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BRIEF REPORT

Airway

Characteristics and outcomes of prehospital and emergency department surgical airways

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Abstract

Objectives: The surgical airway is a high acuity, low occurrence procedure. Data on the complications and outcomes of surgical airways are limited. Our primary objective was to describe immediate complications, late complications, and clinical outcomes of patients who underwent a surgical airway procedure in the prehospital or emergency department (ED) setting.

Methods: We conducted a retrospective chart review of patients ≥14 years at an academic medical center who underwent a surgical airway procedure in the ED, the prehospital setting, or at a referring ED prior to interfacility transfer. We identified cases from keyword searches of prehospital text pages and hospital electronic medical records from June 1, 2008 to July 1, 2022. Manual chart review was used to confirm inclusion and determine patient and procedure characteristics. Outcomes included immediate complications, delayed in-hospital complications, and neurologic disability as defined by Modified Rankin Score (mRS) at discharge.

Results: We identified 63 patients (34 prehospital, 11 ED, and 18 referring ED). Immediate complications included mainstem intubation (46.0%) and bleeding that required direct pressure (23.4%). Overall, 29 patients (46%) died after arrival to the hospital. Of the patients surviving to hospital admission, 25 (48%) had an airway-related complication. Nine complications were deemed directly related to technical components of the procedure. Of the patients who survived to discharge, 18 (52.9%) had poor neurologic function (mRS 4–5).

Conclusion: Procedural complications, mortality, and poor neurologic function were common following a surgical airway procedure in the prehospital or ED setting. Most patients surviving to discharge had a moderate to severe neurologic disability.

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1 | INTRODUCTION

1.1 | Background

Emergency airway management encompasses the assessment, planning, and procedure(s) used to secure an airway in the critically ill patient. More than 1 million adults require emergency airway management, annually. While the majority of emergency airway patients undergo endotracheal intubation successfully, in select cases surgical airway management (including cricothyrotomy and tracheostomy) may be required.[1–3] In the prehospital setting, the incidence of surgical airways is 0.5%–0.7%.[4] The reported rate of surgical airways performed in the emergency department (ED) setting is 0.28%—1.1%.[5]

The Bottom Line

Data on the complications and outcomes of emergency surgical airways are limited. This study assessed the course and outcomes of 63 patients undergoing surgical airway management (34 prehospital and 29 ED). Immediate complications included mainstem intubation (46.0%) and bleeding requiring direct pressure (23.4%). Of the patients surviving to hospital admission, 48% had an airway-related complication. Procedural complications, mortality, and poor neurologic function are common following emergency surgical airway management.

1.2 | Importance

Data on surgical airways are limited given the low frequency of the procedure. Existing literature focuses on incidence and the characteristics of patients who require surgical airways and existing studies have small patient cohorts limiting confidence of conclusions. One small study found a high overall complication rate (21%) from surgical airways completed in the hospital.[6] Additional studies have found cricothyrotomy complication rates ranging from 41.9% to 57% and post-procedural mortality ranging from 44.4% to 87%.[7-10] A systematic review of surgical airways evaluated early and late complications regardless of location of procedure or provider experience and found that tracheostomy had more long-term complications compared to cricothyrotomy.[11] Information regarding immediate and late complications, factors including provider experience, and associated morbidity and mortality is needed.

1.3 | Goals of this investigation

The primary objective of this study was to describe immediate and late complications, morbidity, and in-hospital outcomes of patients who underwent surgical airway management in the prehospital or ED setting.

2 | METHODS

2.1 | Study design

We conducted a retrospective chart review of patients who underwent a surgical airway procedure in either the Vanderbilt University Medical Center (VUMC) ED, the prehospital setting, or at a referring ED prior to intrafacility transfer between June 1, 2008 and July 1, 2022. The study was approved by the local institutional review board.

2.2 | Setting

VUMC is a quaternary care, regional referral center with level 1 trauma accreditation in the southeastern United States. The ED cares for 73,000 patients per year. Approximately 21,000 patients arrive by emergency medical services (EMS). Of patients arriving by EMS, 6000 patients arrive as transfers from outside hospitals. There are approximately 8600 trauma activations that arrive by EMS or transfers from outside facilities, annually. Each year the VUMC ED manages an average of 300 patients from the prehospital setting who have undergone endotracheal intubations and 500 patients who are intubated by providers in the ED.

