Complications of cricothyroidotomy versus tracheostomy in emergency surgical airway management: A systematic review

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Fabricio Batistella Zasso
University of Toronto

Kong Eric You-Ten
University of Toronto

Michelle Ryu
University of Toronto

Khrystyna Losyeva
University of Toronto

Jaya Tanwani
University of Toronto

Naveed Siddiqui
University of Toronto

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Abstract
Background Airway guidelines recommend an emergency surgical airway as a potential life-saving treatment in a “Can’t Intubate, Can’t Oxygenate” (CICO) situation. Surgical airways can be achieved either through a cricothyroidotomy or tracheostomy. The current literature has limited data regarding complications of cricothyroidotomy and tracheostomy in an emergency situation, such as in a CICO scenario. The objective of this systematic review is to analyze complications following cricothyroidotomy and tracheostomy in this situation.

Methods This synthesis of literature was exempt from ethics approval. Eight databases were searched from inception to October 2018, using a comprehensive search strategy. Studies were included if they were randomized controlled trials or observational studies reporting complications following emergency surgical airway. Complications were classified as minor (evolving to spontaneous remission or not requiring intervention or not persisting chronically), major (requiring intervention or persisting chronically), early (from the start of the procedure up to seven days) and late (beyond seven days of the procedure).

Results We retrieved 2,659 references from our search criteria. Following the removal of duplicates, title and abstract review, 33 articles were selected for full-text reading. 21 articles were finally included in the systematic review. We found no differences in minor, major or early complications between the two techniques. However, late complications were significantly more frequent in the tracheostomy group [OR (95% CI) 0.21 (0.20-0.22), p<0.0001].

Conclusions Our results demonstrate that cricothyroidotomies performed in emergent situations resulted in fewer late complications than tracheostomies. This may be indicative that cricothyroidotomy is safer than tracheostomy as an emergency surgical airway. This finding supports the recommendations from the latest Difficult Airway Society (DAS) guidelines regarding using cricothyroidotomy as the technique of choice for emergency surgical airway in a CICO situation.

Background
Airway management is an essential element of several medical specialties, including anesthesia, intensive care and emergency medicine. The vast majority of airways are managed uneventfully
through basic and advanced use of available techniques and equipment. Failed airway management can lead to a “Can't Intubate Can't Oxygenate” (CICO) situation, which is defined by failed attempts to deliver oxygen to the patient by face-mask ventilation, tracheal intubation, and placement of a supraglottic airway [1–3]. CICO is a life-threatening situation which can result in significant morbidity and mortality leading to brain hypoxia or death, unless there is rapid resolution [4].

Airway management guidelines have been systematically developed to assist physicians in making decisions. An unanticipated difficult airway can lead to a CICO crisis. When this feared situation happens, airway guidelines recommend that an emergency surgical airway should be performed either through a cricothyroidotomy or tracheostomy [3, 5, 6].

Historically, the guidelines progressed over the years on which technique should be used. In 1993, the first American Society of Anesthesiologists (ASA) guideline recommended that tracheostomy should be the surgical airway approach [7]. During the next decades, guidelines suggested that either cricothyroidotomy or tracheostomy could be performed [5, 6, 8, 9]. The Difficult Airway Society (DAS) published their last guidelines recommending that cricothyroidotomy should be preferentially performed [3]. This recommendation was based on expert opinions, and it was supported by the concept that a surgical airway should be a fast and simple procedure done with readily available equipment. This approach would increase the chances of success and decrease negative consequences for the patient. However, the DAS guidelines authors recognized that there is a lack of evidence in the literature if one technique is superior to another [3].

Despite the recommendation towards cricothyroidotomy, the definitive technique for an emergency surgical airway is still debatable. The ideal approach should result in a high success rate and a low complication rate [10]. There are a considerable amount of studies analyzing the complications of elective and urgent surgical airways. However, the current literature has limited data regarding complications of cricothyroidotomy and tracheostomy in an emergency situation, such as in a CICO scenario. Given the limited evidence supporting the preferred emergency surgical airway technique in the literature, we conducted a systematic review in order to compare the rate of complications in patients requiring an emergency cricothyroidotomy or tracheostomy. The goal of this systematic
review was to compare the rates of early, late, minor and major complications between both the techniques.

