Available online at www.sciencedirect.com

Resuscitation Plus

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

Clinical paper

Trends in tracheostomy placement after out-of-hospital cardiac arrest

Francisco Gallegos-Koyner[a], Nelson Barrera[a], Ricardo M. Carvalhais[b], David H. Chong[a], Anica Law[c], Ari Moskowitz[b,*]

Abstract

Purpose: Out-of-hospital cardiac arrest (OHCA) is a major public health burden. The purpose of this study was to assess the incidence of tracheostomy placement after OHCA and to evaluate trends over time and cost.

Methods: Using the National Inpatient Sample data 2016–2021, we examined a weighted sample of adults admitted after OHCA who underwent mechanical ventilation within the first 24 h of arrival and had an admission longer than 24 h. The primary outcome of interest was incidence of tracheostomy placement after cardiac arrest. Secondary outcomes of interest included hospitalization costs, days to tracheostomy placement, length of stay and discharge disposition.

Results: A total of 47,550 admissions fulfilled the inclusion criteria. Of those, 1,450 (3.0%) patients received a tracheostomy during their hospitalization. There was no change in the incidence of tracheostomy placement over the analyzed years. Median hospitalization costs for patients with OHCA who received a tracheostomy were $96,038 (IQR= $66,415−$148,633). Hospitalization costs steadily increased over the analyzed years, from $83,668 in 2016 to $109,032 in 2021. Median days to tracheostomy placement was 11 days (IQR = 8–15) and median length of stay of patients with OHCA and tracheostomy was 23 days (IQR = 16–36). There was no significant change over the years in days to tracheostomy placement or in length of stay to explain the increase in hospitalization costs. Among patients with tracheostomy, 76.2% were discharged to a Skilled Nursing Facility, 13.8% died, 4.8% were discharged to a short-term hospital, and 5.2% were discharged home.

Conclusions: An estimated 3.0% of patients who are admitted to the hospital after OHCA and require mechanical ventilation will receive a tracheostomy. Between 2016–2021 the rates and timing of tracheostomy placement remained stable in patients admitted with OHCA. However, we observed a rise in hospitalization costs associated with patients admitted for OHCA.

Keywords: Critical Illness, Heart Arrest, National Inpatient Sample, Tracheotomy, OHCA

Background

Out-of-hospital cardiac arrest (OHCA) affects around 3.8 million people annually worldwide.[1] In the United States alone, around 356,000 people suffer from OHCA every year,[2] and the survival rate for OHCA has most recently been estimated to be ~10%.[3,4] Over the past decades, this survival rate has gradually increased from improved resuscitation practice, standardized post-cardiac arrest care, and avoidance of early withdrawal of life-sustaining therapies,[4] but the rise in survival rates may have led to a larger population of individuals suffering from chronic illness, requiring extended reliance on mechanical ventilation.[5] Understanding trends in tracheostomy placement is critical because tracheostomy placement confers substantial costs to health systems and impacts OHCA survivorship. In the setting of acute stroke, for instance, tracheostomy placement increased hospitalization costs up to 10 times.[6] In 2017 alone, the hospitalization costs for patients with strokes who had a tracheostomy placed was 824 million dollars/year.[6] Tracheostomy placement also carries a significant social impact, both for family members and for patients, with studies showing few out-of-institution days in the first year after tracheostomy among general critically ill patients.[7,8]

Previous nationwide studies have described trends in tracheostomy placement after acute brain injury, although none have specifically focused on an OHCA population. Krishnamoorthy et al.

* Corresponding author at: Division of Critical Care Medicine, Department of Medicine, Montefiore Medical Center, Bronx, New York, USA.
E-mail address: amoskowitz@montefiore.org (A. Moskowitz).

https://doi.org/10.1016/j.resplu.2025.100956
Received 29 March 2025; Accepted 5 April 2025

found an increase in tracheostomy placement in the patients with Severe Acute Brain Injury (SABI) due to cardiac arrest during the period of 2002 to 2011.[9] However, more recent data suggests that trends in tracheostomy have reversed in the last decade.[10] Given the rise in tracheostomy utilization in patients with SABI due to cardiac arrest, but also recently reported decrease in trends of tracheostomy, it remains unclear what recent trends have been for tracheostomy placement among patients with OHCA. In this nationwide study, we aim to describe the incidence and trends in tracheostomy placement after OHCA, along with median days to tracheostomy placement, hospitalization costs, length of stay and discharge disposition, using a contemporary cohort from the National Inpatient Sample (NIS) database.

Methods

Data source

We used data from the Healthcare Cost and Utilization Project's National Inpatient Sample, 2016–2021. The NIS is a publicly available database created by the Agency for Healthcare Research and Quality (AHRQ) and is the largest all-payer inpatient data set in the United States.[11] It provides a stratified sample of 20% of discharges from US hospitals, and unweighted, includes up to 7 million hospital discharges per year.[12] Weighted, it estimates around 35 million hospitalizations nationally.[13] This database includes primary diagnoses and secondary diagnoses using the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes. ICD-10 procedure codes were used to identify inpatient procedures. This database is completely de-identified and publically available. The Albert Einstein College of Medicine Institutional Review Board has provided an exempt status for this work (IRB# 2024-15910).

