Laryngoscope Investigative Otolaryngology

Best Practices for Emergency Surgical Airway: A Systematic Review

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Objective: In the case of an emergency surgical airway, current guidelines state that surgical cricothyrotomy is preferable to tracheotomy. However, complications associated with emergency cricothyrotomy may be more frequent and severe. We systematically reviewed the English literature on emergency surgical airway to elicit best practices.

Methods: PubMed, Embase, MEDLINE, and the Cochrane Library were searched from inception to January 2019 for studies reporting emergency cricothyrotomy and tracheotomy outcomes. All English-language retrospective analyses, systematic reviews, and meta-analyses were included. Case reports were excluded, as well as studies with pediatric, nonhuman, or nonliving subjects.

Results: We identified 783 articles, and 20 met inclusion criteria. Thirteen evaluated emergency cricothyrotomy and included 1,219 patients (mean age = 39.8 years); 4 evaluated emergency tracheotomy and included 342 patients (mean age = 46.0 years); 2 evaluated both procedures. The rate of complications with both cricothyrotomy and tracheotomy was comparable. The most frequent early complications were failure to obtain an airway (1.6%) and hemorrhage (5.6%) for cricothyrotomy and tracheotomy, respectively. Airway stenosis was the most common long-term complication, occurring at low rates in both procedures (0.22–7.0%).

Conclusions: Complications associated with emergency cricothyrotomy may not occur as frequently as presumed. Tracheotomy is an effective means of securing the airway in an emergent setting, with similar risk for intraoperative and postoperative complications compared to cricothyrotomy. Ultimately, management should depend on clinician experience and patient characteristics.

Key Words: Tracheotomy, retrospective studies, emergencies, postoperative complications.

Level of Evidence: IV

INTRODUCTION

Early establishment of a safe airway is a basic tenet of trauma care. The American Society of Anesthesiologists defines the difficult airway as "the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both," and recommends a surgical airway should be obtained.[1] The most recent Advanced Trauma Life Support (ATLS) manual specifies that "a surgical cricothyrotomy is preferable to a tracheotomy for most patients requiring an emergency surgical airway," based on the perception that the cricothyrotomy is easier and safer to perform, associated with less bleeding, and requires less surgical time.[2] Traditional surgical teaching has also dictated that a cricothyrotomy should be converted to a tracheotomy within 72 hours, based on presumed association with subglottic stenosis.[3,4]

However, emerging data on the outcome and morbidity of cricothyrotomy compared to tracheotomy do not always support these assumptions.[5–8] The most common complications of cricothyrotomy include incorrect execution resulting in injury of cartilaginous structures with failure to obtain an airway, occurring at a rate of 0–31.6%.[8] Serious complications after tracheotomy occur at a rate of 0–5%, and include damage to nearby structures, hemorrhage, and pneumothorax.[9] Furthermore, conversion from cricothyrotomy to tracheotomy tube may be associated with underappreciated risk, associated with increased length of hospital stay, neurologic impairment, and death.[6] On the other hand, cricothyrotomy is the procedure of choice for nonsurgical clinicians, in contrast to emergency tracheotomies. It is uncommon for an otolaryngologist to be the first responder in airway emergencies. Instead, otolaryngologists are often consulted for conversion of cricothyrotomy to tracheotomy, or for tracheotomy management. Thereby, otolaryngologists are in the position to observe short- and long-term complications associated with both procedures. We systematically examined the current evidence and recommendation regarding the most appropriate surgical airway procedure in the "cannot ventilate–cannot oxygenate" scenario, in terms of intraoperative and postoperative complication rates. The purpose of this study was to systematically review the current literature on emergency surgical airway to better elicit best practices and guide management for the practicing otolaryngologist. We hypothesized that tracheotomy was safer and more effective than cricothyrotomy in an emergency surgical airway.

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Funding and Conflict of Interest: None declared.

Meeting Information: American Bronchoesophageal Association's 2019 Spring Meeting at COSM, Austin, Texas, May 1–3, 2019.

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DOI: 10.1002/lio2.314

METHODS

We adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) recommendations in formulating this review.[10] We addressed the following PICOS (Patient, Population, or Problem, Intervention, Comparison, Outcomes and Setting) question: "Among adults requiring an emergency surgical airway, what intervention, cricothyrotomy versus tracheotomy, is associated with the fewest early and long-term complications?"