2.3 | Sources of data

Data was collected from EPIC, our institutional electronic medical record (EMR) using manual chart abstraction. Operator experience was obtained from self-report of individual operator(s) when possible.

2.4 | Selection of patients

Patients were eligible for inclusion if they presented to the VUMC ED and had any of the following present on manual chart review: (1) surgical airway performed by EMS prior to hospital arrival; (2) surgical airway performed at an outside ED prior to transfer to the VUMC ED; or (3) surgical airway completed emergently in the VUMC ED. Patients were excluded if they were <14 years of age or procedure was unable to be confirmed by manual chart review.

We identified patients using two methods. First, we searched a prehospital text page database for potential prehospital surgical airway cases. Our institutional, prehospital text page database contains a repository of text pages (<250 characters) from EMS services notifying providers with abbreviated patient information and care details prior to hospital arrival. For the period from June 1, 2008 to July 1, 2022, we identified pages with the keywords “front of neck access,”

"FONA," "emergency front of neck access," "eFONA," "cricothyrotomy," "cric," "tracheotomy," and "trach." Second, we searched the clarity data warehouse which houses data for our EPIC EMR for all clinical notes including the text "emergency cric," "cricothyrotomy," or "emergency trach." Manual chart review identified true cases and determined study eligibility. Charts were independently reviewed by two authors (ACM and KM) and final adjudication was performed by a third author (AJL) in the case of a disagreement. The EMR used for prehospital critical care transport service categorizes all patients <14 years of age as pediatric patients and thus were not included in the database search.

2.5 | Methods of measurement and outcomes

Study personnel manually abstracted pre-defined exposure and outcome covariates in the EMR from patients within the final cohort. Patient characteristics of interest included demographics, comorbidities, indication for surgical airway, and physical examination findings. Procedural characteristics included procedure technique, immediate complications, as well as associated delayed in-hospital complications. Pre-hospital outcomes of interest included confirmation tool for placement of tube following surgical airway and bleeding requiring direct pressure. In-hospital outcomes of interest included morbidity and mortality, successful tube placement in the trachea, right mainstem intubation, airway complications in the hospital, and hospital length of stay. Modified Rankin Scale (mRS)[12,13] was retrospectively calculated at discharge from physical therapy and occupational therapy notes for all patients.

2.6 | Data analysis

Data were collected and stored in REDCap[14,15] and analyzed using STATA version 16 (StataCorp). Demographic and clinical characteristics were reported as median values with associated interquartile range (IQR) or count (proportion) as appropriate (Table 1).

3 | RESULTS

3.1 | Study cohort

A total of 111 charts were identified using the pre-defined search criteria. The prehospital text page database identified 77 unique patients. The institutional EMR database identified an additional 34 unique patients. Forty-eight patients were excluded. Sixty-three patients were included in the final analysis (Figure 1).

3.2 | Procedural characteristics

Within the study cohort ($n = 61$), 49 patients (77.8%) had documentation on the number of prior oral endotracheal tube (ETT) attempts.

TABLE 1 Patient characteristics.

Characteristic	Value
Median age (interquartile range), years	45 (28, 54)
Female, *n* (%)	8 (12.7)
Race, *n* (%)	
White	45 (71.4)
Black	17 (27.0)
Other	1 (1.6)
Hispanic ethnicity, *n* (%)	3 (4.8)
Median BMI (interquartile range), kg/m^2	26.6 (23.5, 30.0)
Comorbidities, *n* (%)	
OSA	1 (1.6)
COPD	3 (4.8)
CHF	1 (1.6)
Prior or active head/neck cancer	6 (9.5)
Prior radiation to head/neck	6 (9.5)
Prior surgical neck procedure[a]	5 (8.5)
Physical examination findings, *n* (%)[b]	
Limited mouth opening	11 (17.5)
Airway obstruction	26 (41.3)
Acute trauma to head/neck	41 (65.1)
More than one of the above exam findings	59 (93.7)
Background indication, *n* (%)	
Medical	20 (31.8)
Trauma	43 (68.3)

Abbreviations: BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; OSA, obstructive sleep apnea.
[a]Prior neck procedures included the following: 1, prior head and neck lymph node dissection for head and neck cancer; 2, prior tracheal surgery; 3. Previous tracheostomy.
[b]Examination findings not mutually exclusive.