Study population

We identified hospitalizations of adults >= 18 years of age admitted for OHCA with the ICD-10-CM code I46 as the primary diagnosis. This approach has been used in prior studies to identify patients with OHCA using administrative billing codes[14], and the positive predictive value of this code for identifying patients with OHCA is greater than 90%.[15–17] Patients with a secondary billing code for OHCA were excluded given a higher risk of misclassification. Patients who were not placed on mechanical ventilation within the first 24 h of admission were excluded, and patients with suspected early death based on a hospitalization lasting less than 24 h from admission were excluded as well. Data reported is from the weighted cohort.

Covariates

Sociodemographic data (including age, sex, race or ethnicity, median household income for each patient's zip code, insurance), hospital region, hospital size, hospital location and teaching status were collected from the database. Comorbidities were identified using the AHRQ's Elixhauser Comorbidity Software,[18] which uses the "present-on-admission" indicator to identify pre-existing conditions.

Study exposures and outcomes

Patients who had a tracheostomy placed during their hospitalization were identified with the ICD-10 procedure codes *0B110F4, 0B113F4* and *0B114F4*. The outcome of interest was the incidence of tracheostomy placement after cardiac arrest. Secondary outcomes of interest included days to tracheostomy placement, hospital costs and discharge disposition.

Statistical analysis

Baseline characteristics are described in the inclusion cohort by year. Categorical variables are presented as total numbers and

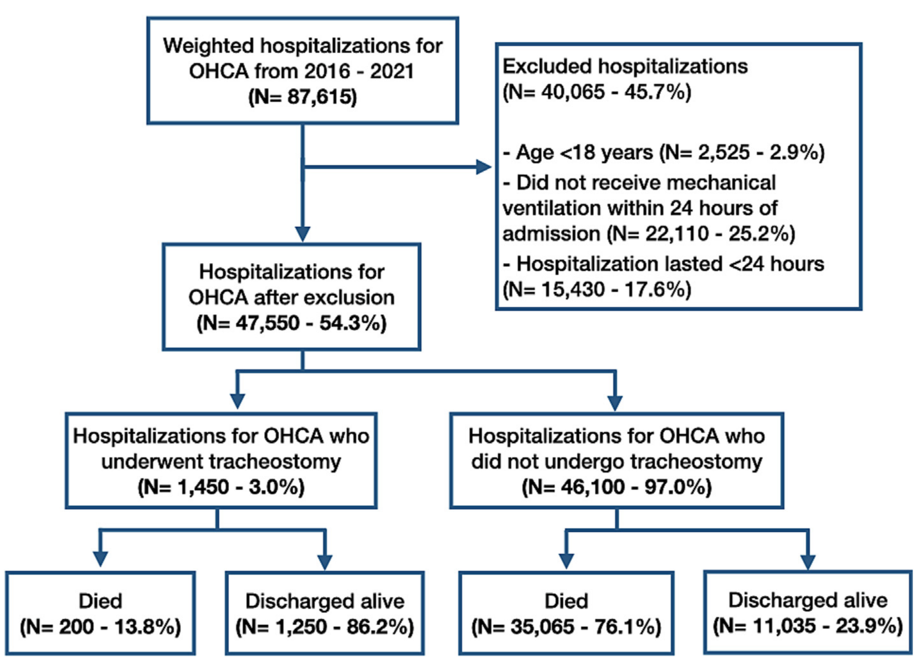

Fig. 1 – CONSORT diagram for inclusion criteria. Flowchart of weighted hospitalizations for OHCA between the years 2016–2021, then substratified into those who underwent tracheostomy or not. OHCA: Out-of-Hospital Cardiac Arrest.

percentages, while continuous variables are presented as means with standard deviations or medians with IQR as appropriate.

The incidence of tracheostomy was reported as the percentage of the included cohort of patients with OHCA who received tracheostomy as well as population-adjusted rates, (i.e., the number of tracheostomies performed in patients with OHCA per 100 million U.S. adults).[19,20] Data visualization techniques were used to illustrate our findings in the context of overall OHCA outcomes. The Mann-Kendall trend test was used to assess if there was any significant change in rate of tracheostomy placement over the analyzed years. Hospitalization costs were analyzed for the included cohort, including those with tracheostomy and those discharged alive

Table 1 – Baseline characteristics of patients admitted for OHCA described by years.

