

# Incidence and outcomes of cricothyrotomy in the “cannot intubate, cannot oxygenate” situation

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## Abstract

Few data are available regarding factors that impact cricothyrotomy use and outcome in general hospital setting. The aim of the present study was to determine the incidence and outcomes of the patients underwent cricothyrotomy in a “cannot intubate, cannot oxygenate” (CICO) situation at university hospitals in Korea.

This was a retrospective review of the electronic medical records of consecutive patients who underwent cricothyrotomy during a CICO situation between March, 2007, and October, 2018, at 2 university hospitals in Korea. Data regarding patient characteristics and outcomes were analyzed using descriptive statistics.

During the study period, a total of 10,187 tracheal intubations were attempted and 23 patients received cricothyrotomy. Hospitalwide incidence of cricothyrotomy was 2.3 per 1000 tracheal intubations (0.23%). The majority of cricothyrotomy procedures (22 cases, 95.7%) were performed in the emergency department (ED); 1 cricothyrotomy was attempted in the endoscopy room. In the ED, 5663 intubations were attempted and the incidence of cricothyrotomy was 3.9 per 1000 tracheal intubations (0.39%). Survival rate at hospital discharge was 47.8% (11 of 23 cases). Except for cardiac arrest at admission, survival rate was 62.5% (10 of 16 cases). Successful cricothyrotomy was performed in 17 patients (73.9%) and 9 patients (52.9%) were survived. Among 6 patients of failed cricothyrotomy (26.1%), 2 patients (33.3%) were survived. After failure of cricothyrotomy, various methods of securing airway were established: 3 tracheal intubations, 1 nasotracheal intubation, and 1 tracheostomy.

The success rate of cricothyrotomy and survival rate in the CICO situation were not high. After failure of cricothyrotomy, various methods of securing airway were performed.

**Abbreviations:** CICO = cannot intubate, cannot oxygenate, CPR = cardiopulmonary resuscitation, ED = emergency department, EM = emergency medicine, ROSC = return of spontaneous circulation.

**Keywords:** cannot intubate, cannot oxygenate, cricothyrotomy, difficult airway, failed intubation, intubation

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## 1. Introduction

In cases of unsuccessful tracheal intubation, placement of supraglottic airway device or face mask ventilation is indicated. However, if maintenance of oxygenation supply fails, hypoxic brain damage or death will result. Therefore, current guidelines recommend cricothyrotomy as a last resort for rapid resolution of “cannot intubate, cannot oxygenate” (CICO) situations.<sup>[1,2]</sup> Cricothyrotomy involves making an incision through the skin and cricothyroid membrane and inserting a tracheostomy tube into the trachea to allow ventilation.<sup>[3]</sup> Common indications for cricothyrotomy are excessive blood in the oropharynx, massive facial trauma or airway obstruction resulting from angioedema, trauma, burns, or a foreign body.

Several cricothyrotomy techniques are available in CICO situations. These include percutaneous cricothyrotomy with a Trocar-type kit or the Seldinger method and transtracheal jet ventilation with a needle or narrow-bore cannula.<sup>[1]</sup> Variable techniques of cricothyrotomy may be a barrier to learning cricothyrotomy. Chang et al reported that given the increasing rarity of this procedure, it is likely that many emergency medicine (EM) residents will not acquire clinical experience with this technique during training.<sup>[4]</sup> In a multicenter questionnaire survey, the reported incidence was 0.003% in the operating room.<sup>[5]</sup> Another questionnaire survey in Korea, anesthesiologists and intensivists had experienced a CICO situation an average of 2.6 times during lifetime.<sup>[6]</sup> A problem with

cricothyrotomy is that, due to the low incidence of CICO situations, physicians have limited experience of cricothyrotomy<sup>[7]</sup> and would not have expertise in performing this task.

