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ORIGINAL ARTICLE

Surgical airways for trauma patients in an emergency surgical setting: 11 years' experience at a teaching hospital in Japan

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Abstract
Purpose Airway management of trauma patients during emergency surgeries can be very difficult and presents a challenge for anesthesiologists. Difficult airways are associated with emergency surgical airways (ESA), but little is known about ESA in the operating room. We conducted this study to clarify the present use of ESA for trauma patients in emergency surgery settings.
Methods We performed a retrospective review of all trauma patients requiring emergency surgery under general anesthesia at our hospital from January 2002 to December 2012, focusing on ESA.
Results During the study period, 15,654 trauma patients were treated at our hospital, of whom 554 (3.5 %) required emergency surgery. Four of these patients (0.72 %) received ESA as definitive airway management. Two patients with severe facial injury and distorted upper airways and 1 patient with penetrating neck trauma received open standard tracheostomy (OST). These three patients received OST as the initial approach to intubation. A fourth OST was performed after several unsuccessful attempts at endotracheal intubation. No cases were classified as "cannot ventilate, cannot intubate" (CVCI), and there were no complications associated with ESA. All cases had good outcomes. Statistical analysis revealed that patients with severe facial trauma (Abbreviated Injury Scale ≥ 3) received ESA at a significantly higher rate than others ($p = 0.015$, odds ratio 14.1).
Conclusion One of the most important functions of anesthesiologists is risk management. We should recognize risks that can cause CVCI situations, and make proper clinical decisions, including providing ESA, to assure patient safety.

Keywords Emergency surgery · Difficult airway · Trauma · Tracheostomy

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Introduction

The keys to saving the life of a severe trauma patient are definitive airway management, proper oxygenation, and stabilizing circulation by early restoration of homeostasis. In the operating room (OR), anesthesiologists participate in airway, respiratory, and circulatory management of trauma patients, and play an important role in trauma resuscitation. Endotracheal intubation (ETI) is the gold standard for securing the airway of trauma patients. However, hemodynamic instability, restlessness, inadequate preoperative evaluation because of limited time and information, the risk of aspiration, the need for cervical spine protection, and face and neck injury all contribute to the difficulty of ETI in trauma patients in emergency surgical settings. These factors present a challenging situation even for anesthesiologists, who are specialists in airway management. Emergency surgical airways (ESA) become the endpoint in "cannot ventilate, cannot intubate" (CVCI) cases [1], and in cases requiring definitive airway management when ETI is not possible [1]. Anesthesiologists can choose ESA as an initial approach to intubation when

they encounter severe face and neck trauma that they predict will be a CVCI situation at induction of general anesthesia. However, little is known about the present use of ESA for trauma patients in the OR. The aims of this study are to clarify the present use of ESA for trauma patients in emergency surgical settings, to clarify the risks and problems related to difficult airways, and to provide important information that can be used to improve clinical practice.

Materials and methods

Ohta Nishinouchi General Hospital is a teaching hospital and a tertiary referral medical center located in Koriyama City, Fukushima, approximately 200 km north of Tokyo. More than 1,400 trauma patients with variably severe injuries are treated at the hospital each year, corresponding to a Level 1 Trauma Center in the United States. We performed a retrospective review of all trauma patients requiring emergency surgery under general anesthesia, brought directly from the emergency room (ER) to the OR from January 1, 2002 to December 31, 2012. Data were collected from medical and anesthesia records, including type of trauma, trauma severity [Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), and American Society of Anesthesiologists Physical Status (ASA-PS)], indication for ESA, procedure of ESA (number of intubation attempts, use of rescue airway, and type of ESA), complications associated with ESA, and patient outcome. All general anesthesias were conducted under the supervision of the attending anesthesiologist, who was well acquainted with the American Society of Anesthesiologists' Difficult Airway Management (ASA-DAM) guidelines [1]. We investigated short-term complications [e.g., bleeding, hypoxia (value of pulse oximetry $\leq$90 %), and aspiration] and long-term complications (e.g., airway stenosis, wound infection, and granulation) by reviewing inpatient and outpatient medical records. Statistical analyses were performed using SPSS software version 17.0 (IBM, Tokyo, Japan). Categorical data were assessed using the chi square test. p values < 0.05 were considered statistically significant.

This study was approved by the institutional review board of the authors' institution.