Variables	2016	2017	2018	2019	2020	2021
Age, mean (SD)	63.6 (±11.0)	65.1 (±10.6)	64.2 (±11.1)	64.5 (±11.2)	62.8 (±11.7)	63.2 (±11.1)
Female Sex, %	3,300 (44.8%)	3,555 (43.9%)	3,580 (42.6%)	3,455 (44.2%)	3,035 (42.0%)	3,545 (41.1%)
Race, %						
White or Caucasian	4,270 (62.2%)	4,525 (58.7%)	4,835 (59.3%)	4,620 (61.3%)	4,225 (61.1%)	5,060 (61.5%)
Black or African American	1,530 (22.3%)	2,000 (25.9%)	1,935 (23.7%)	1,720 (22.8%)	1,570 (22.7%)	1,885 (22.9%)
Hispanic	585 (8.5%)	710 (9.2%)	795 (9.7%)	700 (9.3%)	590 (8.5%)	730 (8.9%)
Asian or Pacific Islander	220 (3.2%)	185 (2.4%)	225 (2.8%)	235 (3.1%)	175 (2.5%)	215 (2.6%)
Native American	20 (0.3%)	60 (0.8%)	40 (0.5%)	30 (0.4%)	70 (1.0%)	35 (0.4%)
Other	240 (3.5%)	230 (3.0%)	320 (3.9%)	230 (3.0%)	280 (4.0%)	305 (3.7%)
Quartile classification of median household income by the patient's ZIP code, %						
0–25%	2,710 (37.5%)	2,900 (36.5%)	2,825 (34.4%)	2,665 (34.9%)	2,490 (35.1%)	2,990 (35.2%)
26–50%	1,800 (24.9%)	2,040 (25.7%)	2,295 (27.9%)	2,040 (26.7%)	1,835 (25.9%)	2,170 (25.6%)
51–75%	1,545 (21.3%)	1,700 (21.4%)	1,790 (21.8%)	1,685 (22.0%)	1,565 (22.1%)	1,880 (22.2%)
76–100%	1,180 (16.3%)	1,305 (16.4%)	1,300 (15.8%)	1,250 (16.4%)	1,195 (16.9%)	1,440 (17.0%)
Insurance, %						
Medicare	4,325 (58.8%)	4,950 (61.1%)	4,890 (58.3%)	4,560 (58.4%)	3,940 (54.5%)	4,430 (51.5%)
Medicaid	1,125 (15.3%)	1,240 (15.3%)	1,360 (16.2%)	1,175 (15.0%)	1,245 (17.2%)	1,640 (19.1%)
Private Insurance	1,350 (18.3%)	1,335 (16.5%)	1,390 (16.6%)	1,365 (17.5%)	1,350 (18.7%)	1,675 (19.5%)
Self-Pay	340 (4.6%)	380 (4.7%)	445 (5.3%)	490 (6.3%)	455 (6.3%)	495 (5.8%)
Other	220 (3.0%)	195 (2.4%)	305 (3.6%)	220 (2.8%)	235 (3.3%)	355 (4.1%)
Elixhauser comorbidities, mean (SD)	5.5 (±2.1)	5.6 (±2.1)	5.7 (±2.1)	5.7 (±2.1)	5.6 (±2.2)	5.7 (±2.2)
Had comorbid COVID-19, %	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	165 (2.3%)	255 (2.9%)
Hospital location and teaching status, %						
Rural	350 (4.7%)	470 (5.8%)	495 (5.9%)	410 (5.2%)	295 (4.1%)	430 (5.0%)
Urban non-teaching	1,860 (25.2%)	1,900 (23.4%)	1,795 (21.4%)	1,340 (17.1%)	1,410 (19.5%)	1,480 (17.1%)
Urban teaching	5,160 (70.0%)	5,735 (70.8%)	6,110 (72.7%)	6,070 (77.6%)	5,520 (76.4%)	6,720 (77.9%)
Hospital size, %						
Small	1,135 (15.4%)	1,240 (15.3%)	1,530 (18.2%)	1,455 (18.6%)	1,430 (19.8%)	1,760 (20.4%)
Medium	2,160 (29.3%)	2,615 (32.3%)	2,695 (32.1%)	2,510 (32.1%)	2,190 (30.3%)	2,620 (30.4%)
Large	4,075 (55.3%)	4,250 (52.4%)	4,175 (49.7%)	3,855 (49.3%)	3,605 (49.9%)	4,250 (49.2%)
Hospital region, %						
Northeast	1,145 (15.5%)	1,275 (15.7%)	1,495 (17.8%)	1,220 (15.6%)	1,010 (14.0%)	1,355 (15.7%)
Midwest	1,720 (23.3%)	1,700 (21.0%)	1,725 (20.5%)	1,585 (20.3%)	1,535 (21.2%)	1,925 (22.3%)
South	3,110 (42.2%)	3,705 (45.7%)	3,670 (43.7%)	3,565 (45.6%)	3,330 (46.1%)	3,930 (45.5%)
West	1,395 (18.9%)	1,425 (17.6%)	1,510 (18.0%)	1,450 (18.5%)	1,350 (18.7%)	1,420 (16.4%)
Total hospitalization costs in median (IQR)	$18,746 ($11,416 – $32,436)	$18,672 ($11,266 – $32,068)	$20,289 ($11,725 – $33,112)	$20,477 ($12,333 – $35,021)	$21,861 ($12,635 – $37,235)	$22,113 ($13,360 – $36,450)
Comorbidities, %						
Congestive Heart Failure	2,645 (35.9%)	3,295 (40.6%)	3,535 (42.1%)	3,270 (41.8%)	2,940 (40.7%)	3,560 (41.2%)
Chronic Pulmonary Disease	2,020 (27.4%)	2,400 (29.6%)	2,580 (30.7%)	2,310 (29.5%)	2,060 (28.5%)	2,375 (27.5%)
Renal Disease	2,245 (30.5%)	2,625 (32.4%)	2,710 (32.3%)	2,440 (31.2%)	2,030 (28.1%)	2,485 (28.8%)
Liver Disease	1,660 (22.5%)	1,755 (21.6%)	1,915 (22.8%)	1,735 (22.2%)	1,870 (25.9%)	2,265 (26.2%)
Substance Abuse	685 (9.3%)	675 (8.3%)	795 (9.5%)	755 (9.6%)	785 (10.9%)	1,065 (12.3%)
Hypertension	4,965 (67.4%)	5,595 (69.0%)	5,860 (69.8%)	5,410 (69.2%)	4,730 (65.5%)	5,700 (66.0%)
Diabetes	2,855 (38.7%)	3,440 (42.4%)	3,545 (42.2%)	3,200 (40.9%)	2,670 (37.0%)	3,120 (36.1%)
Patients who died during the hospitalization	5,670 (77.1%)	6,005 (74.1%)	6,305 (75.1%)	5,705 (72.9%)	5,350 (74.0%)	6,230 (72.2%)
Patients discharged alive without tracheostomy	1,530 (20.8%)	1,855 (22.9%)	1,880 (22.4%)	1,895 (24.2%)	1,685 (23.3%)	2,190 (25.4%)