The efficacy and outcome profile of cricothyrotomy has been challenged. Although there have been studies on incidence or success rate for cricothyrotomy in trauma center of emergency department (ED) or prehospital settings,<sup>[8–12]</sup> or battlefield setting,<sup>[13]</sup> few data are available regarding factors that impact cricothyrotomy use and outcome in general hospitals. Therefore, the aim of the present study was to determine the incidence of cricothyrotomy and examine outcomes of the patients underwent cricothyrotomy in a CICO situation at university hospitals in Korea.

## 2. Methods

### 2.1. Study design and patients

This retrospective study was conducted in 2 hospitals of Hallym University Medical Centres (Dongtan Sacred Heart Hospital and Hallym University Sacred Heart Hospital) in Korea. We retrospectively investigated data of patients, who underwent cricothyrotomy during airway management between March, 2007, and October, 2018. During the study period, all consecutive patients aged >18 years who had cricothyrotomy were analyzed.

The study was approved by the Institutional Review Board of Hallym Medical Centre (approval no. 2018-08-005-001). The requirement for informed consent was waived due to the retrospective nature of the analyses. All study procedures were performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

### 2.2. Data collection and definition

We retrospectively investigated clinical data using the clinical big data analytic solution Smart Clinical Data Warehouse (CDW) from Hallym University Medical Centre. The smart CDW is based on the QlikView Elite Solution. It offers electronic medical record text data analysis and integrated analysis of fixed data. Using the Smart CDW, we collected clinical data of patients with tracheal intubation and cricothyrotomy. Data on the following factors were retrieved from electronic medical records: demographic variables (age and sex), diagnosis upon hospital admission, clinical setting of tracheal intubation, medical indication for intubation, number and duration of intubation attempts before cricothyrotomy, cricothyrotomy technique, operator characteristics, methods and duration of securing the airway after failed cricothyrotomy, duration of cardiopulmonary resuscitation (CPR), return of spontaneous circulation (ROSC), survival at hospital discharge, and cause of death.

A CICO situation was defined as a situation in which tracheal intubation failed and oxygenation via bag-mask or supraglottic airway ventilation was unsuccessful.<sup>[14]</sup> Successful cricothyrotomy was considered as insertion of the tip of the cricothyrotomy tube into the tracheal lumen.

The decision to perform cricothyrotomy during airway management was made by the respective operator without reference to standardized criteria or protocol for difficult airway. Four different cricothyrotomy methods were used: a percutaneous method with a Portex Cricothyrotomy kit (PCK; Smiths Medical Ltd, Hythe, UK); a percutaneous Seldinger technique

with a Melker cricothyrotomy kit (Cook Inc, Bloomington, IL); transtracheal jet ventilation with a catheter (Manujet; VBM Medizintechnik GmbH, Sulz, Germany); and surgical cricothyrotomy.

### 2.3. Statistical analysis

Data on patient characteristics, indication for cricothyrotomy, cricothyrotomy technique, operator characteristics, and outcome variables were analyzed using descriptive statistics. Continuous variables are expressed as the median (interquartile range). Categorical variables are expressed as numbers (percentages). All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) Version 24.0 (IBM Corporation, Armonk, NY).

## 3. Results

During the study period, a total of 10,187 tracheal intubations were performed and 23 patients received cricothyrotomy. Hospitalwide incidence of cricothyrotomy was 2.3 per 1000 tracheal intubations (0.23%). The majority of cricothyrotomy procedures (22 cases, 95.7%) were performed in the ED; 1 cricothyrotomy was attempted in the endoscopy room. In the ED, 5663 intubations were performed and the incidence of cricothyrotomy was 3.9 per 1000 tracheal intubations (0.39%). Five patients who had good recovery were discharged to home and 3 patients with burn injury were transferred to the professional burn hospital after securing airway (Table 1).