Results

During the study period, 15,654 trauma patients were brought to the ER, of whom 554 required emergency surgery under general anesthesia (3.5 % of trauma patients, 402 male, 152 female, age 44.7 $\pm$ 21.7 years, ISS 18.3 $\pm$ 14.0, ASA-PS 2.72 $\pm$ 0.94 E). The distribution of emergency surgeries was 369 open reductions with internal fixation (66.6 %), 123 laparotomies (22.2 %), 12 thoracotomies (2.2 %), 22 craniotomies (4.0 %), and 28 other (5.0 %), including ophthalmectomy, spinal fusion, and femorofemoral bypass. A summary of airway management for the trauma patients taken to emergency surgery is shown in Fig. 1. Forty-four of the 554 patients (7.9 %) died of their injuries, but none because of airway or breathing management failure. In the ER, 119 patients (21.5 %) received ETI by an ER physician: 1 patient (0.18 %; 42-year-old man, airway obstruction caused by severe facial bone fracture with copious bleeding from the mouth) underwent cricothyroidotomy (CTY), and 1 patient (0.18 %; 28-year-old man, comminuted mandibular fracture with distorted upper airway) underwent open standard tracheostomy (OST). In the OR, 2 patients (0.36 %) were managed with face-mask ventilation only and 2 (0.36 %) were managed with laryngeal mask airway (LMA) only. Four hundred twenty-five patients (76.7 %) received ETI, of whom 15 had difficult airways requiring more than three ETI attempts. Two patients initially had failed ETI despite multiple attempts with a Macintosh laryngoscope and video laryngoscope. They were salvaged with endoscope-guided ETI through intubating LMA (iLMA). Despite the use of every available method, 1 case failed ETI and received OST. This case is described later (see case 4, Table 1). Four cases (0.72 %) received ESA as definitive airway management. Further details of ESA are shown in Table 1. Two of the 4 ESA patients (cases 1 and 2) had severe facial injury with upper airway distortion. Each received OST performed by head and neck surgery consultants summoned by the anesthesiologists, as the initial approach to intubation. Case 3 was brought directly to the OR in need of surgery. Initially a tracheostomy cannula was inserted directly from a tracheal wound already communicating with a skin wound, and later OST was performed. The attempt at ETI in case 4 (height 158 cm, weight 51 kg, body mass index 20.4) failed after induction of general anesthesia. Face-mask ventilation was adequate, but ETI was unsuccessful because this patient had morbid micrognathia. Direct visualization of the vocal cords with a Macintosh laryngoscope (Cormack grade 4 view) failed, followed by multiple failed attempts with a video laryngoscope, endoscope-guided nasal intubation, and endoscope-guided ETI through iLMA. Finally, an OST was performed by head and neck surgery consultants under adequate ventilation with an iLMA. All patients who underwent ESA had a good clinical course and returned to normal activities. No short-term or long-term complications associated with ESA were identified. As described in Table 2, we found that patients with severe facial injury (AIS $\geq$ 3) required ESA in the ER and the OR at a significantly higher rate than others (chi square test,