**Methods**

This systematic review was exempt from ethics approval. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to conduct the systematic review of the literature [11].

**Study Identification**

The following electronic bibliographic databases were searched from inception to October 2018 using a comprehensive search strategy developed by an information specialist: (1) Ovid MEDLINE, (2) Ovid Embase, (3) Ovid EBM Reviews - Cochrane Central Register of Controlled Trials, (4) PubMed, and (5) EBSCO CINAHL Complete. We also searched the U.S. ClinicalTrials.gov, the World Health Organization's International Clinical Trials Registry Platform (ICTRP), and the International Standard Randomised Controlled Trial Number Registry (ISRCTNR) for all registered clinical trials and randomized controlled trials (RCTs). A validated search filter for RCTs from the Cochrane Handbook for Systematic Reviews of Interventions [12] and observational studies of surgical interventions search filter by Fraser et al. [13] were used to screen Ovid Medline, Ovid Embase and PubMed. A pre-tested search filter for observational studies and RCTs was adapted from the Scottish Intercollegiate Guidelines Network [14] to screen EBSCO CINAHL Complete. Duplicate records were removed in EndNote X8 citation management software.

The search strategy was structured according to the 2015 Peer-Reviewed Electronic Search Strategies (PRESS) Guidelines. We included Medical Subject Headings (MeSH), Entree terms, and free text terms related to 'emergency medicine', 'critical care', 'cricothyroidotomy', and 'tracheostomy' and 'postoperative complications'. No restrictions were applied to publication language or publication year. The search was complemented by hand-searching references of relevant articles, pre-register repositories (i.e. PROSPERO, Open Science Framework), and related organization websites.

**Eligibility Criteria**

Studies were considered eligible for inclusion if they were randomized controlled trials or observational studies reporting complications following emergency cricothyroidotomy or
tracheostomy. Additionally, the studies were only included if they provided sufficient information to allow the reviewers to classify the type of complications. Studies were excluded if less than four patients were involved (considered case reports), complications for both techniques were reported together, complications for emergent and urgent procedures were not separated, or included patients below ten years old. As this systematic review is focused on clinical practice, animal, cadaver, and mannequin studies were excluded.

Data Collection and Data Extraction
All article titles were screened. Abstracts of potentially relevant articles were subsequently assessed, and those without relevance were eliminated. Full-text manuscripts of all remaining studies were obtained, read and assessed qualitatively. Disagreements between the authors were resolved by a consensus-based discussion. The risk of bias was assessed using the modified Newcastle-Ottawa Scale (NOS). This scale evaluates the quality of studies through three items (selection, comparability and outcome), resulting in a grade between one and eight. We considered articles with less than four points as high-risk for bias, which was the criteria for exclusion.

Complications were classified as minor (evolving to spontaneous remission or not requiring intervention or not persisting chronically), major (requiring intervention or persisting chronically), early (from the start of the procedure up to seven days) and late (beyond seven days of the procedure). A full description of minor and major complications is described in Appendix 1.

We extracted the following data from the included studies: type of study, follow-up period, sample size, number of minor complications, number of major complications, number of early complications, sample size for late complications and number of late complications. We gathered each type of complications in two groups: CRICO (cricothyroidotomy) and TRACH (tracheostomy). Not all articles listed a follow-up period, which resulted in no late complications being reported for those studies. In the ones that did, several patients were lost due to death or failure to follow-up, ultimately making the sample size for late complications smaller from the sample size for early complications.

Statistical Analysis
We compared minor, major, early and late complications between cricothyroidotomy and
tracheostomy groups using the chi-square test. Additionally, we reported the pooled risk ratio with 95% confidence intervals using weighted logistic regression to compare the two techniques (the weight was defined as the ratio of the sample size for each study and the total sample size of all studies). A difference of \( p < 0.05 \) was considered statistically significant in all analyses.

