Prehospital Surgical Cricothyrotomy in a Ground-Based 9-1-1 EMS System: A Retrospective Review

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Abbreviations:
EMS: Emergency Medical Services
ePCR: electronic patient care report
$ETCO_2$: end-tidal carbon dioxide
ETI: endotracheal intubation
HEMS: helicopter Emergency Medical Services
SGA: supraglottic airway

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Abstract

Background: Airway management is a cornerstone in the prehospital care of critically ill or injured patients. Surgical cricothyrotomy offers a rapid and effective solution when oxygenation and ventilation fail using less-invasive techniques. However, the exact indications, incidence, and success of prehospital surgical cricothyrotomy are unknown, with variable rates reported in the literature. This study aimed to examine prehospital indications and success rates for surgical cricothyrotomy within a large, suburban, ground-based Emergency Medical Services (EMS) system.

Methods: This is a retrospective analysis of 31 patients who underwent paramedic performed surgical cricothyrotomy from 2012 through 2022. Key demographic parameters were analyzed, including the incidence of cardiac arrest, call type (trauma versus medical), initial airway management attempts, number of endotracheal intubation (ETI) attempts before surgical airway, and average time to the establishment of a surgical airway in relation to the number of ETI attempts. Surgical cricothyrotomy success was defined as the acquisition of four-phase end-tidal capnography reading. The primary data sources were the EMS electronic medical records, and descriptive statistics were calculated.

Results: A total of 31 patients were included in the final analysis. Of those who received a surgical cricothyrotomy, 42% (13/31) occurred in the trauma setting, while 58% (18/31) were medical calls. In all patients who underwent surgical cricothyrotomy, the median (IQR) time to the procedure was 17 minutes (IQR = 11-24). In trauma patients, the median time to surgical cricothyrotomy was 12 minutes (IQR = 9-19) versus 19 minutes (IQR = 14-33) in medical patients. End-tidal carbon dioxide ($ETCO_2$) detection and placement success was confirmed in 94% (29/31) of patients. Endotracheal intubation was attempted in 55% (17/31) before subsequent surgical cricothyrotomy, with 29% (9/31) receiving more than one ETI attempt. The median time to surgical cricothyrotomy when multiple prior intubation attempts occurred was 33 minutes (IQR = 23-36) compared to 14.5 minutes (IQR = 6-19) in patients without a preceding intubation attempt.

Conclusion: Prehospital surgical airway can be performed by paramedics with a high degree of success. Identification of the need for surgical cricothyrotomy should be determined as soon as possible to allow for rapid securement of the airway and to ensure adequate oxygenation and ventilation.

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Introduction

Airway management is a foundation of patient care in the prehospital setting, and effective delivery of oxygenation and ventilation by bag-valve mask, supraglottic device, and endotracheal intubation (ETI) are core skills for Emergency Medical Services (EMS) clinicians. Prehospital surgical cricothyrotomy is an established last resort airway intervention for patients where oxygenation and ventilation are impossible via any other means, often following failed attempts of other airway adjuncts and techniques. This inability to definitively establish an airway may lead to permanent disability or death.[1]

Prehospital surgical cricothyrotomy is performed with the least frequency of all EMS airway management skills, often in the most critically ill patients.[2] While the exact incidence of prehospital surgical cricothyrotomy is unknown, it is estimated that less than one percent of prehospital patients require surgical cricothyrotomy.[3] Despite the rarity of this procedure,