Study Identification

PubMed, Embase, MEDLINE, and the Cochrane Library databases were searched from inception through January 2019. All English-language retrospective analyses, systematic reviews, and meta-analyses were included. Case reports were excluded, as well as studies with pediatric, nonhuman, or nonliving subjects. We also excluded studies of surgical airways performed by nonphysicians, those performed in nonemergency settings, as well as those focused on surgical airway technology and training techniques without mention of intra- or postoperative complications. Articles evaluating both surgical and percutaneous tracheotomy were included. The terms "emergency tracheostomy" or "emergency tracheotomy" or "emergency cricothyrotomy" or "emergency cricothyroidotomy" were used to identify articles. A list of titles was generated, and duplicate references were then removed. Title and abstract reviews were conducted to identify articles for possible inclusion. Full articles were then obtained from this list and reviewed independently. In addition, further articles were retrieved by reviewing the references of included studies.

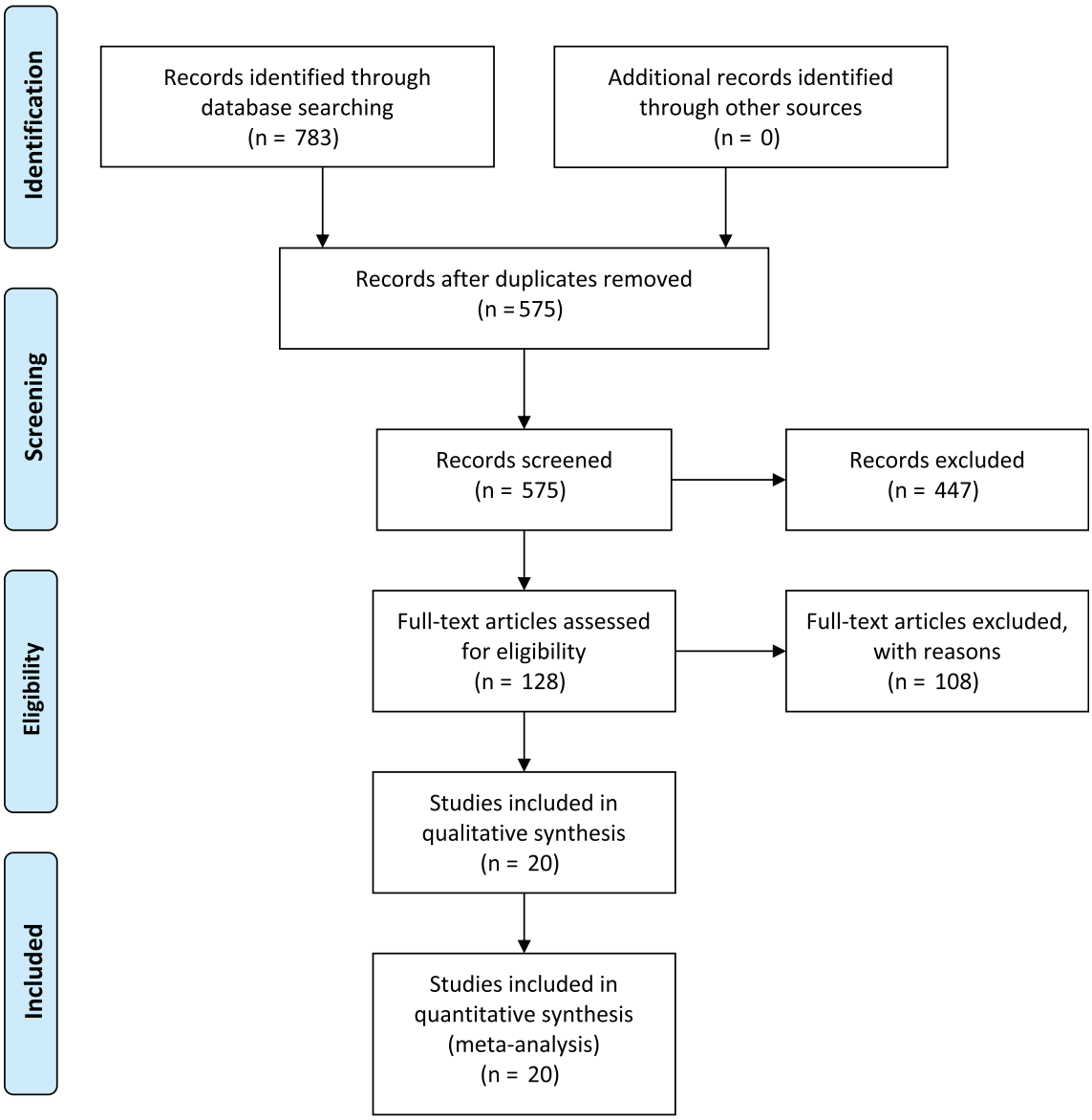

Fig. 1. Flow diagram of the literature search based on the PRISMA recommendations. PRISMA = preferred reporting items for systematic reviews and meta-analysis.