**Results**

We retrieved 2,659 references from our databases search. After removing duplicates, 2,452 records were obtained. Following the title and abstract review, 33 articles were selected for full-text reading. Twelve articles were excluded as they did not meet the study criteria. Therefore, 21 articles were included in the systematic review. (Fig. 1 - Flow chart).

We found 20 observational studies (19 retrospective and one prospective), and one randomized clinical trial (RCT) describing complications following emergency surgical airway. The number of studies in each category is not additive. Five studies reported only tracheostomy complications [15–19]; 14 studies reported only cricothyroidotomy complications [20–33]; and two studies reported complications from both techniques (RCT included) [34–35].

Two articles from the TRACH group included elective, urgent and emergent procedures [15, 18], but only data from the latter was extracted (Table 1). The remaining articles contained only emergency procedures. In the TRACH group, three articles performed percutaneous [16, 17, 35], and four performed surgical approach [15, 18, 19, 34]. In the CRICO group, only one article used percutaneous [35], one used both (13 procedures under percutaneous and 16 under surgical) [27], and all other used surgical technique [20–26, 28–34].
Table 1
Studies reporting complications after emergency Tracheostomy (TRACH group)

| Author, Yr | Type of study | Type of procedure | Type of technique | Setting; Performer | Follow-up period | Sample size | Complications | Sample size for Late complications |
|------------|---------------|-------------------|-------------------|-------------------|-----------------|-------------|---------------|----------------------------------|
| Waldron et al, 1990 [15] | Retrospective | Elective, urgency, emergency | Surgical | OR; ENT | Minimum 6 months | 38 | Minor 5, Major 4, Early 7, Late 2 | 38 |
| Gillespie et al, 1999 [34] | Retrospective | Emergency | Surgical | Intra-hospital; ENT, general surgeon | Average 23 months | 14 | Minor 1, Major 2, Early 3, Late 0 | 8 |
| Ben-Nun et al, 2004 [16] | Retrospective | Emergency | Percutaneous | ED, ICU; Thoracic surgeons | 1 year | 10 | Minor 1, Major 0, Early 0, Late 1 | 5 |
| Davidsohn et al, 2012 [17] | Retrospective | Emergency | Percutaneous | Intra-hospital; Trauma surgeons | NA | 18 | Minor 0, Major 1, Early 1, Late NA | NA |
| Muhmad et al, 2012 [18] | Prospective cohort | Elective, urgency, emergency | Surgical | OR; ENT | 7 days | 50 | Minor 17, Major 11, Early 28 | NA |
| Beshey et al, 2014 [35] | RCT | Emergency | Percutaneous | ED, ICU; Physician | Maximum 48 hours | 84 | Minor 1, Major 2, Early 3 | NA |
| Fang et al, 2015 [19] | Retrospective | Emergency | Surgical | OR, bedside; ENT | Mean 7.2 weeks | 68 | Minor 10, Major 29, Early 11 | 28, 49 |
| TOTAL | | | | | | 282 | Minor 35, Major 49, Early 53, Late 31 | 100 |

OR Operation Room, ENT Ear, Nose, Throat, ED Emergency Department, NA Data Not Available, ICU Intensive Care Unit, RCT Randomized Clinical Trial

Table 2
Studies reporting complications after emergency Cricothyroidotomy (CRICO group)