The median number of ETT attempts prior to a surgical airway was 2 (IQR 0–3). Six patients (12%) underwent a surgical airway without an initial attempt at endotracheal intubation (Table 2). Thirty-four patients (54.0%) had a surgical airway performed by EMS personnel (24 by flight-based and 10 by ground-based) and 29 (46.0%) by a hospital physician (by specialty: 18 ED physicians, six trauma surgeons, one otolaryngologist, one anesthesiologist, and three without operator recorded). Distribution of levels of training for the hospital physicians were as follows: 22 attending physicians, four surgical fellows, and three ED residents. Procedural technique was recorded in 58 patients. Forty-six procedures (73%) were completed by primary surgical approach and 12 (19%) by primary percutaneous approach. Fifty-four were cricothyrotomies (46 surgical and eight percutaneous) and four were percutaneous tracheostomies. Confirmation of tube placement by end tidal carbon dioxide monitoring ($ETCO_2$), either waveform or colorimetric, was performed in half of patients (49.2%).

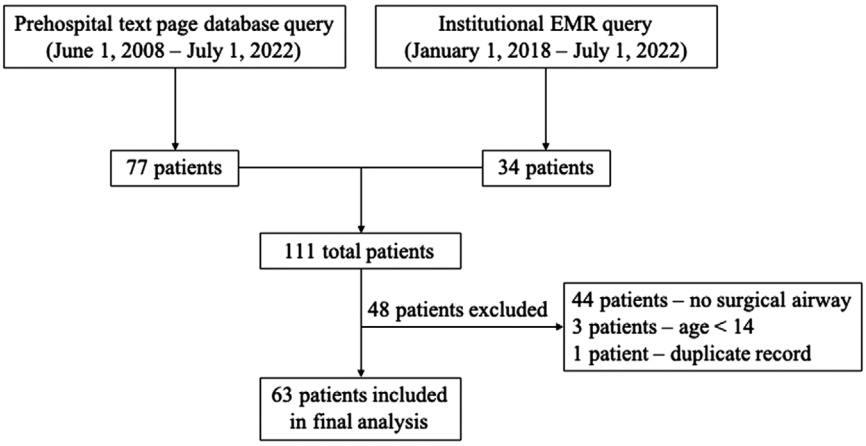

FIGURE 1 Consort diagram.

3.3 | Complications

Recorded immediate procedure complications included mainstem intubation (46.0%) and bleeding that required direct pressure (23.8%) (Table 2).

While in-hospital, 25 patients (39.6%) had an airway-related complication. Nine complications were deemed directly related to the technical components of the procedure. Of these nine complications, there were two aspiration events during or immediately after the procedure, one delayed bleeding event leading to aspiration, two ETT dysfunction events requiring a new airway, one post-procedural abscess, one retained foreign body felt to be secondary to the procedure, one surgical airway site wound dehiscence, and one pharyngotomy repair secondary to structural damage (Table S1). Sixteen patients developed documented pneumonia or pneumonitis.

3.4 | In-hospital outcomes

Fifty-four patients (85.7%) visited the ED with a palpable pulse. Thirty patients had formal tracheostomies completed during their hospital stay and four were able to be orally intubated. Twenty-two (73%) patients were ultimately able to decannulated. Of the 34 patients who survived to discharge, 18 (52.9%) were discharged with an mRS of four or five, indicating moderately severe disability requiring assistance. Twenty-nine patients (46%) died after arrival to the hospital: seven patients had death pronounced on arrival with no further resuscitative measures, four died in the ED prior to hospital admission, and 18 died while admitted. Seventeen patients (27.0%) were able to be discharged home. Thirteen (20.6%) were discharged to an acute care or rehabilitation facility (Table 3). Average hospital length of stay for discharged patients was 12 days (Table 3).

4 | LIMITATIONS

There were six limitations to this study. First, data were obtained from a single, academic medical center that limits the generalizability of our descriptive analysis. Second, this was a retrospective analysis limited by data available within the EMR at the time of surgical airway procedure. Due to a hospital-wide change in EMR, we were limited in our institutional EMR database search to records occurring after January 1, 2018. Third, several records including those documenting procedures completed at outside hospitals or EMS systems were incomplete. Intrinsic missingness in physical examination findings do not represent an absence of features, but rather an absence of mention in the available records. It is possible the recorded physical examination findings were an underestimation of high-risk airway characteristics within this population. Fourth, our cohort only included patients stable enough for transfer to a level 1 trauma center and excluded patients deceased on scene limiting the generalizability of this study. Fifth, we used mRS as a surrogate assessment of functional neurologic outcomes. While not developed for use in a retrospective fashion or for non-stroke populations, it has been used to measure functional outcomes in other populations.[16] We considered it a reasonable surrogate measure in our cohort. Finally, we were underpowered to conduct meaningful statistical models predicting the outcomes listed above.

