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Clinical paper

Secular trends in airway management of out-of-hospital cardiac arrest in the National Emergency Medical Services Information System (NEMSIS) dataset

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Abstract

Introduction: Prehospital airway management is essential in resuscitation from out-of-hospital cardiac arrest (OHCA). No longitudinal national studies have described longitudinal trends in airway device choice. We sought to evaluate secular trends of OHCA endotracheal intubation (ETI) and supraglottic airway (SGA) in the United States (US).

Methods: We evaluated ETI and SGA use for 2013–2022 in adult OHCA in the US using the National EMS Information System (NEMSIS) database. We identified OHCA events (CPR performed or defibrillation) and evaluated the proportions of ETI and SGA used during OHCA. We repeated the results stratified by urbanicity. We used descriptive statistics to describe the prevalence of airway device use by urbanicity.

Results: During the study period, we observed 320,154,097 adult 9-1-1 events. Of 3,118,703 OHCA, there were 699,568 and 337,458 cases with reported ETI and SGA attempts. The dominant airway choice was ETI, though the trend of ETI choice decreased as SGA increased over time. From 2013 to 2022, SGA use increased in urban settings, while rural and suburban remained stable.

Conclusion: Over ten years, rates of advanced airway use have increased, with ETI remaining the predominant airway for adults in OHCA. Interestingly, ETI choice decreased as SGA increased over the study period. SGA use distinctly differed in urban settings, increasing concerns for disparities in care provision among communities. With the increased use of SGA over time, further evaluation of patient outcomes is required in datasets with robust linkage to Utstein variables.

Keywords: Emergency medical service, Airway management, Out-of-hospital cardiac arrests, Laryngeal mask airway, Endotracheal intubation, Supraglottic airway device

Introduction

Approximately 350,000 people annually experience out-of-hospital cardiac arrest (OHCA) in the United States, of which only 15% survive.[1] Survival from OHCA depends on factors like bystander cardiopulmonary arrest (CPR), early defibrillation, and effective airway management. Prehospital airway management in OHCA care is essential, allowing for effective ventilation and optimizing resuscitation during cardiac arrest.[2,3] Prehospital clinicians perform airway management through differing combinations of non-invasive and invasive techniques, including bag-valve mask-only (BVM), supraglottic airway devices (SGA), and endotracheal intubation (ETI).

Abbreviations: CPR, cardiopulmonary resuscitation, BVM, bag valve mask, EMS, emergency medical services, ETI, endotracheal intubation, ICD, International Classification of Diseases, IRB, international research board, NEMSIS, National Emergency Medical Services Information System, OHCA, out of hospital cardiac arrest, ROSC, return of spontaneous circulation, SGA, supraglottic airway, SNOMED, systematized nomenclature of medicine

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For decades, ETI was the dominant advanced airway approach for OHCA. However, recent studies have promoted the utility of SGA in OHCA. Recent randomized control trial (RCT) data demonstrated that 72-hour survival, return of spontaneous circulation, hospital survival, and favorable neurological status at discharge are higher for SGA than ETI.[4] In this trial, SGA had higher overall success rates, fewer first attempts, and fewer complications (e.g., unrecognized airway misplacement and inadequate ventilation) than ETI.[4] In contrast, another RCT found no difference in good neurological outcome (modified Rankin Scale 0–3) between SGA and ETI, though SGA was significantly more successful in achieving ventilation after up to 2 attempts, especially when placed before an ETI attempt.[5] Even with the data described, the overall picture of airway management in OHCA is unclear.[6]

No national longitudinal study has evaluated whether the choice of advanced airway management between SGA and ETI in OHCA has changed. We sought to assess whether the proportions of these advanced airway devices have changed in OHCA patients over the last decade.

Methods

Study Design and Population

This retrospective study assessed airway device use in OHCA patients from the National Emergency Medical Services Information System (NEMSIS) dataset from 2013 to 2022. The American Institutes of Research Institutional Review Board determined this study as exempt research (IRB# EX00643).

