.7–76.7)
Rapid sequence intubation	206/227	90.7 (86.2–94.2)
Supraglottic Airways	500/568	88.0 (85.1–90.6)
Laryngeal Mask Airway	271/303	89.4 (85.4–92.7)
Laryngeal Tube	216/250	86.4 (81.5–90.4)
Combitube	12/15	80.0 (51.9–95.7)

Table 4 – Event characteristics associated with EMS pediatric tracheal intubation (TI) and supraglottic airway (SGA) success rates. N/A = not applicable.

	Tracheal Intubation			Supraglottic Airway		
Procedure	n successful/ N events	% Successful (95% CI)	Univariate Odds Ratio (95% CI)	n successful/ N events	% Successful (95% CI)	Univariate Odds Ratio (95% CI)
Activation Type						
Ground	1,900/2,611	72.8 (71.0–74.5)	Reference	447/505	88.5 (85.4–91.2)	Reference
Air	369/399	92.5 (89.4–94.9)	4.6 (3.1–6.7)	24/30	80.0 (61.4–92.3)	0.5 (0.2–1.3)
Missing	82/116	70.6 (61.5–78.8)	N/A	29/33	87.9 (71.8–96.6)	N/A
Cardiac Arrests						
Prior to EMS Arrival	1,285/1,778	72.3 (70.1–74.3)	0.8 (0.7–1.0)	356/398	89.4 (86.0–92.3)	1.3 (0.7–2.5)
After EMS Arrival	149/197	75.6 (69.0–81.5)	0.9 (0.7–1.4)	32/39	82.1 (66.5–92.5)	0.7 (0.3–1.9)
Non-Arrest	621/811	76.6 (73.5–79.4)	Reference	92/106	86.8 (78.8–92.6)	Reference
Missing	296/340	87.1 (83.0–90.4)	N/A	20/25	80.0 (59.2–93.2)	N/A
Injury (Trauma)						
Yes	896/1,092	82.1 (79.6–84.3)	1.9 (1.5–2.2)	157/176	89.2 (83.7–93.4)	1.1 (0.6–2.0)
No	1,213/1,704	71.2 (69.0–73.3)	Reference	277/315	87.9 (83.8–91.3)	Reference
Missing	242/330	73.3 (68.2–78.0)	N/A	66/77	85.7 (75.9–92.6)	N/A
Age						
Newborn (0–0.9 Months)	100/176	56.8 (49.2–64.2)	0.3 (0.2–0.4)	31/36	86.1 (70.5–95.3)	0.5 (0.2–1.4)
Infant (1–11.9 Months)	530/780	67.9 (64.5–71.2)	0.5 (0.4–0.6)	121/146	82.9 (75.8–88.6)	0.4 (0.2–0.7)
Toddler (1–4.9 Years)	455/609	74.7 (71.1–78.1)	0.6 (0.5–0.8)	87/99	87.9 (79.8–93.6)	0.5 (0.2–1.2)
Child (5–10.9 Years)	327/416	78.6 (74.3–82.5)	0.8 (0.6–1.1)	83/96	86.5 (78.0–92.6)	0.5 (0.2–1.0)
Adolescent (11–17.9 Years)	939/1,145	82.0 (79.7–84.2)	Reference	178/191	93.2 (88.6–96.3)	Reference
Population Setting						
Urban	1,815/2,446	74.2 (72.4–75.9)	Reference	431/484	89.0 (85.9–91.7)	Reference
Rural	221/284	77.8 (72.5–82.5)	1.2 (0.9–1.6)	29/40	72.5 (56.1–85.4)	0.3 (0.2–0.7)
Suburban	179/231	77.5 (71.6–82.7)	1.2 (0.9–1.7)	15/17	88.2 (63.6–98.5)	0.9 (0.2–4.1)
Wilderness	52/61	85.2 (73.8–93.0)	2.0 (1.0–4.1)	10/10	100.0 (69.2–100.0)	–
Missing	84/104	80.8 (71.9–87.8)	N/A	15/17	88.2 (63.6–98.5)	N/A
US census region						
South	1,300/1,758	73.9 (71.8–76.0)	Reference	267/309	86.4 (82.1–90.0)	Reference
Midwest	384/498	77.1 (73.2–80.7)	1.2 (0.9–1.5)	73/81	90.1 (81.5–95.6)	1.4 (0.6–3.2)
Northeast	233/297	78.5 (73.3–83.0)	1.3 (1.0–1.7)	20/22	90.9 (70.8–98.9)	1.6 (0.4–7.0)
West	434/573	75.7 (72.0–79.2)	1.1 (0.9–1.4)	140/156	89.7 (83.9–94.0)	1.4 (0.7–2.5)