5 | DISCUSSION

We sought to describe both immediate and in-hospital complications of patients who underwent a surgical airway in either the prehospital or ED setting. Immediate complications in our study included nearly half of patients with a mainstem intubation and a quarter of patients with a bleeding complication immediately after the procedure. There was high morbidity and mortality in our study with half of the patients who survived to hospital discharge requiring continuous physical assistance.

Select studies have described outcomes and adverse events after surgical airway management. One single site study of 35 patients found a 21% complication rate for patients undergoing in-hospital surgical airways, which was slightly higher than our 14% overall complication rate. This study did stratify complications by provider, but only one surgical airway was completed by an ED provider and none in the pre-hospital setting.[6] An analysis of the NEAR database included 49

TABLE 2 Procedural details.

	EMS personnel[a]	Hospital physician[b]	All operators
Operator, *n* (%)	34 (54.0)	29 (46.0)	24 (38.1)
Operator experience, *n* (%), years			
0–5	0 (0.0)	5 (100.0)	5 (7.9)
6–14	3 (18.8)	13 (81.2)	16 (25.4)
15+	8 (61.5)	5 (38.5)	13 (20.6)
Unknown	23 (79.3)	6 (20.7)	29 (46.0)
Airway technique, *n* (%)[c]			
Surgical	26 (56.5)	20 (43.5)	46 (73.0)
Percutaneous	6 (50.0)	6 (50.0)	12 (19.0)
Not recorded	2 (40.0)	3 (60.0)	5 (7.9)
Cervical collar, *n* (%)			
Present	17 (77.3)	5 (22.7)	22 (34.9)
Absent	12 (37.5)	20 (62.5)	32 (50.8)
Not recorded	5 (55.6)	4 (44.4)	9 (14.3)
Supraglottic device used prior to surgical airway			
Yes	7 (53.8)	6 (46.2)	13 (20.6)
No	21 (58.3)	15 (41.7)	36 (57.1)
Not recorded	6 (42.9)	8 (57.1)	14 (22.2)
Endotracheal intubation attempts prior to surgical airway			
0	2 (33.3)	4 (66.7)	6 (9.5)
1	8 (50.0)	8 (50.0)	16 (25.4)
2	7 (58.3)	5 (41.7)	12 (19.0)
3 or more	8 (53.3)	7 (46.7)	15 (23.8)
Not recorded	9 (64.3)	5 (35.7)	14 (22.2)
Successful placement in trachea, *n* (%)[d]	29 (51.2)	27 (48.2)	56 (88.9)
Tube confirmation, *n* (%)			
$ETCO_2$	18 (58.1)	13 (41.9)	31 (49.2)
Bilateral breath sounds auscultated	14 (56.0)	11 (44.0)	25 (39.7)
Chest rise	14 (66.7)	7 (33.3)	21 (33.3)
Fogging of tube	0 (0.0)	2 (100.0)	2 (3.2)
Surgical airway mainstem intubation confirmed by CXR, *n* (%)			
Right	14 (58.3)	10 (41.7)	24 (38.1)
Left	3 (60.0)	2 (40.0)	5 (7.9)
Unknown	6 (66.7)	3 (33.3)	9 (14.3)
Bleeding during procedure requiring direct pressure, *n* (%)	8 (53.3)	7 46.7)	15 (23.8)

Abbreviations: CXR, chest x-ray; EMS, emergency medical services; $ETCO_2$, qualitative end tidal carbon dioxide detection; SpO_2, oxygen saturation.

[a]Flight EMS personnel (24/34), ground EMS personnel (10/34).

[b]ED physician (21/29), trauma surgeon (6/29), otolaryngologist (1/29), anesthesiologist (1/29), and not recorded (3/29).

[c]Surgical technique was defined as initial skin break made with a scalpel, percutaneous technique was defined as initial skin break made by a hollow needle; 8/12 (2/3) percutaneous cricothyrotomy; 4/12 (1/3) percutaneous tracheostomy.