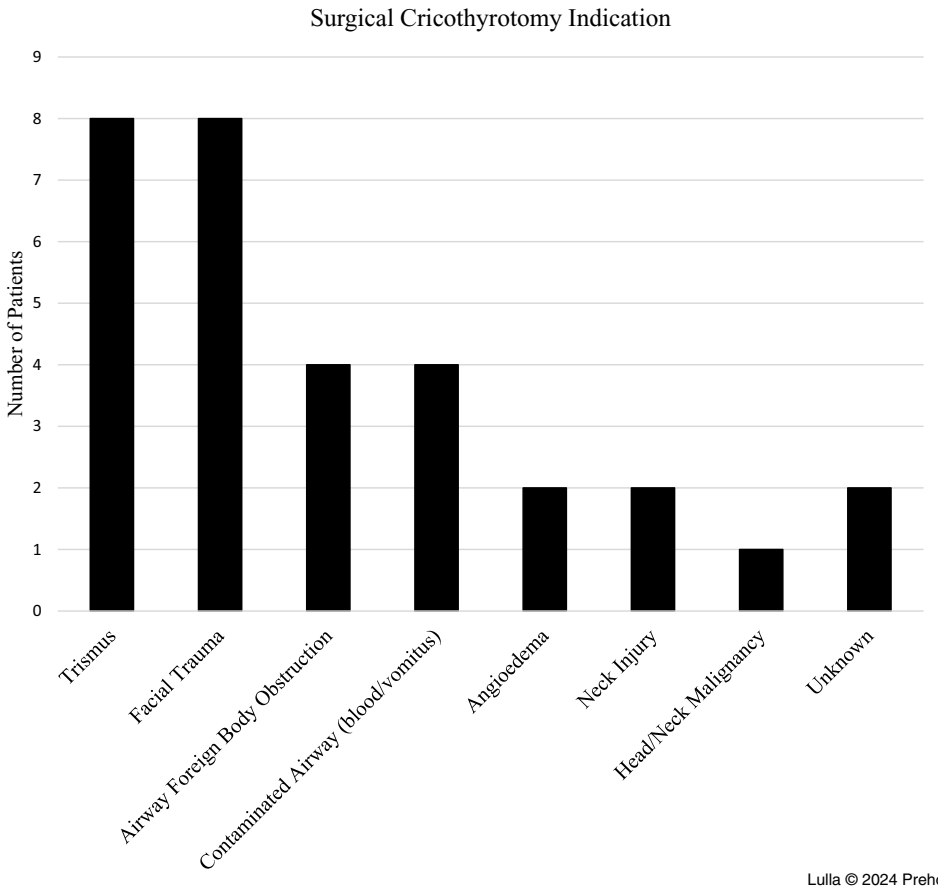

Figure 1. Indications for Prehospital Surgical Cricothyrotomy.

some studies, specifically in air medical services, have demonstrated high success at performing surgical cricothyrotomy, with one study reporting a 94% success rate.[4,5]

More robust data exist for surgical cricothyrotomy's indications, incidence, and success in air medical EMS programs, especially those utilizing physician response, as opposed to ground-based, paramedic-led systems.[4,5] Therefore, surgical airway evidence is limited in ground-based 9-1-1 EMS systems where paramedics use a standing order protocol for surgical cricothyrotomy.[6] This study examined prehospital indications and success rates for surgical cricothyrotomy within a large, suburban, ground-based EMS system.

Methods

A retrospective review was performed of all EMS electronic patient care reports (ePCRs) in which surgical airway placement was attempted from November 1, 2012 through March 31, 2022 from a suburban, county-based EMS service in Texas (USA). The data review was a quality improvement initiative related to a previously implemented EMS protocol for allowing for paramedic-initiated surgical airway placement in "can't oxygenate, can't ventilate" situations. The sponsoring EMS agency currently employs approximately 300 paramedics supported by 13 first responder organizations, which includes an additional 1,100 emergency medical technicians. The service area covers 1,100 square miles and, in 2023, responded to more than 80,000 dispatches. The Baylor College of Medicine Institutional Review Board (Houston, Texas USA) approved this study with a waiver of informed consent (H-51505).

The "scalpel, finger, bougie" technique is a well-known and effective approach to surgical cricothyrotomy[7] and was exclusively taught and used throughout the study period (Figure 1). Supraglottic airway (SGA) devices, paralytic-assisted intubation, and standard Basic Life Support airway management options were available during the study period. The specific advanced airway management progression was left to paramedic discretion.

During protocol implementation—and throughout the study period—the paramedic staff completed regular, annual training sessions on surgical airway indications, anatomy, and landmark-guided placement. These included simulation sessions, tissue models, and cadaveric training and were reinforced through internally produced videos, podcasts, and other supplemental materials. Surgical cricothyrotomy understanding was demonstrated via recurring written, psychomotor, and scenario evaluations. Lastly, all surgical airway cases were reviewed by medical direction as soon as possible following the incidents.