There are important distinctions between the prior and current analyses. The 2012 analysis found that 4.5% of pediatric patient care encounters involved airway or ventilatory management procedures; we observed airway procedures in only 2% of pediatric events.[12] The incidence of TI was lower for 2019 than 2012 (276 vs. 329 per 100,000 patient care encounters). The use of SGAs was also higher. Several factors may be responsible for these observed trends. First, the number of states contributing data to NEMSIS increased from 40 to 48, and the number of captured EMS events increased over this time period. The 2019 NEMSIS data set identifies procedures using SNOMED CT, an international healthcare terminology standard that is more granular than the original NEMSIS procedure coding system; this newer taxonomy may have altered the detected number and range of procedures. Clinical practice has also evolved since the original report. Specifically, pediatric SGA use has increased from 1% to 10%.

Our analysis provides important perspectives of contemporary EMS pediatric airway management practices. Supported by data from clinical trials, adult out-of-hospital SGA is increasing in the US.[9,10,14] While relatively new in the United States, we observed considerable numbers of children undergoing SGA insertion. This observation signals the need for expanded training in pediatric

Table 5 – Complications associated with EMS pediatric airway cases. Total of 22,637 cases.

Complication	N	n per 1000 airway interventions (95% CI)
Vomiting	223	9.9 (8.6–11.2)
Bleeding	167	7.4 (6.3–8.6)
Airway Injury	83	3.7 (2.9–4.5)
Hypoxia	81	3.6 (2.8–4.4)
Esophageal intubation–immediately detected	60	2.7 (2.0–3.4)
Bradycardia	20	0.9 (0.5–1.4)
Hypotension	2	0.1 (0.0–0.3)

SGA insertion as well as continued research to improve understanding of process and complications of pediatric SGA insertion. While we observed similar rates of LMA and LT use, there is increasing EMS use of the newer iGel airway; iGel use is not currently coded in the NEMSIS data set. Similar to observations by Jarvis, et al., intubation success rates decreased with lower age.[3] This finding suggests that EMS clinicians may need to tailor airway management strategies for different age groups. In contrast to the adult EMS population where most advanced airways are for treatment of cardiac arrest, most pediatric airway cases in this series involved non-arrest patients. Preservation of physiologic status (-e.g., avoidance of hypoxia and hypotension) is essential in the airway management of the non-arrest patient and likely deserves emphasis in EMS pediatric airway training curricula.

Two striking observations were that almost half of pediatric airway cases received TI and that the TI success was only 75%. Based upon the Gausche, et al. trial, experts believe that EMS clinicians should use BVM rather than TI in children.[5] However, despite the Gausche trial results, a follow-up study found that many EMS medical directors and clinicians favored TI over BVM.[8] Reasons cited for retaining TI in paramedic practice included the perceived need for more scientific evidence, the lack of applicability of the results, paramedic reluctance to give up TI, and political pressure. The continued prevalence of TI use in the current NEMSIS analysis suggests that these beliefs may still persist. Our results do not directly reflect the airway management skills of current EMS clinicians, but some would voice concern regarding the modest TI success rate (75%), which may reflect suboptimal intubation skill. A prior meta-analysis suggest sEMS clinician TI success rates over 85%, but in the recent Pragmatic Airway Resuscitation Trial, adult TI success was only 51%.[9,15]

The observations of our study point to the need for new clinical trial data to inform the best pediatric out-of-hospital airway management strategies. Future trials of pediatric airway management would need to account for several important elements to reflect contemporary practice patterns. For example, in addition to BVM and TI, novel trials must include SGAs and account for different disease groups such as cardiac arrest, trauma and respiratory failure. Since airway anatomic differences and airway success rates vary with age, analytic plans must account for varying age strata. Given the low frequency of pediatric prehospital airway episodes, traditional trial designs are likely not sufficient. Sophisticated designs such as the use of Bayesian adaptive platform techniques are likely required to enhance the feasibility of a new trial.