[d]Defined as a successful placement by initial evaluating physician or by operating room note from revision procedure. Unsuccessful placement of the tube included the following: 2, not within the trachea; 5, missing data confirming placement.

patients who had a surgical airway in the ED. This study had similar rates of trauma versus medical indications for surgical airway, as well as a similar number of oropharyngeal intubation attempts prior to surgical airway when compared to our study. The NEAR analysis did not report data on procedural complications. Interestingly, the NEAR cohort had higher rates of survival to hospital admission compared to our cohort with a 73.5% survival rate.[5] Our survival rate is likely lower due to including pre-hospital surgical airways in our analysis as this group of patients is likely even sicker than patients who had an in-hospital surgical airway. Overall, we found that the rate of surgical airways encountered in our study is consistent with prior literature on patients undergoing advanced airway procedures in the prehospital and ED setting.[4,5]

Although our sampling methodology precludes a formal calculation of procedure incidence, and the study is underpowered to draw statistical conclusions, several results are hypothesis generating and have important clinical implications. Forty-five states include surgical airways in paramedic scope of practice,[17] and the ability to perform a surgical airway is imperative for emergency medicine physicians. Understanding expected immediate complications and downstream adverse events secondary to the procedure can specifically guide how the procedure is taught and reviewed with prehospital and ED operators. Given the high acuity and low frequency of this procedure, routine procedural skills review with a focus on mitigating hemorrhage and mainstem intubation merit attention. Table S1 explores the multiple different in-hospital complications that can arise from a surgical airway completed in the pre-hospital and ED setting. These case vignettes demonstrate that technical mastery of this procedure can not only prevent short-term complications such as bleeding and mainstem intubation, but also in-hospital complications such as aspiration, abscess, and wound dehiscence.

Similar to prior work, this study highlights that overall mortality after a surgical airway is high with nearly half of the patients not surviving to hospital discharge. We identified both immediate and in-hospital outcomes that may be linked to technical deficiency in the performance of a surgical airway independent of operator and location. Outcomes described here may be used to frame discussions regarding operator technical skills, expected clinical course, and potential complications of patients who survive to hospital admission.

TABLE 3 In-hospital outcomes.

Death pronounced on arrival with no further resuscitative measures, *n* (%)	7 (11.1)
Death in the ED following resuscitative measures, *n* (%)	4 (6.3)
In-hospital mortality at 24 h, *n* (%)	16 (25.4)
Proecedurally related complications, *n* (%)[a]	9 (14.3)
Bleeding and aspiration	3 (33.3)
Tube dysfunction	2 (22.2)
Abscess	1 (11.1)
Foreign body in airway	1 (11.1)
Pharyngotomy repair	1 (11.1)
Procedural site dehiscence	1 (11.1)
Pneumonia/pneumonitis complications, *n* (%)	16 (25.4)
Length of stay, *n* (%), days	
0–7	30 (47.6)
8–14	17 (27.0)
15–29	10 (15.9)
30+	6 (9.5)
Modified Rankin Score at discharge, *n* (%)[b]	
0	0 (0)
1	5 (14.7)
2	6 (17.6)
3	5 (14.7)
4	14 (41.2)
5	4 (11.8)
Discharge location, *n* (%)	
Home	17 (27.0)
Nursing home/assisted living	1 (1.6)
Rehab facility/LTAC facility	13 (20.6)
Hospice	1 (1.6)
Deceased	29 (46.0)
Other	2 (3.2)

Abbreviations: ED, emergency department; LTAC, long-term acute care.
[a]See Table S1 for details of complications.
[b]Calculated post hoc by reviewers from the last physical therapy and occupational therapy clinical note prior to hospital discharge or the first intake note at the medical center–affiliated rehabilitation hospital.

AUTHOR CONTRIBUTIONS

Jeremy Brywczynski, Aaron J. Lacy, and William B. Stubblefield: Study concept and design; Amanda C. Mathews, Kaitlin McLeod, Aaron J. Lacy, and Jesse O. Wrenn: Acquisition of data; Amanda C. Mathews, Kaitlin McLeod, Aaron J. Lacy, and William B. Stubblefield: Analysis and interpretation of data; Amanda C. Mathews, Kaitlin McLeod, and William B. Stubblefield: Manuscript drafting. Amanda C. Mathews, Aaron J. Lacy, Jeremy Brywczynski, Jesse O. Wrenn, Jared J. McKinney, and William B. Stubblefield: Manuscript revision. Kaitlin McLeod and William B. Stubblefield: Statistical analysis.

CONFLICT OF INTEREST STATEMENT

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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