The National Emergency Medical Services Information System (NEMSIS) is the national data standard for emergency medical services (EMS) in the United States. It was developed by the National Association of State EMS Directors and the National Highway Traffic Safety Administration in 1996. NEMSIS is designed to improve the quality and efficiency of EMS by providing a common language for exchanging data between EMS agencies and organizations and is used for various purposes, including quality improvement, research, and policy development.[7] NEMSIS versions include Version 1 from 1996-2009, Version 2 from 2010-2016, and its current Version 3 starting in 2017. In 2012, 19,831,189 EMS activations were reported to NEMSIS by 8,439 agencies located in 42 states and territories,[8] and in 2022, those numbers increased to 51,379,493 EMS activations submitted by 13,946 EMS agencies serving 54 states and territories.[9]

Selection of subjects and identification of cases

We included NEMSIS 911 events for adults $\geq$18 years. Using similar methods developed by Chan et al. for the NEMSIS data set, we identified OHCA episodes presenting with at least one of four constructs: 1) performance of CPR, 2) provision of CPR before or after EMS arrival, 3) chest compression procedure, and 4) defibrillator or cardioversion procedure.[10] We assumed each EMS activation represented a separate patient.

In 2017, NEMSIS implemented a transition from Version 2 to the Version 3 data standard. A salient update in Version 3 was the addition of the International Classification of Diseases (ICD) codes, ICD-9 and 10, now the coding standard for electronic healthcare records.[11] Since this longitudinal analysis bridged the transition between data set versions, we used the NEMSIS crosswalk corresponding variable changes between the Versions 2 and 3 data sets.[12] This crosswalk allows users to understand updates between variable identifiers from data dictionary 2.2.1 to 3.4.0, but unfortunately, it lists only data elements from Version 2 that remain in Version 3. Therefore, in addition to the crosswalk, we used Diggs 2014 and Wang 2011 for Version 2 (Appendix 1) and SNOMED Clinical Terms Browser and Hanlin 2022 for Version 3 (Appendix 2) to categorize the different airway devices used in our OHCA population.[13–16] The definitions for ETI and SGA airway use are noted in Appendix 1 (Version 2) and Appendix 2 (Version 3). This definition accounts for all airway attempts during any phase of an OHCA event, regardless of success. Therefore, a patient receiving an ETI and an SGA in an OHCA event would be considered to have two advanced airway device placement attempts.

Outcomes

The primary outcome was the adult OHCA proportions receiving SGA or ETI. (Appendix 2) We did not include bag-value mask (BVM) ventilation because of inconsistent reporting in the NEMSIS data set. In addition, we did not include surgical airways because of their uncommon use in the OHCA.

Measures

Demographic characteristics related to the analysis included age (year), gender (designated as male or female), and race (defined as White, Black or African American, Asian, American Indian or Alaska Native, Native Hawaiian or Other Pacific Island, or Other). Because ethnicity was reported with race in Version 2 but separately in Version 3 (Hispanic/Latino and Not Hispanic/Latino), and there was a significant amount of missingness, we chose not to report this demographic. There were 246 ICD-10 codes for incident locations in NEMSIS (Appendix 3). These codes were categorized into Home/Residence, Healthcare Facility, Non-Healthcare Business, Street or Highway, and Other (e.g., sporting event, outdoors). Due to differences between versions, all variable codes are listed in their respective demographic tables.

The NEMSIS Project classified population setting (urbanicity) using the 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 or small metropolitan county; Rural (Urban Influence Codes 4, 6, 8, 9), non-urban core counties neighboring 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).[14,17] We used these classifications to evaluate airway proportions by urbanicity. Due to low population numbers, Wilderness populations were combined with Rural populations.[18]

Statistical analysis

We graphed the annual proportion of each airway (ETI and SGA) to visually describe trends over time. We calculated the yearly advanced airway proportion rate by dividing the number of SGA by the total number of SGA plus ETI and the number of ETI divided by the total number of SGA plus ETI. We further stratified the analysis by urbanicity to assess for differences in airway device attempts among urbanicity. Additionally, we graphed the annual trend for the number of advanced airway devices per OHCA event. Given the

large sample size of this data, we did not perform any significance testing, fearing they would be overly sensitive, detecting inconsequential differences. Descriptive statistics of population demographics were calculated. All analyses were conducted with Stata 17/Standard Edition.[19]

Results

From 2013–2022, there were 320,154,097 EMS activations reported in the NEMSIS data, resulting in a 123% increase in overall EMS activations. There was a stepwise increase in EMS activations across Version 2 and again in Version 3 after a reduction in calls in 2017 during the transition period between versions. In this population, 3,118,703 events were identified as adults suffering from OHCA (Fig. 1). The overall percentage of OHCA events remained stable despite these changes. An average of 1.0% annually met the OHCA inclusion criteria in Version 2 and 0.92% in Version 3 (Table 1).