Patients included in the chart review encompassed all those who had received attempted surgical cricothyrotomy during the study period. Data were abstracted from the EMS ePCR by a two-person expert review panel (one physician and one paramedic) with a standardized data collection form. The study variables recorded were demographic information and call type with dispatch determinants. Additionally, data regarding comprehensive airway management decisions and timing were also collected. Surgical airway placement confirmation was determined using continuous waveform end-tidal capnography as interpreted by the lead paramedic caring for the

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	All Subjects (n = 31)		Trauma (n = 13)		Medical (n = 18)	
Median Age in Years (IQR))	58 (IQR = 40-74)		50 (IQR = 28-68)		59 (IQR = 44-74)	
Sex						
Male	22	71%	11	85%	11	61%
Female	9	29%	2	15%	7	29%
Cardiac Arrest	26	84%	9	69%	17	94%
On EMS Arrival	21	68%	5	38%	16	89%
After EMS Arrival	5	16%	4	31%	1	6%
Termination of Resuscitation	15	48%	5	38%	10	56%
Airway Attempts						
Median ETI Attempts	1	(IQR = 0-2)	0	(IQR = 0-1)	1	(IQR = 0-2)
Supraglottic Attempted	12	39%	3	23%	9	50%
ETI Attempted	18	58%	5	38%	13	72%
More than One ETI Attempt	9	29%	2	15%	7	39%
Surgical Airway						
Time to SC (minutes)	17	(IQR = 11-24)	12	(IQR = 9-19)	19	(IQR = 14-33)
$ETCO_2$ Confirmation	29	94%	12	92%	17	94%
Time to SC w/o ETI (minutes)	14.5	(IQR = 6-19)	11	(IQR = 5-18)	18	(IQR = 13-19)
Time to SC w/ ETI (minutes)	19	(IQR = 14-33)	17	(IQR = 9-19)	22	(IQR = 15-35)

Table 1. Description of Patients Evaluated in the Study
Abbreviations: ETI, endotracheal intubation; EMS, Emergency Medical Services; SC, surgical cricothyrotomy; $ETCO_2$, end-tidal carbon dioxide.

patient or the presence of end-tidal carbon dioxide ($ETCO_2$) values documented after surgical airway.

Stata 18 (StataCorp; College Station, Texas USA) was used to complete the analyses. Descriptive statistics were calculated with median (IQR) presented for continuous variables and frequency (%) presented for categorical variables.

Results

A total of 31 patients underwent prehospital surgical cricothyrotomy during the study period, of which 22 (71%) patients were male and nine (29%) were female. During this period, there were 409,125 total patient transports for a surgical cricothyrotomy rate of 0.008%. The median age of all subjects was 58 (IQR = 40-74) years. Of the patients studied, 42% (13/31) underwent surgical cricothyrotomy in the setting of trauma, while 58% (18/31) underwent surgical cricothyrotomy for medical emergencies. Surgical cricothyrotomy was successful in 94% (29/31) of cases, with 92% success in cases of trauma (12/13) versus 94% success in medical patients (17/18), as confirmed by continuous waveform end-tidal capnography. A summary of individual patient care details is presented in Table 1.

In addition to procedural success, time to surgical cricothyrotomy from EMS contact was also measured. The median time to surgical cricothyrotomy from patient contact time was 17 minutes (IQR = 11-24). In trauma patients, the median time to surgical cricothyrotomy was 12 minutes (IQR = 9-19) versus 19 minutes (IQR = 14-33) in medical patients. Endotracheal intubation was attempted in 55% (17/31) of cases before subsequent surgical cricothyrotomy, with 29% (9/31) of patients undergoing more than one intubation attempt. For patients with more than one intubation attempt, the median time to surgical cricothyrotomy was 33 minutes (IQR = 23-36) compared to 14.5 minutes (IQR = 6-19) in patients without a preceding intubation attempt.

Of all patients included in the study, 84% (26/31) suffered cardiac arrest, with 81% of those patients (21/26) in cardiac arrest on EMS arrival; EMS witnessed the arrest in 19% (5/26) of patients who suffered cardiac arrest. Termination of resuscitation in the field was performed in 54% of cases (14/26), with the remaining patients being transported to appropriate destination facilities. The indications for surgical cricothyrotomy varied, with the most common and over one-half of the overall indications being trismus (8/31) and facial trauma (8/31); Figure 1.