a. All the numbers represented in this Table are admissions in which discharge-level weights were applied, as recommended by AHRQ.[22]

without tracheostomy. All costs were adjusted to 2024 US dollars using the gross domestic product price index to adjust for inflation.[21] A Mann-Kendall trend test was used to assess if there was a statistical difference in hospital costs during the analyzed years. Days to tracheostomy from admission were calculated using medians with IQR. An analysis of days to tracheostomy placement and length of stay was performed to analyze for observed trends in hospitalization costs, and a Mann-Kendall trend test was run to analyze if there were significant differences over the years. As a sensitivity analysis, the same data but excluding patients who were admitted with a secondary diagnosis of COVID-19 was used. Discharge-level weights, strata, and cluster elements were applied to account for the complex survey design and clustering as recommended by the AHRQ.[22] All analyses were performed using the survey suite of commands in STATA 18.0 (StataCorp, Texas, USA).

Results

We identified a total of 47,550 weighted admissions for OHCA meeting the inclusion criteria between 2016–2021. Of these, 1450 (3.0%) patients received a tracheostomy during their hospitalization (Fig. 1). The mean age of the patients who received a tracheostomy was 59.5 years (SD 14.8) and 770 (53.1%) were male. Additional baseline characteristics of the groups categorized by year are shown in Table 1.

Annual incidence of tracheostomy placement, both in percentages of patients with OHCA and in population-adjusted rates, is shown in Fig. 2. There was no significant temporal trend in tracheostomy placement in patients admitted with OHCA over the analyzed years (trend test p = 0.92). Annual trends of tracheostomy placement in the context of OHCA outcomes are shown in Fig. 3. The results of the sensitivity analysis excluding those who had COVID-19 can be found in Table 2.

Median hospitalization costs for all of the patients admitted with OHCA was \$20,401 (IQR= \$12,061 − \$34,442). Costs steadily increased through the years from 2016 to 2021 (trend test p < 0.001). For those patients who had a tracheostomy placed, median hospitalization costs were \$96,038 (IQR= \$66,415 − \$148,633). Median total hospitalization costs stratified by year of OHCA patients with tracheostomy are denoted in Table 2. These also steadily increased through the years, from \$83,668 in 2016 to \$109,032 in 2021 (trend test p = 0.04). For the patients who were discharged alive without tracheostomy, median hospitalization costs were \$29,013 (IQR= \$17,193 − \$48,792), and costs stratified by year are also depicted in Table 2. These remained stable through the study period (trend test p = 0.23).