Data Extraction

Data extracted from each manuscript included study setting, type of study, type of surgical airway, surgical service performing the procedure, complication rate, and complication type. The number of patients undergoing conversion to tracheotomy was also recorded for patients undergoing cricothyrotomy. Studies were grouped into those that evaluated cricothyrotomy or tracheotomy. All studies that described cricothyrotomy as the only treatment or the initial treatment were included in the review of cricothyrotomy outcomes, while all studies that reported tracheotomy treatment were evaluated in the review of tracheotomy outcomes. Studies that evaluated both treatments were included in both analyses, with patients separated into the appropriate category.

For the purposes of this study, emergency surgical airway was defined as a procedure performed to secure the airway in patients with upper airway obstruction who could not be managed with intubation or mechanical ventilation (eg, bilevel positive airway pressure (BiPAP)). The primary outcome was defined as any complication listed in the studies reviewed, and further subclassified as either an early or late complication. Early complications included those that occurred perioperatively or hours after the surgery, while late complications included those that manifested days, weeks, or months after surgery. The rate of complications was recorded, as well as the number of patients experiencing each complication type. Percutaneous and surgical tracheotomy were analyzed together in the review of tracheotomy outcomes.

Descriptive statistics were calculated in the standard fashion. For the purposes of this study, the incidence of complications was calculated as the number of complications per number of emergency procedures performed per study. Statistical analysis was performed using Excel.

RESULTS

Overall, 783 studies were identified; 208 duplicates were removed, leaving 575 studies for title review (Fig. 1). Of these, 447 were removed. Abstract review was completed on the remaining 128 studies, and an additional 94 were excluded for failure to meet inclusion criteria (ie, nonemergent surgery or inclusion of non-human subjects). Full text article review was performed for the remaining 34 articles. Fourteen were further excluded because they were focused on surgical airway technology and training techniques without mention of complications, or concentrated on treatment of late sequelae of airway surgery. The remaining 20 articles were included in the qualitative and quantitative analysis. Of these, 13 evaluated outcomes after initial or sole treatment with emergency cricothyrotomy,[4,5,7,10–20] while four discussed outcomes related to emergency tracheotomy.[21–24] The remaining two studies reported outcomes for both procedures.[6,25]

Emergency Cricothyrotomy

The 13 studies that evaluated emergency cricothyrotomy as the sole or initial treatment were included in this review, along with data from patients that underwent cricothyrotomy in the two studies reporting outcomes for both treatments (Table I). The included studies were published between 1979 and 2016. Evidence ranged from IV to III, and all were retrospective. There were 1,219 patients treated with emergency cricothyrotomy. The mean age was 39.8 years, and a majority of patients were male. The most common indication for the procedure was a traumatic event. The cricothyrotomy was performed in a hospital setting in all but one study,[16] which evaluated the procedure in a

TABLE I.
Studies Evaluating Emergency Cricothyrotomy.

Source	Level of Evidence	Procedures per Study	Mean Age (yr)	Complications		Conversion to Tracheotomy (n)
				Early	Late	
Macêdo et al[8]	III	316	41	14.8%	3.2%	142
Dillon et al[7]	IV	10	44.9	10.0%	U	9
King et al[5]	IV	47	50	12.7%	10.6%	24
Graham et al[11]	IV	95	36	U	3.15%	23
Talving et al[6]	III	368	U	U	1.1%	15
Bair et al[12]	IV	28	U	32.1%	U	U
Wright et al[13]	IV	46	32	0%	15.2%	8
Isaacs et al[14]	IV	27	U	U	51.9%	U
Gillespie et al[25]	IV	23	50	26.1%	8.7%	10
Isaacs et al[15]	IV	65	48	16.9%	4.6%	U
Leibovici et al[16]	IV	29	29.7	13.8%	10.3%	U
Hawkins et al[17]	IV	58	U	5.2%	0%	19
Salvino et al[18]	IV	20	35	0%	20.0%	3
DeLaurier et al[19]	IV	34	U	5.9%	20.6%	9
McGill et al[20]	IV	38	41	23.7%	7.9%	U
Boyd et al[4]	IV	15	67	13.3%	53.3%	U

All of the studies were retrospective reviews.
U = unreported.