| Author, Yr | Type of study | Type of procedure | Type of technique | Setting; Performer | Follow-up period | Sample size | Complication | Sample size for Late complications |
|------------|---------------|-------------------|-------------------|-------------------|-----------------|-------------|--------------|----------------------------------|
| Miklus et al, 1989 [20] | Retrospective | Emergency | Surgical | Pre-hospital; Physicians | NA | 20 | Minor 0, Major 0, Early 0 | 0, 8 |
| Cook et al, 1991 [21] | Retrospective | Emergency | Surgical | Pre-hospital; Nurse/Paramedics | 24 hours | 68 | Minor 0, Major 3, Early 3 | NA, NA |
| Nugent et al, | Retrospective | Emergency | Surgical | Pre-hospital | NA | 55 | Minor 0, Major 11, Early 9 | 2, 15 |
| Study                        | Design | Setting                      | Intervention | Follow-up | ED | Trauma Surgeon (n = 58) | Nurse (n = 8) | Impact | 5 years | 3 | 3 | 0 | 26 |
|------------------------------|--------|------------------------------|--------------|-----------|----|-------------------------|---------------|--------|---------|----|----|----|----|
| Boyle et al., 1993 [23]      | Rетrosp. | Emergency | Pre-hospital Nurses | NA | 69 | 0 | 6 | 6 | NA | NA |
| Hawkins et al., 1995 [24]    | Rетrosp. | Emergency | Pre-hospital Nurses | 5 years | 66 | 0 | 3 | 3 | 0 | 26 |
| Jacobson et al., 1996 [25]   | Rетросп. | Emergency | Pre-hospital Paramedics | 2 to 5 years | 50 | 5 | 6 | 11 | 0 | 19 |
| Isaacs et al., 1997 [26]     | Rетросп. | Emergency | In-hospital ENT Physicians | Average 8 months | 65 | 0 | 13 | 10 | 0 | 26 |
| Leibovic et al., 1997 [27]   | Rетросп. | Emergency | Percutaneous (n = 13), surgical (n = 16) | NA | 29 | 3 | 4 | 7 | 0 | 13 |
| Gillespie et al., 1999 [34]  | Rетросп. | Emergency | In-hospital ENT, general surgeon | Average 23 months | 20 | 2 | 2 | 3 | 1 | 12 |
| Wright et al., 2003 [28]     | Rетросп. | Emergency | Pre-hospital Surgeons | Minimum 6 months | 46 | 0 | 7 | 2 | 5 | 15 |
| Bair et al., 2003 [29]       | Rетросят. | Emergency | Pre-hospital Nurses (n = 22) ED; EM, Trauma Surgeon (n = 28) | NA | 50 | 40 | 15 | 55 | NA | NA |
| McIntosh et al., 2008 [30]   | Rетросп. | Emergency | Pre-hospital Nurse/Paramedics | NA | 17 | 0 | 5 | 5 | NA | NA |
| Warner et al., 2009 [31]     | Prospective Cohort | Emergency | Pre-hospital Paramedics | NA | 11 | 0 | 3 | 3 | NA | NA |
| King et al., 2012 [32]       | Rетросп. | Emergency | Pre-hospital Nurse/Paramedics (n = 6) ED; Surgeons (n = 48) | NA | 54 | 2 | 9 | 11 | NA | NA |
| Beshey et al., RCT [33]      | Emergency | Percutaneous | ED, ICU, Physic | Maximum 48 | 85 | 2 | 12 | 14 | NA | NA |
The location and healthcare providers performing the emergency surgical airways varied between tracheostomies and cricothyroidotomies. All emergency tracheostomies were performed in the hospital, in settings such as Operation Room (OR), Emergency Department (ED), Intensive Care Unit (ICU), and on Inpatient Unit, mainly by surgeons (ENT - Ear, Nose, Throat, thoracic, general, trauma) [15–19, 34, 35]. In contrast, cricothyroidotomies were performed in both pre- and intra-hospital by a variety of healthcare workers including physicians and non-physicians. 50% of the 16 included studies reported only pre-hospital cricothyroidotomies. In six out of eight pre-hospital studies, non-physicians (nurses and/or paramedics) performed the surgical procedures [21–23, 25, 30, 31], whereas physicians executed the pre-hospital interventions in the remaining two studies [20, 27]. Five studies reported only intra-hospital emergency cricothyroidotomies performed by different physicians (ENT, general surgeons, ICU physicians) and in different locations (ER, OR, Inpatient Unit). Three studies described a mix of pre- and intra-hospital cricothyroidotomies [24, 29, 32]; intra-hospital cases were performed in the ED by trauma surgeons or emergency medicine (EM) physicians whereas nurses or paramedics carried out pre-hospital procedures. The third study did not specify location of emergency cricothyroidotomies.

There was a marked heterogeneity in the follow-up periods. In the TRACH group, the period ranged from a maximum 48 hours to 23 months average, and one article did not report it [17]. In the CRICO group, the period varied from 24 hours to 5 years. However, nine articles did not describe it [20, 22, 23, 27, 29–33]. Two articles still reported late complications despite not specifying the follow-up period [22, 27].