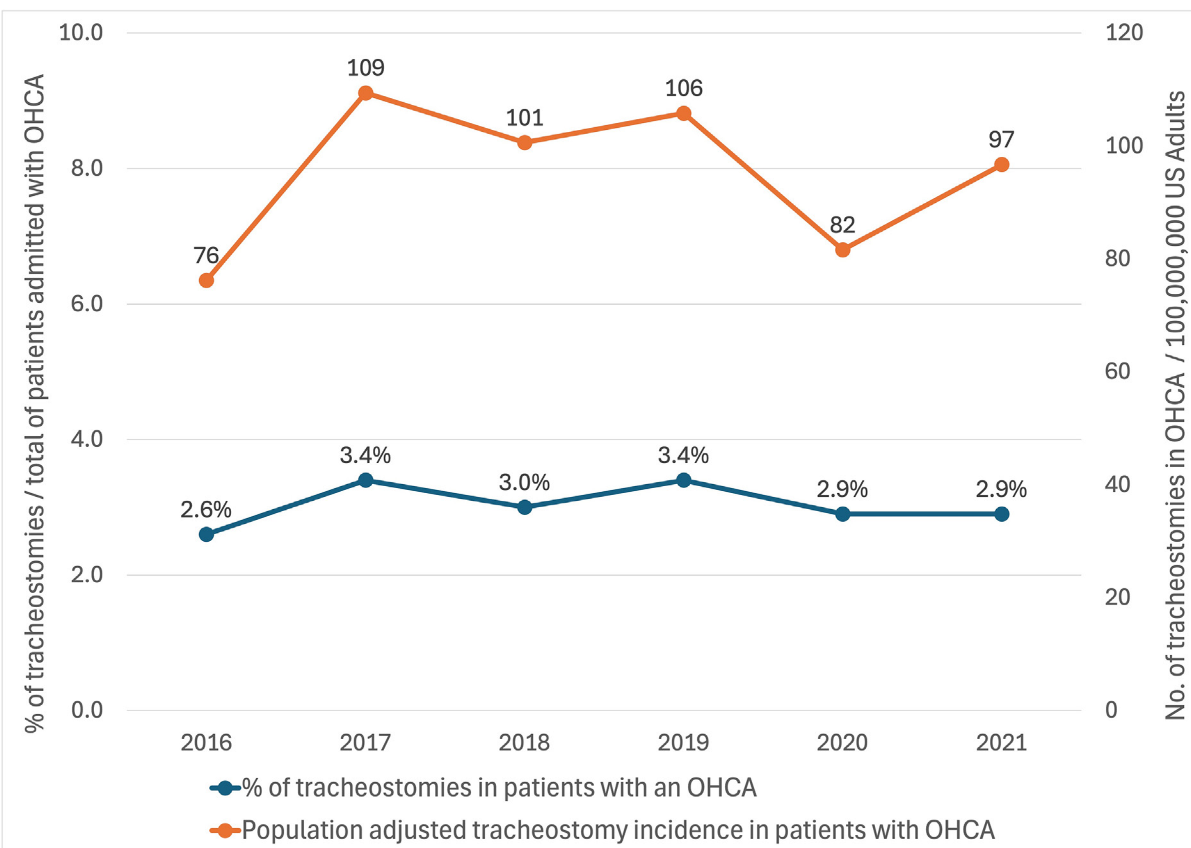

Fig. 2 – Incidence of Tracheostomy Placement in Patients with OHCA by Percentage and Population-Adjusted Rates by Year On the left Y-axis, the graph depicts the percentage of patients who received a tracheostomy, with the denominator being the cohort of patients that fulfilled the inclusion criteria. On the right Y-axis, the graph depicts the population-adjusted tracheostomy incidence in patients with OHCA by year. OHCA: Out-of-hospital cardiac arrest.

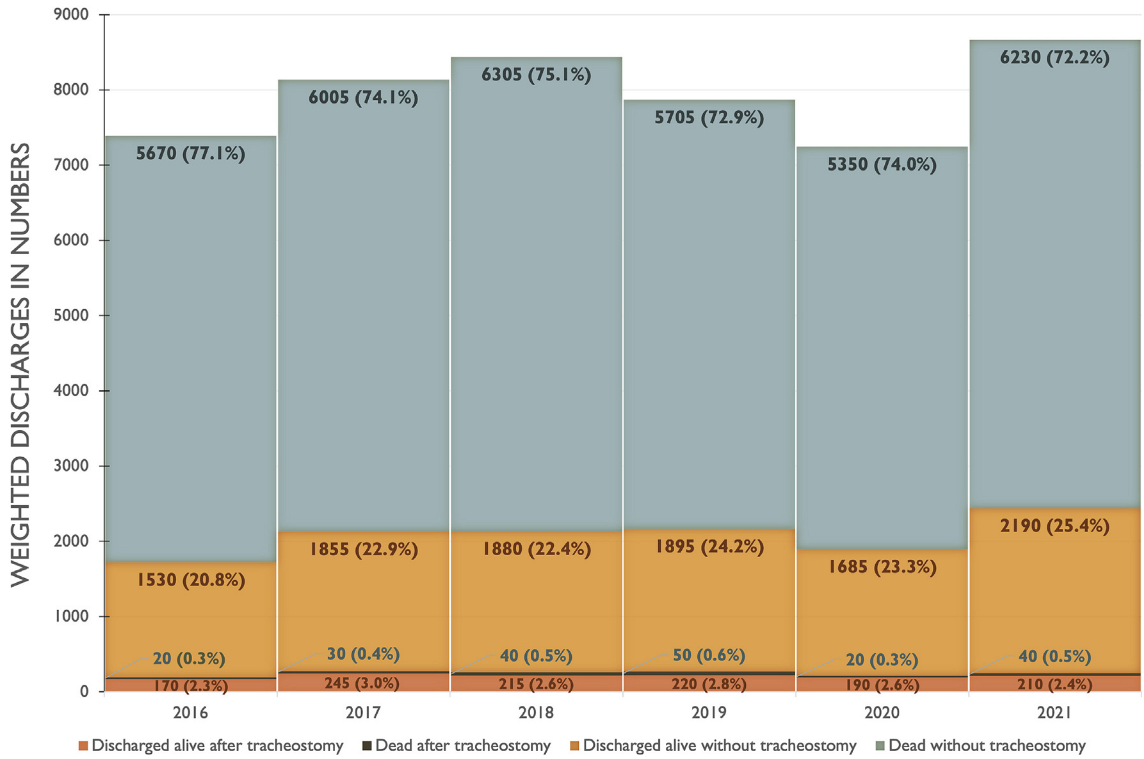

Fig. 3 – Yearly Trend Of Patients Admitted With OHCA Who Underwent Tracheostomy. The figure shows the summed total discharges for patients admitted with an OHCA, where the blue bars represent patients who died without tracheostomy, the yellow bars represent patients who were discharged alive without tracheostomy, the black bars represent patients who died after tracheostomy placement, and the orange bars represent patients who received a tracheostomy and were discharged alive. Percentages representing each discharge category of the total patients with OHCA that year are depicted next to the numbers for reference. OHCA: Out-of-Hospital Cardiac Arrest. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2 – Tracheostomy placement, length of stay and hospitalization costs trends by year.