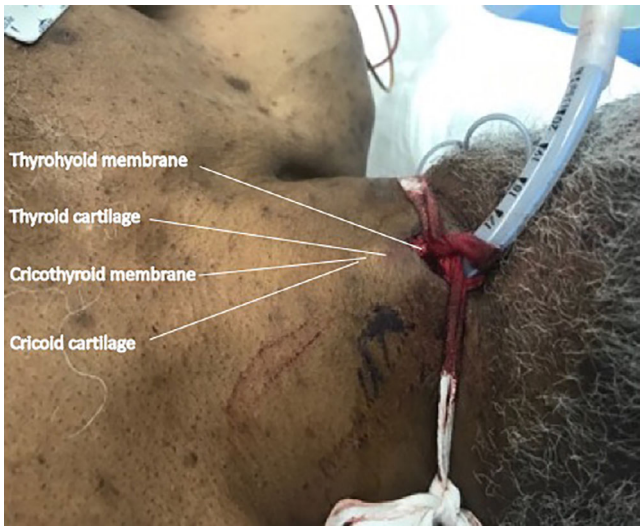

Fig. 2. Cricothyrotomy attempt in thyrohyoid space. This patient underwent accidental cannulation of the thyrohyoid membrane, rather than cricothyroid membrane, during a cricothyrotomy attempt.

prehospital setting. In all studies, physicians performed the procedure. Most were executed by general or trauma surgeons, while others were completed by emergency physicians, anesthesiologists, or otolaryngologists.[7,16,25] Cricothyrotomy was not uniformly converted to tracheotomy in all series.

Among the 13 studies reporting early complications, the mean rate of early complications was 13.4%. The most frequent early complication was incorrect execution of the technique (Figs. 2 and 3), resulting in injury of cartilaginous structures (1.6%) and failure to obtain an airway (1.6%) (Table II).[5,7,8,12–15,25] Less common early complications included hemorrhage, execution time, pneumothorax, and subcutaneous emphysema.[5,12,13] Late complications occurred at a mean rate of 13.6%. Airway stenosis was the most common long-term complication, occurring at a low rate (1.1%) regardless of whether conversion to tracheotomy was performed.[8,11,13,25] Other long-term complications included peristomal bleeding, dysphonia, aspiration pneumonia, peristomal infection, granulation tissue, dysphagia, and air leak.[8,18] Follow-up time was not always specified in the literature, however, occurred at a minimum of 6 months.

TABLE II.
Prevalence of Complication Types After Cricothyrotomy.

	Number of Patients With Complication	Rate of Complication (n = 1,219)
Early complications		
Injury to cartilaginous structures	19	1.6%
Failure to obtain an airway	19	1.6%
Hemorrhage	9	0.7%
Execution time	8	0.7%
Pneumothorax	2	0.2%
Subcutaneous emphysema	1	0.1%
Late complications		
Airway stenosis	14	1.1%
Peristomal bleeding	11	0.9%
Dysphonia	10	0.8%
Aspiration pneumonia	6	0.5%
Peristomal infection	5	0.4%
Granulation tissue	5	0.4%
Dysphagia	4	0.3%
Air leak	1	

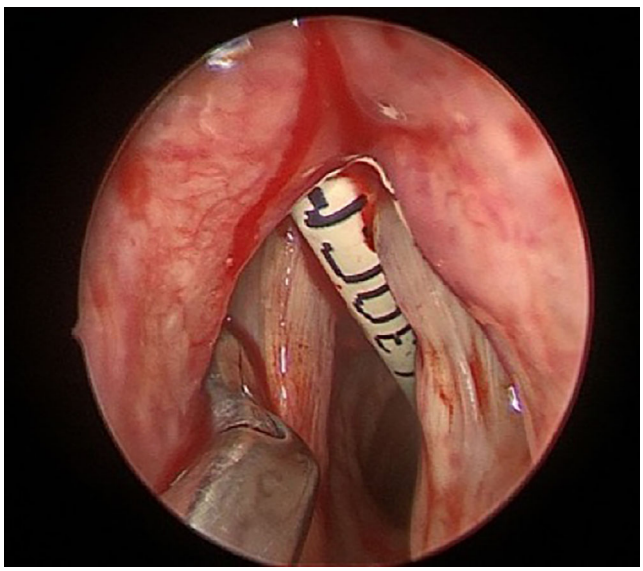

Fig. 3. Endoscopic view of the endotracheal tube entering through the thyrohyoid space during a cricothyrotomy attempt.