Limitations

This study has several limitations. Given the retrospective research design, this study cannot be used to imply causality. Although the NEMSIS data set provides for a large national sample, not all EMS agencies or States participate in this collaborative database; therefore, the data in this study cannot be generalized to all EMS agencies. All data within the NEMSIS database rely on the patient record completed by the out-of-hospital provider and are subject to reporting and recall bias and missing data elements. NEMSIS has no defined criteria for procedure success rate and success status is determined solely by the provider completing the EMS record. This introduces subjectivity and may bias the data toward higher success rates and lower complication rates. NEMSIS now codes procedures using an international coding standard for healthcare terminology, which is highly granular. There were multiple codes for a single procedure and many codes that were not clearly defined. Unspecified codes may have led to misclassification of procedures, missing data, and lower frequencies of certain procedures. The statistical analyses did not account for multiple attempts of a specific procedure within a single patient. Advanced statistical analyses that account for this correlation could be considered. NEMSIS does not contain consistent information on emergency department or hospital outcomes. The number of RSI was limited; we do not know if this is an anomaly of the data set or a true reflection of current clinical practice. The reported adverse event rates were low including the rate of hypoxia; additional study is needed using automated physiologic measurement systems.

Conclusions

In this large national study utilizing the 2019 NEMSIS data set, we found that airway management occurred in 1 of every 50 pediatric EMS encounters. Almost half of pediatric airway cases received TI. These data provide contemporary perspectives of pediatric prehospital airway management.

CRediT authorship contribution statement

Erin R. Hanlin: Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Hei Kit Chan:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Matt Hansen**: Conceptualization, Formal analysis, Writing – review & editing. **Barbara Wendelberger**: Formal analysis, Writing – review & editing. **Manish I. Shah**: Formal analysis, Writing – review & editing. **Nichole Bosson**: Formal analysis, Writing – review & editing. **Marianne Gausche-Hill:** Formal analysis, Writing – review & editing. **John M. VanBuren**: Formal analysis, Writing – review & editing. **Henry E. Wangj:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Software, Supervision, Writing – review & editing.

There is no overlap with other studies. We confirm that the manuscript, including related data, figures and tables, has not been published previously and that the manuscript is not under consideration elsewhere at this time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge the assistance of N. Clay Mann and Mengtao Dai of the NEMSIS Technical Assistance Center, University of Utah, Salt Lake City, Utah.

Appendix A

SNOMED Airway and Ventilation Management Codes.	
Unspecified airway or ventilation management procedure	
11,140,008	Respiratory assist, manual
118,669,005	Procedure on respiratory system
232,663,008	Airway procedure
232,664,002	Manual establishment of airway
266,700,009	Assisted breathing
386,508,008	Airway insertion and stabilization
386,509,000	Airway management
386,518,003	Artificial airway management
397,982,008	Insertion of device into airway
697,979,005	Airway care management
TI	
Unspecified type:	
112,798,008	Insertion of tracheal tube
16,883,004	Tracheal intubation, emergency procedure
182,686,001	Tracheal respiratory assistance
28,760,000	Laryngoscopy
397,874,007	Tracheal or endobronchial tube change over tube exchange catheter
397,892,004	Retrograde intubation
398,128,007	Difficult intubation
429,161,001	Insertion of tracheal tube using laryngoscope
49,077,009	Flexible fiberoptic laryngoscopy
52,765,003	Intubation
66,861,000	Intubation of larynx
673,005	Indirect laryngoscopy
78,121,007	Direct laryngoscopy
182,682,004	Emergency laryngeal intubation
182,709,001	Laryngeal intubation for inhalation
Oral:	
232,669,007	Oral laryngoscopy
232,674,004	Orotracheal intubation
232,675,003	Oral intubation awake
232,678,001	Orotracheal fiberoptic intubation
418,613,003	Tracheal intubation through a laryngeal mask airway
Nasal:	
232,679,009	Nasotracheal intubation
232,680,007	Nasal intubation awake
232,681,006	Blind nasal intubation
RSI:	
241,689,008	Rapid sequence induction
429,734,006	Intubation using medication
Airway suction	
129,112,001	Aspiration from trachea
18,540,005	Suction of newborn
225,713,007	Removal of vomit from airway
225,715,000	Tracheal tube suction
230,040,009	Airway suction technique
232,702,005	Orotracheal suction
232,703,000	Tracheal suction via tracheostomy
310,583,000	Suction clearance of tracheostomy tube
397,964,005	Bronchial suction via tracheostomy
41,351,007	Suction and cleaning of tracheostomy tube
443,533,003	Irrigation and suction of tracheal tube
58,058,006	Suction of patient
68,187,007	Tracheobronchial suctioning
84,856,008	Oropharyngeal suctioning
Nebulizer	
1,366,004	Inhalation therapy procedure
182,707,004	Respiratory medication
19,861,002	Intermittent positive pressure breathing treatment with nebulized medication
243,132,000	Inhaled drug administration
445,141,005	Administration of medication using nebulizer mask
56,251,003	Nebulizer therapy
Surgical airway	
173,067,007	Cricothyroidotomy
232,685,002	Insertion of tracheostomy tube
232,686,001	Insertion of tracheal T-tube
232,689,008	Percutaneous cricothyroidotomy
232,690,004	Percutaneous dilatational cricothyroidotomy
232,692,007	Open cricothyroidotomy
25,017,002	Tracheostomy, emergency procedure by cricothyroid membrane approach
307,007,002	Percutaneous tracheostomy
398,142,004	Emergency cricothyrotomy
448,442,005	Transtracheal jet ventilation
55,622,001	Tracheostomy, emergency procedure by transtracheal approach
Alternate Airway	
232,673,005	Obturator airway insertion
LMA:	
424,979,004	Laryngeal mask airway insertion