Discussion

Prehospital surgical cricothyrotomy is often performed under highly stressful and austere conditions. While some studies have demonstrated the clinician's ability to perform the skill under stressful simulated scenarios, it remains associated with significant delay, given the cognitive effort involved.[8] These data reported that most paramedics attempted alternative airway management strategies before surgical cricothyrotomy, including ETI and SGA placement, as over one-half of patients underwent at least one attempt at ETI. As anticipated, increasing attempts at ETI were associated with significant delays in performing surgical cricothyrotomy, which stresses the importance of training and early identification of "can't oxygenate, can't ventilate" scenarios. Prevention of prehospital delays in performing surgical cricothyrotomy and consideration of faster and less-invasive approaches to secure the airway, including supraglottic devices as opposed to prolonged ETI, should be a paramedic education focus.

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Murphy, et al reported that increased prehospital intubation attempts were associated with worsened neurological outcomes.[9] Given delays associated with intubation attempts, in patients who present with "can't oxygenate, can't ventilate scenarios," there may be a role for rapid attempt of airway control via SGA before proceeding with surgical cricothyrotomy with elimination of ETI attempts.

Surgical cricothyrotomy is often characterized as a "high acuity, low occurrence (HALO)" procedure, often being performed on the most critically ill patients. One study conducted in a helicopter EMS (HEMS) service retrospectively reviewed 22,434 transports and identified only 13 (0.057%) patients who underwent the procedure.[4] The rare nature of this procedure was confirmed by the current study, in which only 31 surgical airway patients were identified out of just over 400,000 transports (0.008%), which is seven-times less common than in the HEMS setting. This difference is likely explained by the increased patient acuity level seen in the HEMS as opposed to the ground-based EMS environment. While the current study found a low incidence in a suburban EMS system, others found even lower surgical airway usage rates in rural systems, with one study reporting just four instances across 11 agencies over ten years.[10] While the procedure remains essential in the EMS airway management toolkit, there are valid concerns for skill degradation and lack of proficiency when a surgical airway is indicated.

Marcolini, et al investigated prehospital surgical cricothyrotomy and identified that 59% (36/61) were in cardiac arrest at the time of surgical cricothyrotomy, with only 13% (8/61) surviving to hospital discharge.[6] Notably, only two out of 61 patients had minimal to no neurological impairment at discharge, with the remaining patients having moderate to severe neurological impairment. The current study reported a higher rate of cardiac arrest than other studies. However, this finding illustrates the overall significant acuity of patients undergoing prehospital surgical airway placement. Furthermore, the procedure is associated with considerable morbidity, with the most common complications being hemorrhage, injury to cartilaginous structures, and failure to obtain an airway.[11,12]

Despite the rarity of the procedure, this study suggests that paramedics can perform prehospital surgical cricothyrotomy with a high degree of success in a ground-based 9-1-1 system. Surgical cricothyrotomy success, indications, and relationship to other airway attempts were also evaluated, such as ETI. There are varying reported rates of success from surgical airway depending on the type of EMS system, ranging from 82%-100%.[4,5,13] The current data further suggest that surgical cricothyrotomy can be performed with comparable success rates (94% in this study) in a ground-based 9-1-1 EMS system without online medical direction. Prehospital surgical cricothyrotomy remains a skill utilized primarily in patients who are critically ill, and the critical nature of this patient population likely confounds the overall outcomes of the procedure.

Limitations

The study's limitations included the retrospective review of patient care records and small sample size. Given the rare occurrence of surgical cricothyrotomy in the field, larger data sets with more enrolled patients will be required to ascertain the success rate of prehospital surgical cricothyrotomy and identify areas for improvement.

Conclusion

Prehospital surgical airway placement can be performed by paramedics with a high degree of success (94%) in a ground-based 9-1-1 EMS system that provides adequate training and ensures proficiency in the procedure. Identification of the need for surgical cricothyrotomy should be determined as soon as possible to allow for rapid securement of the airway and to ensure adequate oxygenation and ventilation.

Author Contributions

The authors have made substantial contributions to the conception and design of the study (CP, AL, MW, MG, KRK, and RD), acquisition of data (CP, AL, and MW), analysis and interpretation of data (CP, AL, and MW), and drafting/revising it critically for important intellectual content (CP, RD, AL, and MW). All authors have read and approved the submitted manuscript, and the manuscript has not been submitted elsewhere nor published elsewhere in whole or in part, except as an abstract. The corresponding author takes responsibility for the paper as a whole (CP).

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