Emergency Tracheotomy

The four studies that evaluated emergency tracheotomy were included in this review, along with data on tracheotomy patients from the two studies that addressed both treatments (Table III). These studies were published between 1999 and 2015, with evidence ranging from IV to II. All but one[21] were retrospective. A total of 342 patients underwent tracheotomy, with a mean age of 46 years. Similar to cricothyrotomy, the procedure was most commonly performed in the setting of trauma. All tracheotomies were performed in a hospital facility by a physician. Unlike cricothyrotomy, emergency tracheotomies were more commonly performed by otolaryngologists than general surgeons.[7,8,25]

For patients undergoing tracheotomy, the mean rate of early complications was 15.6%. The most common early complication was hemorrhage (5.6%),[22–25] while subcutaneous emphysema, pneumothorax, injury to cartilaginous structures, and operating room fire were less common.[7,21,23,24] Of note, there were no instances of failure to

TABLE III.
Studies Evaluating Emergency Tracheotomy.

Source	Level of Evidence	Procedures per Study	Mean Age (yr)	Rate of Complications	
				Early	Late
Panajaroen et al[21]	II	14	65	35.7%	0%
Dillon et al[6]	IV	24	44.9	0%	U
Muhammad et al[22]	IV	50	32	16.0%	40.0%
Gilyoma et al[23]	IV	172	38.3	1.2%	22.7%
Goldenberg et al[24]	IV	68	U	19.1%	48.5%
Gillespie et al[25]	IV	14	50	21.4%	14.3%

U = unreported.

TABLE IV.
Prevalence of Complication Types After Tracheotomy.

	Number of Patients With Complication	Rate of Complication (n = 342)
Early complications		
Hemorrhage	19	5.6%
Pneumothorax	5	1.5%
Subcutaneous emphysema	5	1.5%
Injury to cartilaginous structures	1	0.3%
Operating room fire	1	0.3%
Failure to obtain an airway	0	0.0%
Late complications		
Peristomal infection	26	7.6%
Airway stenosis	24	7.0%
Granulation tissue	17	5.0%
Accidental decannulation	14	4.1%
Aspiration pneumonia	6	1.8%
Tracheocutaneous fistula	6	1.8%
Tracheal tube obstruction	4	1.2%
Tracheoesophageal fistula	1	0.3%

obtain an airway (Table IV).[7,21–25] Late complications were more common, occurring at a mean rate of 25.1%. The most common late complications were peristomal infection (7.6%) and airway stenosis (7.0%).[23,24] Granulation tissue, accidental decannulation, aspiration pneumonia, tracheocutaneous fistula, tracheal tube obstruction, and tracheoesophageal fistula were less common.[21–25] Follow-up time was not always specified.

DISCUSSION

The most frequently cited long-term morbidity associated with cricothyrotomy is the development of subglottic stenosis; however, the literature on the incidence and management of this complication is now almost 100 years old. In a 1921 publication on operative airway techniques, Jackson reported on a series of 170 cases of subglottic stenosis after the surgical creation of airways, 158 (92.9%) of which had undergone cricothyrotomy.[3] He concluded that the use of cricothyrotomy was associated with a prohibitive risk of stenosis compared with tracheotomy. Surgical dogma subsequently developed advising against elective cricothyrotomy and supporting the practice of early conversion to tracheotomy after emergent cases. This practice continued unquestioned for the next 50 years.[26] Brantigan and Grow[27] were among the first to challenge this dogma in 1976, reporting on the use of elective cricothyrotomy in 655 patients without a single incidence of subglottic stenosis. Since then, multiple series have followed reporting similarly low rates of subglottic stenosis after cricothyrotomy.