The median age of the cohort was 63 years (range, 41–78 years), and 18 patients (78.3%) were males (Table 2). The most common indication for intubation was airway protection (10 cases, 43.5%). Diagnoses on admission were as follows: pneumonia (3 cases, 13.0%); brain hemorrhage (2 cases, 8.7%); deep neck infection (3 cases, 13.0%); inhalation burn injury (2 cases, 8.7%); trauma (4 cases, 17.4%); seizure (1 case, 4.3%); cardiac arrest (7 cases, 30.4%); and non-ST elevation myocardial infarction (1 case, 4.3%). Twenty-one patients (91.3%) underwent percutaneous techniques: percutaneous method with a PCK (n=16, 69.6%); percutaneous Seldinger technique with a Melker cricothyrotomy kit (n=4, 17.4%); and transtracheal jet ventilation with a catheter (n=1, 4.3%). The remaining 2 underwent surgical cricothyrotomy (8.7%). The majority of cricothyrotomy procedures (19 cases, 82.6%) were performed by EM attending physicians; the remaining 4 cases were performed by residents: 2 EM 3rd grade residents, an ENT 3rd resident, and an ENT 1st grade resident.

The success rate according to the method of cricothyrotomy was as follows: 75% (12 of 16 cases) with PCK; 60% (3 of 4 cases) with Melker cricothyrotomy kit; 100% (1 of 1 case) with transtracheal jet ventilation with a catheter; and 50% (1 of 2 cases) with surgical method, respectively. The success rate of cricothyrotomy performed by EM attending physicians was 68.4% (13 of 19 cases), and that by residents was 100% (4 of 4 cases). Number of intubation attempts before cricothyrotomy was 1 (range, 1–3) and duration of intubation attempts before cricothyrotomy was 18 minutes (range, 13–29 minutes). Five of 6 patients who failed cricothyrotomy had secured airway using other methods and it took 37 minutes (range, 34–40 minutes).

Outcomes of the patients underwent cricothyrotomy are demonstrated in Table 3. Survival rate at hospital discharge was 47.8% (11 of 23 cases). Survival rates were 16.7% (1 of 6 cases)