The overall demographics of the OHCA population are noted in Table 2. The median age was 66 years old for each year in the study period, with males the most common gender (59.3%). Across the study period, OHCA events were more common in Urban settings compared to rural and suburban areas. Additionally, the majority of OHCA events occurred in Home/Residential settings, with the lowest proportion in non-healthcare and public areas (Table 2).

Over the last decade, the percentage of advanced airways performed per OHCA events increased (Fig. 2). When evaluating the contribution of each advanced airway device, the predominant airway approach remained ETI over the study period. Despite this dominance, there was a proportional decreasing trend for ETI with a corresponding increase in SGA use (Fig. 2). Specifically, ETI use appeared to decline over the last three years, with a subsequent increase in SGA use.

These proportional changes were also noted when evaluated based on urbanicity (Fig. 3). In urban settings, the proportion of SGA use increased from 27% to 39%. However, in both suburban and rural areas, ETI remained predominant, with no differences in the proportion of SGA use between 2013 and 2022 (suburban 31% to 29%, and rural 28% to 29%).Fig. 4..

Discussion

While advanced airway usage has increased in adult OHCA events, ETI usage has decreased and been replaced with SGA. This trend was more dramatic in urban areas compared to suburban or rural

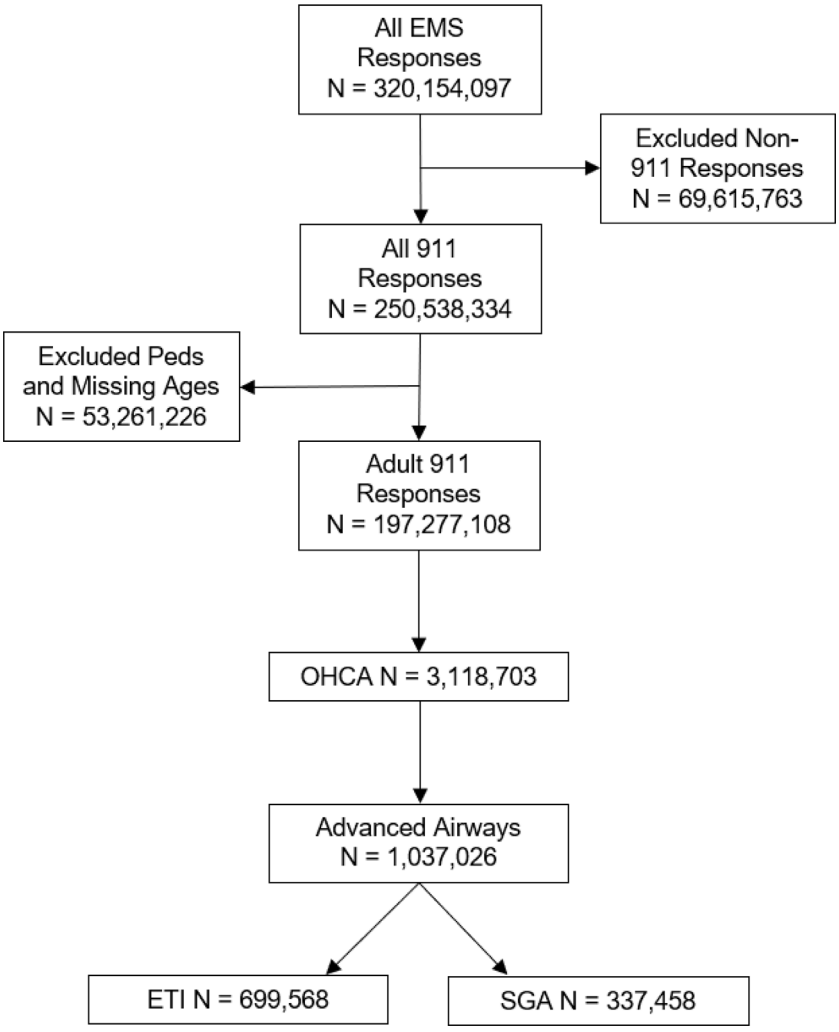

Fig. 1 – Study design with inclusion and exclusion criteria. Abbreviations: EMS – emergency medical services, ETI – endotracheal intubation, OHCA – out-of-hospital cardiac arrest, Peds – pediatrics, SGA – supraglottic airway.