	2016	2017	2018	2019	2020	2021
Total number of tracheostomies performed	190	275	255	270	210	250
Number of tracheostomies performed excluding patients who had a concomitant diagnosis of COVID-19	190	275	255	270	210	245
Median day of tracheostomy placement (IQR)	11 (8–15)	12 (8–17)	13 (7–18)	10 (7–16)	11 (9–12)	11.5 (8–15)
Median length of stay (IQR)	22 (14–37)	22 (15–35)	29 (18–46)	23.5 (15–37)	22 (19–27.5)	21 (16–33)
Median hospitalization costs of patients admitted with an OHCA who had a tracheostomy (IQR)	$83,668 ($53,148 – $139,515)	$92,501 ($62,458 – $129,804)	$103,633 ($66,151 – $190,520)	$96,038 ($66,415 – $137,918)	$96,039 ($72,022 – $138,291)	$109,032 ($74,236 – $150,671)
Median hospitalization costs of patients admitted with an OHCA who were discharged alive without tracheostomy (IQR)	$30,971 ($16,452 – $48,077)	$27,692 ($16,910 – $48,191)	$28,109 ($17,886 – $43,838)	$28,689 ($16,142 – $46,133)	$31,633 ($17,369 – $54,646)	$29,552 ($17,646 – $52,823)

All the numbers represented in this Table are admissions in which discharge-level weights were applied, as recommended by AHRQ.[22]

The median day of tracheostomy placement was 11 days after admission (IQR = 8–15). The median and interquartile range for day of tracheostomy placement by year is shown in Fig. 4 and the values are displayed in Table 2. Median length of stay of patients with OHCA who received a tracheostomy was 23 days (IQR = 16–36). There was no significant change in median day of tracheostomy placement (trend test p = 0.42) or in length of stay (trend test p = 0.98) in patients with OHCA who received a tracheostomy over the analyzed years.

Among the patients who had a tracheostomy placed, 76.2% were discharged to a Skilled Nursing Facility, 13.8% died, 4.8% were discharged to a short-term hospital, and 5.2% were discharged home.

Discussion

In our study of a nationwide cohort, we found that the incidence of tracheostomy placement after OHCA remained approximately 3%

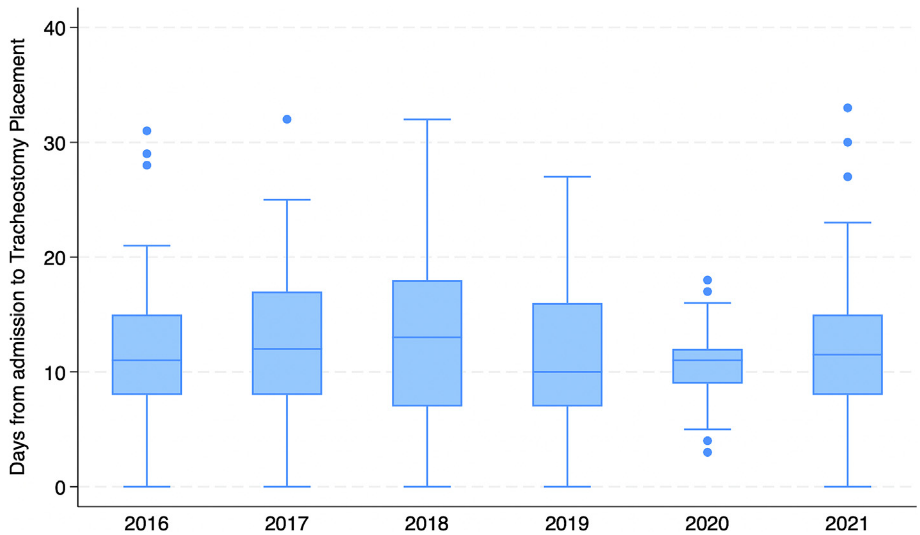

Fig. 4 – Days To Tracheostomy Placement by Year depicted in a Box Plot. The chart depicts in box plots the days from admission in which tracheostomy was placed. Box plots demonstrate the median in the line, the interquartile range in the box, the minimum and maximum values in the longer lines, and the outliers in dots.

between 2016 and 2021. During this period, costs of hospitalization increased for all OHCA patients, and was especially high for patients who received a tracheostomy. The median hospitalization day of tracheostomy placement was day 11. Most OHCA patients who underwent tracheostomy were discharged to a skilled nursing facility.

The results of the present study extend prior work which found an increasing incidence of tracheostomy placement in patients with SABI in the setting of cardiac arrest between 2002 and 2011.[9] Mehta et al. found that the age-adjusted incidence of tracheostomy placement on mechanically ventilated patients in the U.S. increased from 6.9% in 1993 to 9.8% in 2008, and then started to decrease to 8.7% in 2012.[23] Similarly, Abril et al.[24] described a decrease in tracheostomy placement in the years 2002–2017 in all patients and Law et al.[10] also described a decrease in tracheostomy placement in the years 2011–2019 in critically older adults. Taken together, this data suggests that the general incidence of tracheostomy has been decreasing over the last decade and a half and now remains at a stable, low rate following OHCA.