**Table 1**

**Characteristics of the 23 cricothyrotomy cases.**

No	Age	Sex	Presentation	Clinical setting	How CICO situation occurred	Technique	Operator	Outcome
1	91	M	Cardiac arrest	ED	CPR - failed 1st TI - failed cricothyrotomy - successful 2nd TI - dead	Surgical	EM attending physician	Died in ED
2	77	F	Cardiac arrest	ED	CPR - failed 1st TI - successful cricothyrotomy - dead	Portex	EM attending physician	Died in ED
3	52	M	Pneumonia	ED	Failed 1st TI - CPR - failed 2nd TI - i-gel insertion - ROSC - failed cricothyrotomy - 3rd TI - i-gel insertion - successful cricothyrotomy	Portex	EM attending physician	Died in the ICU
4	83	M	Acute SDH	ED	Failed 1st TI - CPR - failed 2nd TI - failed 3rd TI - failed cricothyrotomy - CPR - ROSC - successful 4th TI - CPR - ROSC - CPR - ROSC	Portex	EM attending physician	Died in the ICU
5	76	M	Hypopharyngeal cancer, pneumonia	Endoscopy room	i-gel insertion - failed 1st TI - CPR - successful cricothyrotomy - ROSC	Manujet	EM 3rd grade resident	Good recovery, discharged to step-down referral
6	79	F	Pneumonia	ED	Failed 1st TI - CPR - i-gel insertion - failed cricothyrotomy - ROSC - CPR - failed 2nd TI - successful nasotracheal intubation - dead	Portex	EM attending physician	Died in ED
7	63	M	Seizure	ED	Failed 1st TI - failed 2nd TI - failed 3rd TI - failed 4th TI - failed 5th TI - failed 6th TI - failed 7th TI - successful cricothyrotomy	Surgical	EM attending physician	Good recovery, discharged to home
8	27	M	Fell down: cervical spinal cord injury	ED	Failed 1st TI - failed 2nd TI - CPR - ROSC - failed 3rd TI - CPR - failed cricothyrotomy - successful tracheostomy - ROSC	Melker	EM attending physician	Good recovery, discharged to home
9	26	M	Motor vehicle crash: hemoperitoneum	ED	Failed 1st TI - successful cricothyrotomy - CPR - ROSC - CPR - dead	Melker	ENT 1st grade resident	Died in ED
10	62	M	Inhalation burn injury	ED	Failed 1st TI - failed 2nd TI - failed 3rd TI - failed 4th TI - successful cricothyrotomy - CPR - ROSC	Melker	EM attending physician	Transferred to burn center
11	46	M	Submandibular abscess	ED	Failed 1st nasotracheal intubation - failed 2nd nasotracheal intubation - failed tracheostomy - successful cricothyrotomy	Melker	ENT 3rd grade resident	Good recovery, discharged to home
12	39	M	Facial trauma, mandibular fracture	ED	Failed 1st TI - failed 2nd TI - successful cricothyrotomy - CPR - ROSC	Portex	EM attending physician	Poor recovery, transfer to step-down referral
13	27	M	Inhalation burn injury	ED	Failed 1st TI - failed 2nd TI - failed 3rd TI - failed bougie-assisted intubation - successful cricothyrotomy	Portex	EM attending physician	Transferred to burn center
14	42	M	Cardiac arrest	ED	CPR - i-gel insertion - failed 1st TI - i-gel insertion - successful cricothyrotomy - dead	Portex	EM attending physician	Died in ED
15	66	F	Cardiac arrest	ED	CPR - successful cricothyrotomy - dead	Portex	EM 3rd grade resident	Died in ED
16	18	M	Motor vehicle crash: traumatic brain injury	ED	Failed 1st TI - successful cricothyrotomy	Portex	EM attending physician	Poor recover, transfer to step-down referral
17	82	M	Cardiac arrest	ED	CPR - failed 1st TI - failed 2nd TI - failed 3rd TI - successful cricothyrotomy - dead	Portex	EM attending physician	Died in ED
18	60	M	Retropharyngeal abscess	ED	Failed 1st TI - failed 2nd TI - successful cricothyrotomy	Portex	EM attending physician	Good recovery, discharged to home
19	19	M	Motor vehicle crash: traumatic brain and chest injury	ED	i-gel insertion - failed bronchoscopy-guided intubation - i-gel insertion - successful cricothyrotomy - CPR - dead	Portex	EM attending physician	Died in ED
20	65	F	Cardiac arrest	ED	CPR - failed 1st TI - successful cricothyrotomy - ROSC	Portex	EM attending physician	Transferred to burn center
21	67	M	Epiglottitis	ED	Failed 1st TI - failed 2nd TI - failed 3rd TI - failed cricothyrotomy - successful 4th TI	Portex	EM attending physician	Good recovery, discharged to home
22	81	M	Cardiac arrest	ED	CPR - failed 1st TI - failed cricothyrotomy - dead	Portex	EM attending physician	Died in ED
23	78	F	Cardiac arrest	ED	CPR - failed 1st TI - successful cricothyrotomy - dead	Portex	EM attending physician	Died in ED

CICO = cannot intubate, cannot oxygenate, CPR = cardiopulmonary resuscitation, ED = emergency department, EM = emergency medicine, ENT = ear, nose, and throat, ICU = intensive care unit, ROSC = return of spontaneous circulation, SDH = subdural hemorrhage, TI = tracheal intubation.

**Table 2**  
Baseline demographic and clinical characteristics of the patients.

Variable	Total (n=23)
Age, yrs	63 (41–78)
Male, %	18 (78.3)
Indication for intubation, %	
Airway protection	10 (43.5)
Hypoxic respiratory failure	4 (17.4)
Shock	1 (4.3)
Cardiac arrest	8 (34.8)
Diagnosis, %	
Pneumonia	3 (13.0)
Brain hemorrhage	2 (8.7)
Deep neck infection	3 (13.0)
Inhalation burn injury	2 (8.7)
Trauma	4 (17.4)
Seizure	1 (4.3)
Cardiac arrest	7 (30.4)
NSTEMI	1 (4.3)
Technique, %	
Seldinger method with portex cricothyrotomy kit	16 (69.6)
Seldinger method with Melker cricothyrotomy kit	4 (17.4)
Transtracheal jet ventilation with a catheter	1 (4.3)
Surgical cricothyrotomy	2 (8.7)
Operator, %	
EM attending physician	19 (82.6)
EM 3rd grade resident	2 (8.7)
ENT 3rd grade resident	1 (4.3)
ENT 1st grade resident	1 (4.3)