Table 1 – Yearly proportions for inclusions, exclusions, and percentage for OHCA / all NEMSIS calls. Abbreviations: CI – confidence interval, NEMSIS – national emergency medical services information system, OHCA – out-of-hospital cardiac arrest, Peds – pediatrics. Version 2: 2013–2016, Version 3: 2017–2022.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
All NEMSIS Calls	23,897,211	25,835,729	30,206,450	29,919,652	7,907,829	22,532,890	34,203,087	43,488,767	48,982,990	53,179,492
Exclude Non-911 Events	5,341,048	5,623,484	6,689,361	6,250,969	1,562,727	4,690,575	7,701,119	9,694,880	10,879,838	11,181,762
911 Responses	18,556,163	20,212,245	23,517,089	23,668,683	6,345,102	17,842,315	26,501,968	33,793,887	38,103,152	41,997,730
Exclude Peds and Missing	3,814,650	4,096,026	4,805,988	4,988,810	1,272,537	3,995,932	5,762,803	7,182,452	8,191,589	9,150,439
Adults and 911 Calls Only	14,741,513	16,116,219	18,711,101	18,679,873	5,072,565	13,846,383	20,739,165	26,611,435	29,911,563	32,847,291
Adults and 911 Calls Only (%)	61.69%	62.38%	61.94%	62.43%	64.15%	61.45%	60.64%	61.19%	61.07%	61.77%
OHCA Events Included	267,999	258,961	287,712	328,745	68,745	197,933	287,028	437,284	481,142	503,154
OHCA Events %	1.12	1.00	0.95	1.10	0.87	0.88	0.84	1.01	0.98	0.95

Some variables between Versions 2 and 3 differ, and comparisons should be performed cautiously.

settings. Many factors can impact these choices, including which level of EMS clinician arrives on the scene first, the local and state protocols, and patient position and location.[20] Factors such as patient improvement, transportation time to the hospital, and the number of assisting responders determine whether the initial device is maintained or if one switches to another.

Two RCTs have evaluated the impact of SGA first as a management strategy for OHCA, with one study demonstrating no difference in outcomes compared to ETI, while another demonstrated improved outcomes utilizing SGA.[4,5] Complications with ETI placement during OHCA often involve interruptions in chest compressions to allow for better vocal cord visualization that may lead to worsened return of spontaneous circulation (ROSC), and neurological outcomes.[21,22] Although there have been many advances around ETI, including gum elastic bougies and video laryngoscopy, concerns around reduced airway opportunities and lack of training may lead many EMS clinicians to choose the least invasive approach to airway management. Based on these and other evaluations, the 2020 American Heart Association (AHA) advanced cardiac life support (ACLS) guidelines recommend that ETI or SGA be used as primary advanced airway strategies for OHCA if ETI placement success rates are high.[23] In situations where ETI placement success rates were low, the recommendation was to place SGA devices due to the higher first-pass success.

One interesting finding in this study is the overall rate of advanced airway use in the US prehospital setting, ranging from 26-35%. In contrast, previous randomized controlled trials demonstrated higher rates of advanced airway use. These rates included 82% in the Airways 2 trial and 88% in the pragmatic airway trial.[4,5] These differences are substantial and may be multifactorial. First, both clinical trials are in the setting of training and recruitment for a randomized trial, which may lead EMS clinicians to favor the placement of advanced airways. Furthermore, in the controlled setting of a randomized clinical trial, the method of identifying suitable cases differs significantly and is likely more precise. The method of case detection in the NEMSIS dataset remains a new approach that likely deserves independent validation.[24] However, a similar NEMSIS-based analysis using a different method demonstrated a 47% advanced airway placement rate similar to that identified in this evaluation.[10] Given the differences between these study methods, the true estimate of advanced airway use remains unclear and warrants further investigation.