In the TRACH group, the number of procedures per study ranged from 10 to 84, with a total sample size of 282, whereas the number of interventions per study varied from 11 to 85, with a total a sample size of 725 in the CRICO group. There were no statistical differences in minor, major and early
complications between TRACH and CRICO groups (Table 3). However, the CRICO group showed less late complications compared to TRACH group [OR (95% CI) 0.21 (0.20–0.22), p < 0.0001] (Table 3).

**Table 3**
Comparison between Cricothyroidotomy (CRICO group) and Tracheostomy (TRACH) complications

| Complications | CRICO | TRACH | p-value 1 | CRICO vs TRACH | p-value 2 |
|---------------|-------|-------|-----------|----------------|-----------|
| Minor<sup>a</sup> | 65/725 (8.97%) | 35/282 (12.41%) | 0.1 | 0.60 (0.08, 4.25) | 0.61 |
| Major<sup>b</sup> | 119/725 (16.41%) | 49/282 (17.38%) | 0.71 | 0.77 (0.16, 3.64) | 0.74 |
| Early<sup>c</sup> | 173/725 (23.86%) | 53/282 (18.79%) | 0.08 | 0.72 (0.14, 3.63) | 0.69 |
| Late<sup>d</sup> | 11/135 (8.15%) | 31/100 (31.00%) | < 0.0001 | 0.21 (0.20, 0.22) | < 0.0001 |

<sup>a</sup>Complications evolving to spontaneous remission or not requiring intervention or not persisting chronically<br>
<sup>b</sup>Complications requiring intervention or persisting chronically<br>
<sup>c</sup>Complications from the start of the procedure up to seven days<br>
<sup>d</sup>Complications beyond seven days of the procedure<br>

A full description of minor and major complications is described in Appendix 1.

Abbreviations: OR = Odds Ratio, CI = Confidence Interval

The reported p-value 1 was based on the comparisons of outcomes between two groups using Chi-squares where the number of events and total sample size were obtained by pooling all the studies.

The reported p-value 2 was based on the weighted logistic regression, where the weight was defined based on the sample size of each study.

**Discussion**

Our systematic review summarized 21 articles from the literature that described complications following surgical airways performed under emergency situations. Our results demonstrated that there was a higher rate of late complications in tracheostomies than in cricothyroidotomies performed in the emergency setting. When comparing minor, major and early complications, there were no differences between the two procedures.

To our knowledge, this is the first systematic review comparing complications of cricothyroidotomies and tracheostomies in emergencies. The majority of the studies assessing complications of both techniques was either elective or urgent procedures. A previous prospective study comparing elective surgical tracheostomy and cricothyroidotomy in the ICU showed that the incidence of minor, major, early, and late complications was similar between both techniques [36]. One possible explanation for the different findings was the emergent nature of the cases in our review. Factors related to emergency procedures, such as time constraints, higher complexity, and higher tissue trauma, can lead to late complications.
The description of complications and safety of cricothyroidotomies was based in non-emergencies for decades. This technique was introduced long after the first tracheostomy was performed. In 1909, Chevelier Jackson described the surgical approach and considerations to perform cricothyroidotomies successfully. In 1921, he published a case series of 200 patients with tracheal stenosis, showing that 158 had undergone cricothyroidotomies. He concluded that this technique had a high risk of complications compared to tracheostomies [37]. In 1976, Brantigan and Grow published a case series of 655 patients that undergone elective cricothyroidotomies. The overall complication rate was 6.1%, and only eight patients developed subglottic stenosis [38]. Thereafter, several subsequent case series reporting low rates of post-procedure complications again popularized the use of cricothyroidotomy as a method of surgical airway management. Our findings aligned with this trend, reassuring the safety of this technique for emergency surgical airway.