LT:	
427,753,009	Insertion of esophageal tracheal double lumen supraglottic airway
Combitube:	
429,705,000	Insertion of esophageal tracheal combitube
CPAP/BIPAP	
182,687,005	Intermittent positive pressure ventilation
229,310,001	Periodic continuous positive airway pressure
243,142,003	Dual pressure spontaneous ventilation support
423,574,009	Continuous positive airway pressure ventilation weaning protocol
430,191,008	Management of noninvasive mechanical ventilation
446,573,003	Continuous positive airway pressure titration
447,243,000	Bilevel positive airway pressure titration
447,837,008	Noninvasive positive pressure ventilation
47,545,007	Continuous positive airway pressure ventilation treatment
Nasopharyngeal airway insertion	
182,692,007	Nasopharyngeal airway insertion
Oropharyngeal airway insertion	
7,443,007	Insertion of oropharyngeal airway
Foreign body removal	
19,433,002	Direct laryngoscopy with foreign body removal
232,706,008	Airway clearance by finger sweep
232,707,004	Removal of foreign body from airway
23,690,002	Heimlich maneuver
311,787,008	Management of choking
Manual airway opening	
232,665,001	Chin lift
232,666,000	Jaw thrust
445,392,009	Obtaining airway by head extension
Other ventilation management- Bag ventilation through an ET tube or other SGA	
243,140,006	Lung inflation by intermittent compression of reservoir bag
243,184,006	Ventilation with self-inflating bag
408,853,006	Intermittent positive pressure ventilation via tracheal tube
Other ventilation management- Ventilator operation	
243,147,009	Controlled ventilation
243,148,004	Controlled mandatory ventilation
243,149,007	Controlled mandatory ventilation with sigh
243,150,007	Assisted controlled mandatory ventilation
243,153,009	High frequency positive pressure ventilation
26,763,009	Controlled ventilation procedure and therapy, initiation and management
286,812,008	Pressure controlled ventilation
286,813,003	Pressure controlled synchronized intermittent mandatory ventilation
385,857,005	Ventilator care and adjustment
405,609,003	Volume controlled ventilation
40,617,009	Artificial respiration
409,025,002	Ventilator care
410,208,007	Ventilator care assessment
410,210,009	Ventilator care management
424,172,009	Dual pressure spontaneous ventilation support weaning protocol
59,427,005	Synchronized intermittent mandatory ventilation
8,948,006	Assisted ventilation therapy, pressure or volume preset, initiation and management
PEEP	
243,161,004	Positive end expiratory pressure increased
243,163,001	Positive end expiratory pressure increased to best positive end expiratory pressure
243,164,007	Positive end expiratory pressure reduced
243,167,000	Positive end expiratory pressure reduced to best positive end expiratory pressure
398,292,008	Positive end-expiratory pressure monitoring
45,851,008	Positive end expiratory pressure ventilation therapy, initiation and management
Other ventilation- mouth-to-mouth or mouth-to-mask	
243,180,002	Expired air ventilation
243,181,003	Expired air ventilation with airway aid
37,113,006	Mouth-to-mouth resuscitation
Capnography	
284,029,005	Respired carbon dioxide monitoring
425,543,005	Digital respired carbon dioxide monitoring
432,987,005	Checking position of tracheal tube using exhaled carbon dioxide
442,013,003	Measurement of corrected end-tidal carbon monoxide
Colorimetric tube confirmation	
428,482,009	Colorimetric respired carbon dioxide monitoring
BVM	
408,852,001	Intermittent positive pressure ventilation via bag and mask
425,447,009	Bag valve mask ventilation
425,696,007	Manual respiratory assistance using bag and mask

Appendix B

EMS personnel primary impression for pediatric airway events. Primary impressions defined by International Classification of Diseases-10 categories. Total of 22,637 events.