Data are expressed as the median (interquartile range) or as number (%) as appropriate. EM=emergency medicine, ENT=ear, nose, and throat, NSTEMI=non-ST segment elevation myocardial infarction.

in Dongtan Sacred Heart Hospital and 58.8% (10 of 17 cases) in Hallym University Sacred Heart Hospital. Success rates of cricothyrotomy were 50% (3 of 6 cases) and 82.4% (14 of 17 cases), respectively. The most common cause of death was cardiac arrest (10 of 12, 83.3%). Other causes of death were brain hemorrhage (1 of 12, 8.3%) and hypovolemic shock (1 of 12, 8.3%). Seven patients were in cardiac arrest at the time of ED visit. Except for cardiac arrest at admission, survival rate was 62.5% (10 of 16 cases). During airway management, cardiac arrest occurred in 17 of 23 patients (73.9%) and duration of CPR was 20 minutes (range, 8–31 minutes). In 41.2% (7 of 17) of cases, this was followed by return of spontaneous circulation. Survival rate of the patients underwent CPR was 29.4% (5 of 17).

Successful cricothyrotomy was performed in 17 patients (73.9%) and 9 patients (52.9%) were survived. Except for cardiac arrest at admission, 66.6% (8 of 12 cases) of patients in the successful cricothyrotomy group survived. Among 6 patients of failed cricothyrotomy (26.1%), 2 patients (33.3%) were survived. After failure of cricothyrotomy, various methods of securing airway were established: 3 tracheal intubations, 1 nasotracheal intubation, and 1 tracheostomy (Fig. 1).

#### 4. Discussion

This retrospective study investigated the incidence and outcomes of patients that underwent cricothyrotomy at university hospitals in Korea. We identified that the success rate for cricothyrotomy in a CICO situation was 74% and survival rate was 48%. After failure of cricothyrotomy, other securing airway methods were established in 83% of patients and 33% were survived. We also

**Table 3**  
Outcomes of the patients.

Variable	Total (n=23)
Successful cricothyrotomy	17/23 (73.9)
Duration of intubation attempts before cricothyrotomy, min	18 (13–29)
Securing the airway after failed cricothyrotomy	5/6 (83.3)
Duration of securing the airway after failed cricothyrotomy, min	37 (34–40)
Number of intubation attempts before cricothyrotomy	1 (1–3)
Survival rate at hospital discharge, %	11/23 (47.8)
Cause of death, %	
Cardiac arrest	10/12 (83.3)
Brain hemorrhage	1/12 (8.3)
Hypovolemic shock	1/12 (8.3)
Patients underwent cardiac arrest, %	17/23 (73.9)
Duration of CPR, min	20 (8–31)
ROSC, %	7/17 (41.2)
Survival rate of the patients underwent CPR, %	5/17 (29.4)

Data are expressed as the median (interquartile range) or as number (%) as appropriate. CPR=cardiopulmonary resuscitation, ROSC=return of spontaneous circulation.

found that most cricothyrotomy was performed by the ED attending staffs in the emergency room and that various methods of cricothyrotomy were used. It is important to establish a standardized airway crisis management protocol based on reliable success rates for the various cricothyrotomy techniques and readily available airway-skilled medical staffs.