Median hospitalization costs were found to be $96,038 in patients with OHCA who received a tracheostomy. In our analysis, hospitalization costs for patients with tracheostomy were 5 times higher compared to the whole cohort of patients admitted with OHCA – all of whom underwent mechanical ventilation. This is similar to the difference in costs reported in patients with stroke who received invasive mechanical ventilation ($23,774) compared to those with stroke who received mechanical ventilation and also underwent tracheostomy placement ($95,380).[6] In addition to this, there was a significant yearly increase in hospitalization costs in OHCA patients who underwent tracheostomy placement over the years 2016 to 2021.

The median time to tracheostomy placement in this cohort was found to be 11 days, and median length of stay in patients with tracheostomy was 23 days. Early and late tracheostomy placement have different definitions depending on the literature, but late tracheostomy placement is often defined as tracheostomy placement after day 10 of hospitalization.[25–30] In our analysis, we found that tracheostomies were done at a median time of 10–13 days throughout the years, consistent with late tracheostomy placement, and the length of stay for these patients was a median of 21–29 days. We had hypothesized that later placement of tracheostomy could have explained rising hospitalization costs, however the timing of tracheostomy placement remained largely stable over the study period.

The findings from the present study should be interpreted in the context of its limitations: First, the study relies on administrative databases, which may be vulnerable to misclassification. However, as previously described, the billing code for OHCA has positive predictive values > 90%, and procedure codes have good-to-excellent quality in reflecting administrative data.[31] Second, although we performed a sensitivity analysis excluding patients with COVID, we cannot exclude the possibility that the COVID-19 pandemic's impact on health care systems and emergency medical services could have also affected the outcomes of patients without COVID-19 who had an OHCA during the years 2020 and 2021. Third, with administrative databases, data such as the etiology of the arrest, location of the arrest, duration, shockable vs non-shockable rhythm and funtional outcomes are unable to be obtained.

Conclusions

In this study we found that between 2016–2021, the incidence in tracheostomy placement in patients admitted with OHCA remained stable at approximately 3%. However, we observed a yearly increase in the hospitalization costs in all patients with OHCA and in those who received a tracheostomy. The findings of this study should guide future epidemiologic efforts regarding OHCA survival and survivorship.

CRediT authorship contribution statement

Francisco Gallegos-Koyner: Conceptualization, Project administration, Data curation, Formal analysis, Writing – original draft, Investigation, Methodology, Resources, Software, Visualization. **Nelson Barrera:** Conceptualization, Methodology. **Ricardo M. Carvalhais:** Formal analysis, Methodology, Software, Writing – original draft. **David H. Chong:** Supervision. **Anica Law:** Supervision, Validation, Writing – review & editing. **Ari Moskowitz:** Conceptualization, Project administration, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Author Ari Moskowitz is funded by a grant from the National Heart, Lung, and Blood Institute (R33HL162980).

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2025.100956.

Author details

[a]*Department of Internal Medicine, SBH Health System, City University of New York School of Medicine, Bronx, NY, USA* [b]*Division of Critical Care Medicine, Department of Medicine, Montefiore Medical Center, Bronx, NY, USA* [c]*Section of Pulmonary, Allergy, Sleep & Critical Care Medicine, Department of Medicine, Boston University Chobanian & Avedisian School of Medicine, Boston, MA, USA*