The rate of airway stenosis reported here is similar to previously published results, occurring at rates as low as 0–5.0% during follow-up periods ranging from 2 to 60 months.[6] Younger age and previous endotracheal intubation may be associated with increased rates of stenosis for cricothyrotomy patients, according to two large case series assessing elective cricothyrotomy in the intensive care unit.[28,29] However, Francois et al[30] later demonstrated no difference in the incidence and severity of over 40 complications during a 6-month follow-up period for patients undergoing elective cricothyrotomy or tracheotomy. Our study corroborates these findings and provides further evidence regarding airway stenosis after emergency cricothyrotomy and tracheotomy.

Variability in the success rates for cricothyrotomy may be influenced by the experience of the professional.[6–8,25] Multiple studies report higher rates of morbidity and mortality with prehospital procedures conducted by nonphysician personnel.[5,8,12] Furthermore, Leibovici et al[16] found variations in cricothyrotomy success among physicians. All cricothyrotomies performed by surgeons, anesthesiologists, and intensive care physicians were successful, whereas failures were associated with nonprocedural physicians; difficulties in performing the procedure were more commonly noted by nonsurgical physicians.[16] In cases of incorrect execution of surgical airway leading to structural damage, the most common site of misplacement is superior to the thyroid cartilage through the thyrohyoid membrane (Figs. 2 and 3).[20] Indeed, locating the cricothyroid membrane (CTM) can be difficult even in the hands of experienced clinicians: in

one prospective observational study, the overall success rate for correctly identifying the CTM was less than 50%, with no differences between anesthesia providers, trauma surgeons, or years of experience.[31,32] As such, reports such as Dilon et al demonstrate similar success rates between nonprocedural and surgical medical teams, demonstrating that provider experience may have no bearing on success rates.[7] Regardless, there is a role for adequate training in cricothyrotomy for both surgical and nonprocedural specialties.

Our review suggests that a higher number of cricothyrotomy procedures are reported in the literature. However, when looking at studies that directly compare cricothyrotomy to tracheotomy in the emergent setting, the ratio is preferentially toward tracheotomy, in contrast to ATLS guidelines.[7,25] Furthermore, cricothyrotomy and tracheotomy were found to be equally efficacious in the emergency situation.[25] In our study, tracheotomy was associated with a 100% success rate, while failure to secure the airway was the most common complication associated with cricothyrotomy. However, emergency tracheotomy was also associated with relatively more frequent overall complications. This data suggest that tracheotomy can serve as a safe and effective means of securing the airway in an emergent setting, if applied by a trained provider in the appropriate setting.[7,25]

This study has a number of limitations. The limited studies available were overall of low quality, with no randomized studies and few prospective analyses. Most of the included studies were large case series or retrospective reviews, and thus contribute level 4 evidence. Controlled, prospective studies with larger sample size are necessary to elucidate best practices. In addition, data were heterogeneous in terms of duration of observation and reporting of complications. There remains no clear evidence regarding the need for conversion of cricothyrotomy or the timing of conversion. Future studies would require a prospectively collected database with long-term follow-up. Finally, there were fewer reports on emergency tracheotomy compared to cricothyrotomy, which may have skewed results.

Current anesthesia guidelines state that surgical cricothyrotomy is preferable to tracheotomy in the setting of an emergency airway; however, our review suggests that the complications and morbidity associated with cricothyrotomy may be comparable to that of tracheotomy. In addition, tracheotomy may serve as a viable surgical airway procedure in appropriate circumstances (such as those involving an otolaryngologist). We hypothesized that tracheotomy would be safer and more effective than cricothyrotomy in an emergency surgical airway. Our data demonstrated tracheotomy was 100% effective, with no instances of failure to obtain an airway reported in the 342 tracheotomy patients. However, cricothyrotomy was also effective, with a failure rate of only 1.6%. Furthermore, the rate of complications with cricothyrotomy and tracheotomy were comparable. These data suggest that both emergency cricothyrotomy and tracheotomy are safe and effective means of securing the airway in an emergent setting, with similar risk for early and late complications. While the need for conversion from cricothyrotomy to tracheotomy is assumed, further evidence is needed to determine timing and necessity.

CONCLUSION

Complications associated with emergency cricothyrotomy may not occur as frequently as presumed. Tracheotomy or cricothyrotomy are both effective means of securing the airway in an emergent setting, with similar risk for complications. Ultimately, management should depend on clinician experience (surgeon vs. nonsurgeon) and patient characteristics.

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