Our study demonstrates that over the last decade, SGA has been adopted by EMS clinicians as a valid advanced airway strategy. When SGA and ETI proportions are stratified by urbanicity, the degree of trend between ETI and SGA in urban settings differs in non-urban areas. The differences between urban and rural settings are noteworthy and could be multifactorial. First, urban and rural communities are different clinical practice settings. OHCA patients in non-urban regions tend to be in homes, have extended downtimes, and are unwitnessed.[10] Rural areas tend to have more volunteer EMS clinicians, longer response and transport times, and sicker patients.[25] Secondly, medical direction and knowledge dissemination practices may differ with urban areas having medical directors from larger, university-based medical centers that are more proactive in spreading current evidence-based knowledge.[25] Differences in airway choice could be a factor leading to urban settings experiencing greater OHCA survival than those in non-urban settings, but a direct impact on patient outcomes is yet to be determined.[26]

Table 2 – Demographics and characteristics (frequency (%)) of out-of-hospital cardiac arrest patients and locations for National Emergency Medical Services Information System (NEMSIS) Version 2, 2013–2016, and Version 3, 2017–2022.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	N = 267,999	N = 258,961	N = 287,712	N = 328,745	N = 68,745	N = 197,933	N = 287,028	N = 437,284	N = 481,142	N = 503,154
Age (median (IQR)	66 (51–79)	66 (52–79)	66 (52–79)	65 (51–78)	66 (53–78)	66 (53–78)	66 (53–77)	66 (52–78)	66 (51–77)	66 (52–78)
Race										
White	160,246 (70.4)	144,345 (68.8)	149,822 (67.6)	173,123 (66.8)	18,109 (80.2)	53,996 (76.7)	88,558 (71.9)	154,341 (69.3)	259,152 (74.0)	288,445 (82.3)
Black or African-American	41,583 (18.3)	40,664 (19.4)	44,326 (20.0)	53,726 (20.7)	3,800 (16.8)	14,733 (20.9)	31,035 (25.2)	62,291 (28.0)	79,608 (22.7)	85,416 (24.4)
Asian	1542 (0.7)	1785 (0.9)	2176 (1.0)	2705 (1.0)	373 (1.7)	701 (1.0)	1853 (1.5)	3374 (1.5)	7221 (2.1)	9072 (2.6)
American Indian or Alaska Native	1123 (0.5)	1247 (0.6)	1355 (0.6)	1331 (0.6)	162 (0.7)	629 (0.9)	1242 (1.0)	2148 (1.0)	2924 (0.8)	2916 (0.8)
Native Hawaiian or Other Pacific Island	496 (0.2)	492 (0.2)	615 (0.3)	714 (0.3)	122 (0.5)	325 (0.5)	416 (0.3)	545 (0.2)	1441 (0.4)	1537 (0.4)
Other	22,670 (10.0)	21,281 (10.1)	23,246 (10.5)	27,544 (10.5)	–	–	–	–	–	–
Missing	40,339	49,147	66,172	69,602	44,254	123,815	152,512	190,107	96,486	81,833
Gender										
Male	144,543 (54.2)	145,007 (56.3)	167,086 (58.4)	184,626 (56.4)	41,943 (61.5)	119,077 (60.6)	175,999 (61.8)	268,875 (62.0)	292,144 (61.7)	305,496 (64.5)
Female	122,217 (45.8)	112,605 (43.7)	119,125 (41.6)	142,558 (43.6)	26,298 (38.5)	77,419 (39.4)	108,772 (38.2)	165,009 (38.0)	181,345 (38.3)	191,928 (40.5)
Missing	1239	1349	1501	1561	388	1174	1578	2131	2831	2823
Urbanicity										
Urban	227,049 (85.6)	213,354 (84.3)	233,765 (84.0)	257,165 (83.4)	51,825 (79.5)	156,247 (81.9)	226,545 (81.7)	355,050 (83.9)	384,597 (83.0)	412,455 (84.2)
Rural	23,984 (9.0)	24,012 (9.5)	25,825 (9.3)	26,329 (8.5)	9837 (15.1)	23,220 (12.2)	33,203 (12.0)	42,246 (10.0)	46,782 (10.1)	44,423 (9.6)
Suburban	14,217 (5.4)	15,599 (6.2)	18,773 (6.7)	24,927 (8.1)	3,511 (5.4)	11,269 (5.9)	17,425 (6.3)	25,757 (6.1)	31,723 (6.9)	33,241 (6.8)
Missing	2749	5996	9349	20,324	3456	6934	9176	12,962	13,218	10,128
Incident Location										
Home/Residence	162,780 (65.0)	158,240 (65.5)	178,158 (66.9)	193,663 (65.3)	33,661 (63.2)	107,787 (65.4)	162,255 (66.3)	230,434 (67.1)	247,329 (66.1)	257,292 (68.8)
Healthcare Facility	49,371 (19.7)	45,384 (18.8)	46,727 (17.6)	52,968 (17.9)	7488 (14.1)	21,000 (12.7)	31,270 (12.8)	47,672 (13.9)	49,206 (13.1)	53,982 (14.2)
Non-Healthcare Business	16,681 (6.7)	14,951 (6.2)	16,010 (6.0)	21,443 (7.2)	5039 (9.5)	16,102 (9.8)	21,336 (8.7)	27,011 (7.9)	32,771 (8.8)	36,189 (9.7)
Street or Highway	19,095 (7.6)	18,602 (7.7)	22,235 (8.4)	25,090 (8.5)	4398 (8.3)	13,650 (8.3)	19,994 (8.2)	26,977 (7.9)	31,690 (8.5)	33,683 (9.0)
Other (e.g., sporting events, outdoors)	2486 (1.0)	4458 (1.8)	3006 (1.1)	3190 (1.1)	2663 (5.0)	6254 (3.8)	9990 (4.1)	11,290 (3.3)	13,203 (3.5)	13,112 (3.5)
Missing	17,586	17,326	21,576	32,391	15,380	32,877	41,504	92,631	102,121	106,989