Cricothyrotomy is a potentially life-saving procedure used for immediate resolution of a CICO situation. In other words, if cricothyrotomy fails, cardiac arrest may occur. Therefore, current guideline for the airway management recommends that an expert operator attempts airway securing techniques such as tracheostomy after failed cricothyrotomy.<sup>[15]</sup> In our cohort, 17% of cricothyrotomies were conducted by EM or ENT residents. One patient with failed cricothyrotomy by an EM physician was underwent tracheostomy by an ENT doctor. Multidisciplinary collaborative system seems reasonable because an experienced expert in both cricothyrotomy and tracheostomy were not always available in a CICO situation. Pracy et al emphasized that, in the event of a failed airway, surgeons may be immediately available and be called anywhere in the hospital.<sup>[16]</sup> Although various difficult airways are managed by EM physicians or anesthesiologists, surgeons should be involved in the CICO situation requiring cricothyrotomy because of its multidisciplinary in nature.

The present study showed that 33% (2 of 6 cases) of patients in the cricothyrotomy failure group survived. In addition, 4 of 6 patients had secured airway using orotracheal or nasotracheal intubation after failure of cricothyrotomy. This suggests that cricothyrotomy may be performed in patients who can successfully undergo tracheal intubation. In a previous report of cricothyrotomy, Bair et al demonstrated that the routine use of rapid sequence intubation has resulted in fewer patients needing surgical airway.<sup>[8]</sup> Therefore, comprehensive strategy to optimize oxygenation and tracheal intubation in critically ill patients would be an important way to avoid CICO situations.

The incidence of CICO varies according to clinical settings.<sup>[14]</sup> The reported incidences of CICO are 0.003% in the operating room<sup>[5]</sup> and 1.0% to 2.8% in trauma patients requiring intubation in the ED setting.<sup>[8,10]</sup> In the prehospital setting, 7.7% to 10.9% of incidence was reported among patients treated by air-medical transport teams.<sup>[8,9]</sup> We found that the incidence of CICO in a nontrauma center ED setting was 0.39%. These

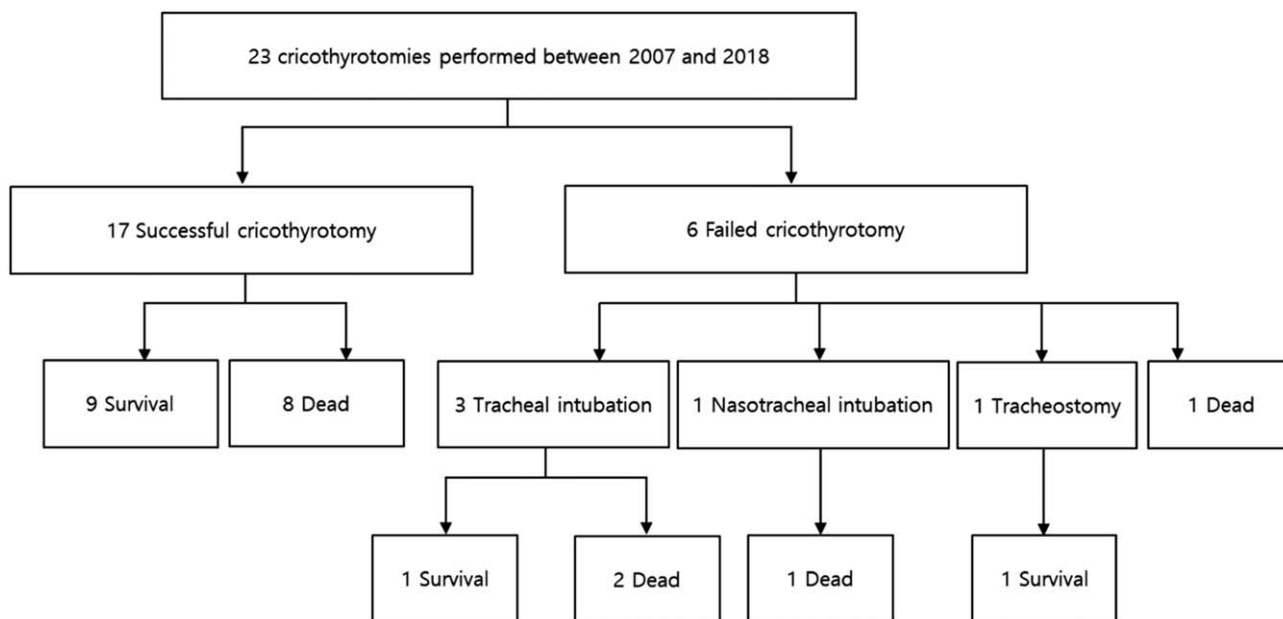


Figure 1. Flow chart of the patients.