REFERENCES

1. Brooks SC, Clegg GR, Bray J, et al. Optimizing outcomes after out-of-hospital cardiac arrest with innovative approaches to public-access defibrillation: a scientific statement from the international liaison committee on resuscitation. Circulation 2022;145(13).
2. Benjamin EJ, Virani SS, Callaway CW, et al. Heart disease and stroke statistics—2018 update: a report from the american heart association. Circulation 2018;137(12)CIR.00000000000.
3. Dyson K, Brown SP, May S, et al. International variation in survival after out-of-hospital cardiac arrest: a validation study of the Utstein template. Resuscitation 2019;138:168–81.
4. Sawyer KN, Camp-Rogers TR, Kotini-Shah P, et al. Sudden cardiac arrest survivorship: a scientific statement from the American heart association. Circulation 2020;141(12).
5. Nelson JE, Cox CE, Hope AA, Carson SS. Chronic critical illness. Am. J. Respir. Crit. Care Med. 2010;182(4):446–54.
6. Albert GP, McHugh DC, Hwang DY, Creutzfeldt CJ, Holloway RG, George BP. National cost estimates of invasive mechanical ventilation and tracheostomy in acute stroke, 2008–2017. Stroke 2023;54(10):2602–12.
7. Swain SK, Acharya S, Das S. Social impact of tracheostomy: our experiences at a tertiary care teaching hospital of eastern India. J Sci Society 2020;47(3):148–52.
8. Law AC, Stevens JP, Choi E, et al. Days out of institution after tracheostomy and gastrostomy placement in critically ill older adults. Ann Am Thorac Soc 2022;19(3):424–32.
9. Krishnamoorthy V, Hough CL, Vavilala MS, et al. Tracheostomy after severe acute brain injury: trends and variability in the USA. Neurocrit. Care. 2019;30(3):546–54.
10. Law AC, Tian W, Song Y, Stevens JP, Walkey AJ. Decline in prolonged acute mechanical ventilation, 2011–2019. Am. J. Respir. Crit. Care Med. 2022;206(5):640–4.
11. HCUP Databases. Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality, Rockville, MD. Available from: www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed April 24, 2024. Healthcare Cost and Utilization Project (HCUP).
12. Barrera N, Jou K, Malik M, et al. Safety of catheter ablation for atrial fibrillation in patients with liver cirrhosis. J. Cardiovasc. Electrophysiol. 2024;1–8.
13. Gallegos-Koyner FJ, Hodo F, Barrera NI, et al. Opioid use disorder's impact on asthma hospitalizations: A propensity-matched nationwide study. Annals of Allergy, Asthma & Immunology. 2024.
14. Patel N, Patel NJ, Macon CJ, et al. Trends and outcomes of coronary angiography and percutaneous coronary intervention after out-of-hospital cardiac arrest associated with ventricular fibrillation or pulseless ventricular tachycardia. JAMA Cardiol 2016;1(8):890–9.
15. DeZorzi C, Boyle B, Qazi A, et al. Administrative billing codes for identifying patients with cardiac arrest. J. Am. Coll. Cardiol. 2019;73(12):1598–600.
16. Hennessy S, Leonard CE, Freeman CP, et al. Validation of diagnostic codes for outpatient-originating sudden cardiac death and ventricular arrhythmia in Medicaid and Medicare claims data. Pharmacoepidemiol Drug Saf 2010;19(6):555–62.
17. Shelton SK, Chukwulebe SB, Gaieski DF, Abella BS, Carr BG, Perman SM. Validation of an ICD code for accurately identifying emergency department patients who suffer an out-of-hospital cardiac arrest. Resuscitation 2018;125:8–11.
18. Elixhauser Comorbidity Software Refined for ICD-10-CM Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality, Rockville, MD. Available from: www.hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp. Accessed February 24, 2024. Healthcare Cost and Utilization Project (HCUP).
19. US Census Bureau. National Population by characteristics: 2020-2023, Table NC-EST2023-AGESEX. Census.gov. https://www.census.gov/data/tables/time-series/demo/popest/2020s-national-detail.html. Accessed on November 27, 2024. .
20. US Census Bureau. National population by characteristics: 2010-2019, Table NC-EST2019-AGESEX. Census.gov. https://www.census.gov/data/tables/time-series/demo/popest/2010s-national-detail.html. Accessed on November 27, 2024. .
21. Dunn A, Grosse SD, Zuvekas SH. Adjusting health expenditures for inflation: a review of measures for health services research in the United States. Health Serv. Res. 2018;53(1):175–96.
22. Houchens R, Ross D, Elixhauser A. Final Report on Calculating National Inpatient Sample (NIS) Variances for Data Years 2012 and Later. HCUP Methods Series Report # 2015-09 ONLINE 2015; https://hcup-us.ahrq.gov/reports/methods/methods.jsp.
23. Mehta AB, Syeda SN, Bajpayee L, Cooke CR, Walkey AJ, Wiener RS. Trends in tracheostomy for mechanically ventilated patients in the United States, 1993–2012. Am. J. Respir. Crit. Care Med. 2015;192(4):446–54.
24. Abril MK, Berkowitz DM, Chen Y, Waller LA, Martin GS, Kempker JA. The epidemiology of adult tracheostomy in the United States 2002–2017: a serial cross-sectional study. Critical Care Explorations. 2021;3(9)e0523.
25. Andriolo BN, Andriolo RB, Saconato H, Atallah ÁN, Valente O. Early versus late tracheostomy for critically ill patients. Cochrane Database Syst. Rev. 2015;2018(12).
26. Young D, Harrison DA, Cuthbertson BH, Rowan K. TracMan collaborators ft. effect of early vs late tracheostomy placement on survival in patients receiving mechanical ventilation: The TracMan randomized trial. JAMA 2013;309(20):2121–9.
27. Shekhar S, Singh RB, De RR, Singh R, Akhileshwar KN. Early versus late tracheostomy in patients with acute brain injury: importance of SET score. Anesth Essays Res 2022;16(1):7–11.

28. Marra A, Vargas M, Buonanno P, Iacovazzo C, Coviello A, Servillo G. Early vs. late tracheostomy in patients with traumatic brain injury: systematic review and meta-analysis. J Clin Med 2021;10(15).
29. Tavares WM, Araujo de França S, Paiva WS, Teixeira MJ. Early tracheostomy versus late tracheostomy in severe traumatic brain injury or stroke: A systematic review and meta-analysis. Aust Crit Care 2023;36(6):1110–6.
30. de Franca SA, Tavares WM, Salinet ASM, Paiva WS, Teixeira MJ. Early tracheostomy in severe traumatic brain injury patients: a meta-analysis and comparison with late tracheostomy. Crit Care Med 2020;48(4):e325–31.
31. Henderson T, Shepheard J, Sundararajan V. Quality of diagnosis and procedure coding in ICD-10 administrative data. Med Care 2006;44(11):1011–9.