The variables for incident location are defined in Version 2 and the International Classification of Diseases-10 codes in Version 3 and cannot be compared between versions (Appendix 3). – These variables are not available in NEMSIS Version 3 data.

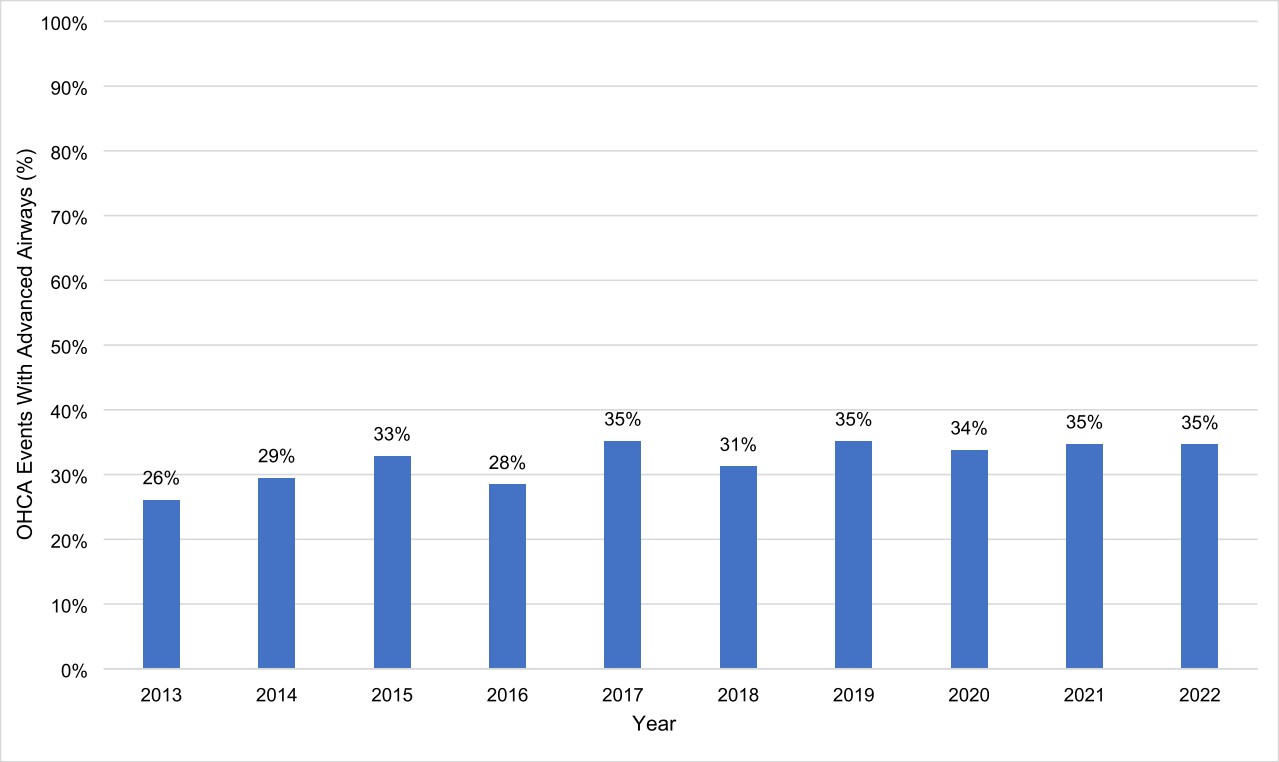

Fig. 2 – Advanced airway proportions per OHCA patient over ten years. Abbreviations: OHCA – out-of-hospital cardiac arrest.

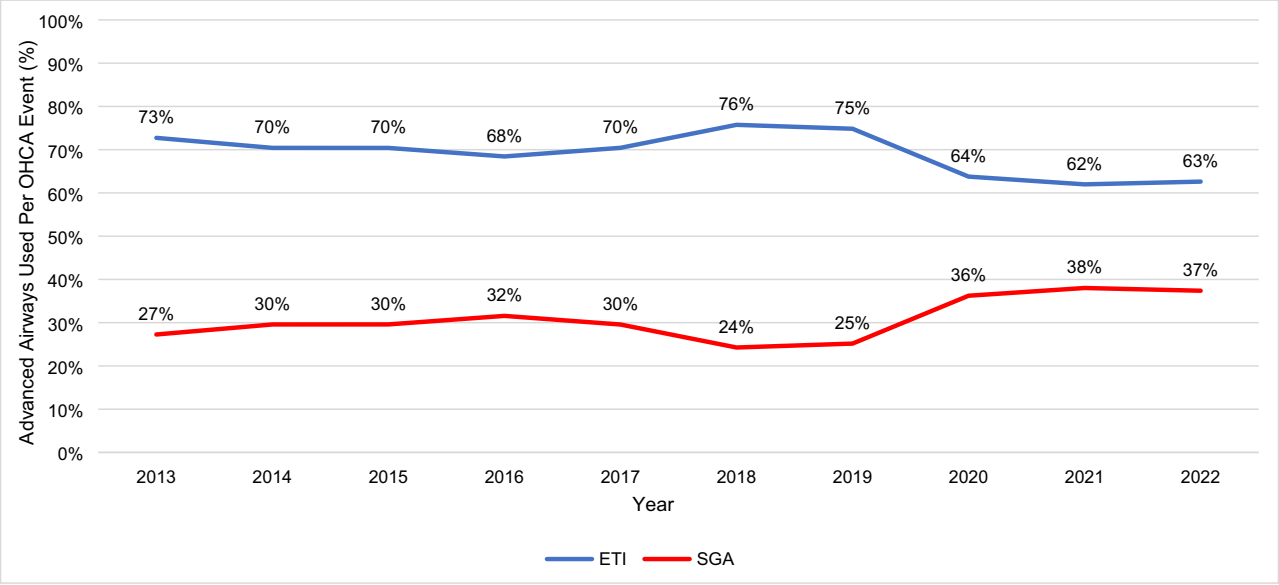

Fig. 3 – Percent of SGA and ETI use per total advanced airway events for OHCA over ten years. Abbreviations: ETI – endotracheal intubation, OHCA – out-of-hospital cardiac arrest, SGA – supraglottic airway.

Understanding the trends in airway management by urbanicity is a significant step in better understanding disparities in care throughout US communities. Linking airway device choice with Utstein variables would help determine the direct impact these decisions have on patient outcomes. Even without this robust evaluation, medical directors should consider enhancing dissemination and training strategies, especially in non-urban areas, to ensure high-level patient outcomes.