ICD-10 Code Range	Primary Impression	N (%)
A00-B99	Certain infectious and parasitic diseases	113 (0.5)
C00-D49	Neoplasms	5 (0.0)
D50-D89	Endocrine, nutritional and metabolic diseases	99 (0.4)
E00-E89	Mental, Behavioral and Neurodevelopmental disorders	868 (3.8)
F01-F99	Diseases of the nervous system	2,697 (11.9)
H00-H59	Diseases of the eye and adnexa	6 (0.0)
H60-H95	Diseases of the ear and mastoid process	2 (0.0)
I00-I99	Diseases of the circulatory system	3,196 (14.1)
J00-J99	Diseases of the respiratory system	4,699 (20.8)
K00-K95	Diseases of the digestive system	73 (0.3)
L00-L99	Diseases of the skin and subcutaneous tissue	3 (0.0)
M00-M99	Diseases of the musculoskeletal system and connective tissue	81 (0.4)
N99-N99	Diseases of the genitourinary system	4 (0.0)
O00-O9A	Pregnancy, childbirth and the puerperium	209 (0.9)
P00-P96	Certain conditions originating in the perinatal period	305 (1.4)
Q00-Q99	Congenital malformations, deformations and chromosomal abnormalities	5 (0.0)
R00-R96	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	4,826 (21.3)
S00-T88	Injury, poisoning and certain other consequences of external causes	3,611 (16.0)
U00-U85	Codes for special purposes	0 (0.0)
V00-Y99	External causes of morbidity	0 (0.0)
Z00-Z99	Factors influencing health status and contact with health services	423 (1.9)
V00-Y99	Missing/Unknown	1,412 (6.2)

REFERENCES

1. Harless J, Ramaiah R, Bhananker SM. Pediatric airway management. Int J Crit Illn Inj Sci 2014;4:65–70.
2. Thim T, Krarup NH, Grove EL, Rohde CV, Lofgren B. Initial assessment and treatment with the Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach. Int J Gen Med 2012;5:117–21.
3. Jarvis JL, Wampler D, Wang HE. Association of patient age with first pass success in out-of-hospital advanced airway management. Resuscitation 2019;141:136–43.
4. Lavonas EJ, Ohshimo S, Nation K, et al. Advanced airway interventions for paediatric cardiac arrest: A systematic review and meta-analysis. Resuscitation 2019;138:114–28.
5. Gausche M, Lewis RJ, Stratton SJ, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. JAMA 2000;283:783–90.
6. Ohashi-Fukuda N, Fukuda T, Doi K, Morimura N. Effect of prehospital advanced airway management for pediatric out-of-hospital cardiac arrest. Resuscitation 2017;114:66–72.
7. Tweed J, George T, Greenwell C, Vinson L. Prehospital Airway Management Examined at Two Pediatric Emergency Centers. Prehosp Dis Med 2018;33:532–8.
8. Youngquist ST, Gausche-Hill M, Squire BT, Koenig WJ. Barriers to adoption of evidence-based prehospital airway management practices in California. Prehosp Emerg Care Off J Nat Assoc EMS Phys Nat Assoc State EMS Direct 2010;14:505–9.
9. Wang HE, Schmicker RH, Daya MR, et al. Effect of a Strategy of Initial Laryngeal Tube Insertion vs Endotracheal Intubation on 72-Hour Survival in Adults With Out-of-Hospital Cardiac Arrest: A Randomized Clinical Trial. JAMA 2018;320:769–78.
10. Benger JR, Kirby K, Black S, et al. Effect of a Strategy of a Supraglottic Airway Device vs Tracheal Intubation During Out-of-Hospital Cardiac Arrest on Functional Outcome: The AIRWAYS-2 Randomized Clinical Trial. JAMA 2018;320:779–91.
11. NEMSIS. (Accessed November 28, 2021, at https://nemsis.org/).
12. NEMSIS TAC Whitepaper. NEMSIS V3 Suggested List - eProcedure.03 - Procedure. (Accessed November 28, 2021, at https://nemsis.org/technical-resources/version-3/version-3-data-dictionaries/).
13. Hansen M, Lambert W, Guise JM, Warden CR, Mann NC, Wang H. Out-of-hospital pediatric airway management in the United States. Resuscitation 2015;90:104–10.
14. Benger JR, Voss S, Coates D, et al. Randomised comparison of the effectiveness of the laryngeal mask airway supreme, i-gel and current practice in the initial airway management of prehospital cardiac arrest (REVIVE-Airways): a feasibility study research protocol. BMJ Open 2013;3.
15. 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 Off J Nat Assoc EMS Phys Nat Assoc State EMS Direct 2010;14:377–401.