CICO is a rare emergency and it is reported to occur in about 1:12,500 of general anesthesia cases [39], and in 3–8:1,000 intubation attempts in the emergency department [40, 41]. Despite emergency cricothyroidotomy being a relatively simple procedure, it is quite rare, with rates ranging from 0.2–1.2%, considering all tracheal intubations [40, 42, 43]. None of the retrieved articles in this review for either group had the procedures performed by anesthesiologists. This was expected for the TRACH group but was surprising for the CRICO group, as most anesthesiologists have either limited or no experience in performing a tracheostomy [44]. Possible explanations are that recommendation for anesthesiologists to perform cricothyroidotomy as Front Of Neck Access (FONA) is recent or anesthesiologists are only publishing case reports as they rarely perform it during their careers or that the anesthesiologists are still not comfortable performing this procedure [4, 45]. A recent editorial stated that there are many CICO situations in which trained surgeons are not readily available, and that the anesthesiologists, who are airway experts, should perform the emergency cricothyroidotomy [46]. Hence it is imperative that anesthesiologists be competent in this technique. To achieve an adequate level of comfort and competence, hands-on training in cricothyrotomy is essential [47].

There are several limitations to our systematic review that deserve consideration. The studied
population is particularly sensitive to loss of follow-up, which reduces the number of patients available for assessment and analysis of late complications. A review of medical-legal claims from the United States highlighted that most FONAs were carried out peri-cardiac arrest or death [48]. Therefore, the number of patients who die immediately or in the first weeks after the event is high.

This systematic review was mainly based on observational studies. For ethical and practical reasons, we expected few, if any, randomized controlled trials to have been conducted. This expectation was proven correct, as we found only one RCT [35]. We found a common lack of standardization. There was a wide range in the length of follow-up. Several articles only reported early complications. Others described late complications but did not define the follow-up period. Additionally, we observed that some articles had a higher incidence of complications than others. A possible reason is a difference in the methodology for their identification. Finally, this observed heterogeneity could bias to concerns about the quality of the evidence of our findings. This issue has been quoted in previous reviews about emergency cricothyroidotomy [49–51]. Future studies should focus on clearly defined and described criteria to determine complications after an emergent surgical airway placement.

Conclusion

In conclusion, this systematic review demonstrates that cricothyroidotomies performed in emergent situations resulted in fewer complications in the long term than tracheostomies. This finding supports the recommendations from the latest DAS guidelines that cricothyroidotomy is the technique of choice for emergency surgical airway placement in a CICO situation.

Abbreviations

ASA
American Society of Anesthesiologists; CICO: Can’t Intubate, Can’t Oxygenate; DAS: Difficult Airway Society; CRICO: cricothyroidotomy; ED: emergency department; EM: emergency medicine; ENT: Ear, Nose, Throat; FONA: Front Of Neck Access; ICU: intensive care unit; MeSH: Medical Subject Headings; NOS: Newcastle-Ottawa Scale; OR: operation room; PRISMA: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PRESS: Peer-Reviewed Electronic Search Strategies; RCT: randomized clinical trial; TRACH: tracheostomy.

Declarations
Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Availability of data and material
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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**Author’s contributions**

FBZ, NS and KEYT conceived the study. MR performed the database search. FBZ, KL and JT screened article titles and abstracts. FBZ, KL and JT reviewed full text of manuscripts. Discrepancies were solved through consensus between all three. FBZ, NS and KEYT evaluated the quality of included studies and extracted the data. XYY conducted the statistical analysis. FBZ wrote the first version of this manuscript. FBZ, NS and KEYT were the major contributors in writing this manuscript. All authors read and approved the final manuscript.

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**Author’s contributions**

FBZ, NS and KEYT conceived the study. MR performed the database search. FBZ, KL and JT screened article titles and abstracts. FBZ, KL and JT reviewed full text of manuscripts. Discrepancies were solved through consensus between all three. FBZ, NS and KEYT evaluated the quality of included studies and extracted the data. XYY conducted the statistical analysis. FBZ wrote the first version of this manuscript. FBZ, NS and KEYT were the major contributors in writing this manuscript. All authors read and approved the final manuscript.
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Figures
PRISMA flow chart of the study

Abbreviations: ICTRP = World Health Organization's International Clinical Trials Registry Platform, ISRCTNR = International Standard Randomised Controlled Trial Number Registry To be positioned in the Results section.

Supplementary Files
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