findings suggest that cricothyrotomy is more likely in the ED setting than in the operating room, particularly among trauma patients. The success rate of cricothyrotomy also varies. Paix and Griggs showed that 63% of patients (15 of 24 cases) underwent emergency surgical cricothyrotomy successfully, and that 73% achieved a good recovery.<sup>[17]</sup> Xeropotamos et al reported that the survival rate in a prehospital setting by the Helicopter Emergency Medical Service, is as low as 37%.<sup>[9]</sup> In the present study, cricothyrotomy success rate was 74%, and 48% of patients discharged alive. This may be the result of heterogeneity in terms of severity of illness, operator's skilfulness or cricothyrotomy techniques. Except for cardiac arrest at admission, 67% (8 of 12 cases) of patients in the successful cricothyrotomy group survived. These findings support that cricothyrotomy is crucial in the CICO situation. However, a patient died of uncontrolled retropharyngeal bleeding, even after successful cricothyrotomy. Therefore addressing potential complications of cricothyrotomy is needed to improve outcomes after successful intervention.

A meta-analysis of prehospital airway management demonstrates that the success rate for surgical cricothyrotomy is higher than for needle cricothyrotomy (90.5% vs 65.8%, respectively).<sup>[18]</sup> Current guidelines suggest that surgical cricothyrotomy, in particular the scalpel-bougie-tube cricothyrotomy technique, is more reliable than percutaneous cricothyrotomy.<sup>[1,15]</sup> In the present study, success rate of Seldinger method with PCK was 75% (12 of 16 cases). However, it is still not clear which cricothyrotomy technique is most effective,<sup>[19]</sup> because the cohort was small and operator's proficiency in the various cricothyrotomy is unknown.

The present study has several limitations. First, the analyses were retrospective with small number of study population, and no data concerning factors such as the characteristics of difficult airways, complications of cricothyrotomy such as posterior tracheal wall injury, or neurologic impairment were available. Moreover, the operators may have had varying degrees of skill in the four cricothyrotomy techniques, and selection of cricothyrotomy technique was made at the discretion of the operator. Barriers

to conducting randomized controlled trials include the rarity of a CICO situation and the difficulty of control across groups for nature of difficulty and operator experience. Therefore, it would be a more realistic approach to set the standardized specific technique with appropriate training, for each center, and to compare each center after prospective monitoring of outcomes. Second, some patients in a CICO situation may have not received cricothyrotomy or may have undergone alternative procedures such as emergency tracheostomy or extracorporeal membrane oxygenation. Hence, the incidence of CICO may have been underestimated. Third, the definition of successful cricothyrotomy may be equivocal in our study. Lockey et al demonstrated that successful procedure is defined as correct placement of a tracheal tube in the trachea followed by adequate ventilation.<sup>[12]</sup> However, in the present study, the proof of cricothyrotomy kit insertion was investigated through careful reviewing detailed electronic medical records. Nevertheless, the strength of the present study is that it involves analysis of data from multiple centers over a long period and enrolled a relatively large number of CICO patients who underwent cricothyrotomy in a real world setting. Therefore, the present results could provide clinically relevant data on airway rescue management in critically ill patients.

In this study, we found that the incidence of cricothyrotomy and outcomes of patients that underwent cricothyrotomy at university hospitals with nontrauma center. The success rate of cricothyrotomy and survival rate in the CICO situation were not high. After failure of cricothyrotomy, various methods of securing airway were performed. To avoid CICO situations, comprehensive strategy in airway management in critically ill patients is necessary. A multidisciplinary collaborative system involving surgeons may be helpful in difficult airway management.

#### Author contributions

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