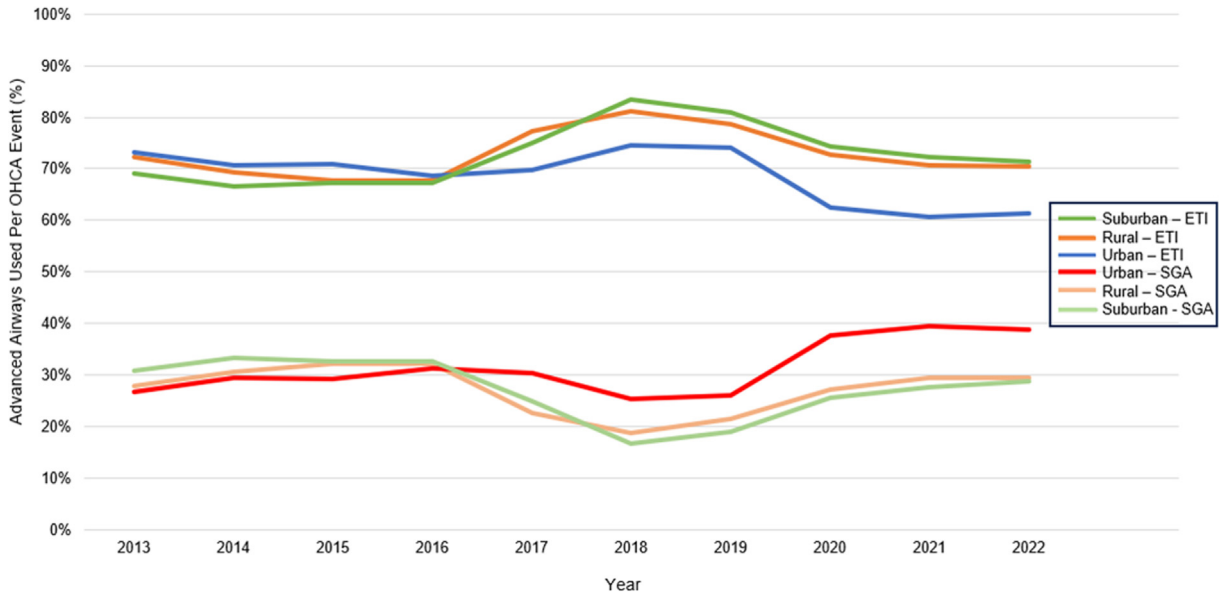

Fig. 4 – Overall SGA or ETI attempts for OHCA by urbanicity. Abbreviations: ETI – endotracheal intubation, OHCA – out-of-hospital cardiac arrest, SGA – supraglottic airway.

Limitations

One of the challenges encountered in this longitudinal study was the need to crosswalk the variables for OHCA and advanced airway devices from NEMSIS Version 2 (2013–2016) to Version 3 (2017–2022). Since Version 3 started incorporating the International Classification of Diseases (ICD) 10 codes and featured many new variables, a true crosswalk for these was unavailable. To combat this problem, we first leveraged the data dictionary, followed by searching for ICD-10 codes, and used previous evaluations to understand the differences in the variables. Since EMS clinicians performed all data entry, reporting bias is possible. Additionally, we limited our evaluation to nationally required variables due to data reporting and could not evaluate cardiac arrest Utstein variables and their association with airway device usage (e.g., shockable vs. non-shockable rhythm and witnessed). Another challenge in this dataset is that urbanicity was defined using Rural-Urban Commuting Area (RUCA) Codes released by the US Department of Agriculture. These are updated using the US Census, last updated in 2013, and are due for an update in 2023. Finally, in this dataset, race is difficult to quantify in NEMSIS due to a large amount of missing or misclassifications.

Conclusion

Over ten years, rates of advanced airway use have increased, with ETI remaining the predominant airway for adults in OHCA. Interestingly, SGA use distinctly differed in urban settings, increasing concerns for disparities in care provision among communities. With the increased use of SGA over time, further evaluation of patient outcomes is required in datasets with robust linkage to Utstein variables.

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CRediT authorship contribution statement

Jonathan R. Powell: Writing – review & editing, Methodology, Conceptualization. **Michelle Nassal:** Writing – review & editing, Methodology, Conceptualization. **Henry Wang:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Ashish R. Panchal:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resuscitation.2023.110024.

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