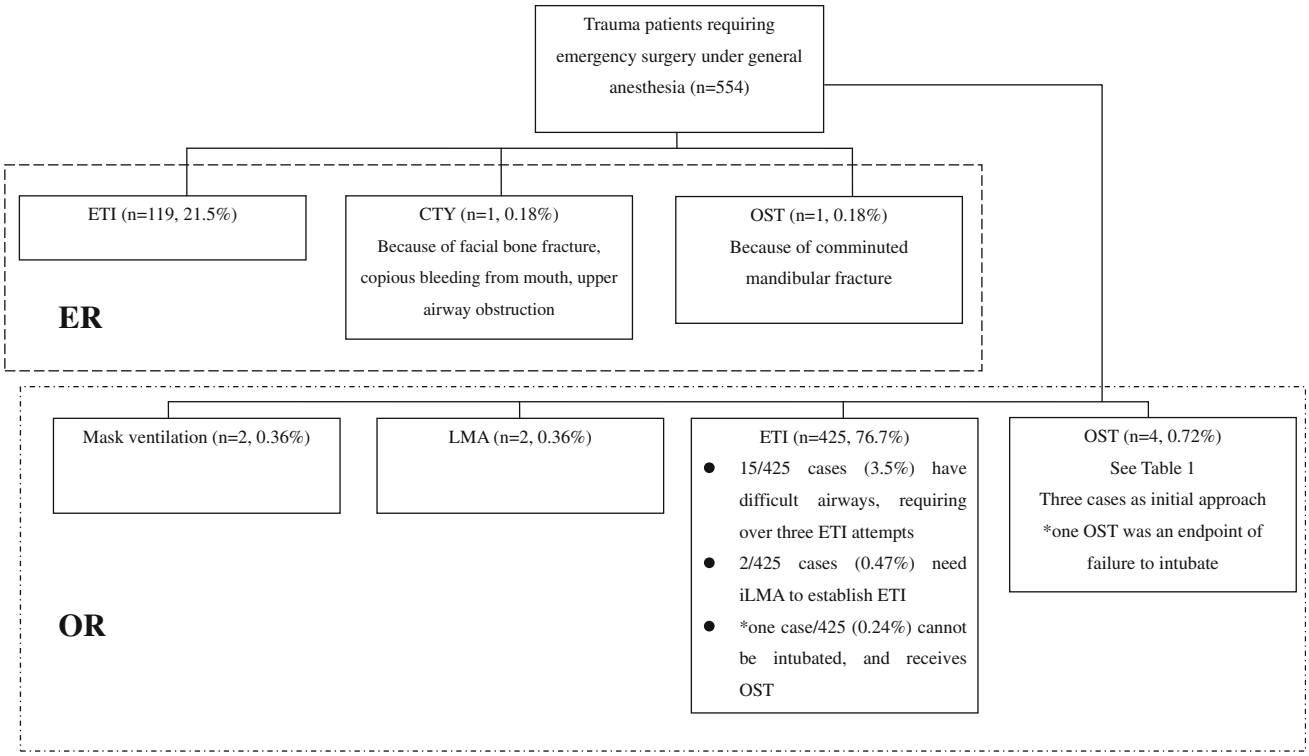

Fig. 1 Summary of airway management for trauma patients requiring emergency surgery. *ETI* endotracheal intubation, *CTY* cricothyroidotomy, *LMA* laryngeal mask airway, *OST* open standard tracheostomy, *ER* emergency room, *OR* operating room

Table 1 Trauma patients requiring surgical airway management in the operating room

Case number	1	2	3	4
Sex	Male	Female	Female	Female
Age (years)	61	25	74	37
Trauma	Self-inflicted gunshot wound (shotgun) to mid- and upper face. Facial and thoracic skin defects and maxilla-mandibular bone fractures	Fall resulting from suicide attempt. Comminuted facial bone fracture, pelvic fracture, left femoral, patellar, and tarsal bone open fractures	Penetrating neck trauma with a knife resulting from suicide attempt. A tracheal wound already communicated with a skin wound	Motor vehicle crash. Liver laceration. Morbid micrognathia
ASA-PS	4E	4E	3E	4E
AIS (face)	3	2	0	0
ISS	13	34	17	17
Type of surgical airway	OST	OST	OST following direct insertion of a tracheal cannula through a tracheal wound	OST
Reason	Distorted upper airway	Distorted upper airway	Distorted upper airway	Failure of endotracheal intubation
Number of intubation attempts	0	0	0	9
Rescue airway device	None	None	None	iLMA
Complications	None	None	None	None
Outcome	Good recovery	Good recovery	Good recovery	Good recovery

ASA-PS American Society of Anesthesiologists Physical Status, *AIS* abbreviated injury scale, *ISS* injury severity score, *OST* open standard tracheostomy, *iLMA* intubating laryngeal mask airway

Table 2 Comparison of airway management in groups with AIS face ≤ 2 versus AIS face ≥ 3

Type of airway management	AIS face ≤ 2 ($n = 535$)	AIS face ≥ 3 ($n = 19$)	p values
ETI	527 (98.5 %)	17 (89.5 %)	0.043
ESA	4 (0.8 %)	2 (10.5 %)	0.015
OST	4 (0.8 %)	1 (5.25 %)	0.161
CTY	0 (0.0 %)	1 (5.25 %)	0.034
LMA	2 (0.4 %)	0 (0.0 %)	1.000
Facial mask ventilation	2 (0.4 %)	0 (0.0 %)	1.000

AIS abbreviated injury scale, *ETI* endotracheal intubation, *ESA* emergency surgical airway, *OST* open standard tracheostomy, *CTY* cricothyroidotomy, *LMA* laryngeal mask airway

$p = 0.015$, odds ratio 14.1). These patients are considered to be at high risk of having difficult airways.

Discussion

In emergency trauma surgery, the general condition of patients is fragile, there are time pressures, and life-saving procedures must be performed. Anesthesiologists' choices for airway management are limited in such situations. Berkow et al. [2] reported that 0.5–2.5 patients per 10,000 (0.005–0.025 %) received ESA among all surgery cases, including planned operations. Our study revealed that 4 of 554 trauma patients (0.72 %) received ESA in emergency surgery settings (odds ratio, 28.9–144.1). In the field of emergency medicine, studies have found that 0.3–0.9 % of trauma patients received CTY in pre-hospital or ER settings [3–6]. Severe facial injury patients received ESA more often than did patients with other types of trauma. Cogbill et al. [7] reported that of patients with severe maxillofacial injury (AIS of the face ≥ 3) with severe oronasal hemorrhage, 8 % received CTY and 6 % received OST in the ER. In our study, there were 19 severe facial injury cases (AIS of the face ≥ 3); of these, 1 (5.3 %; case 1, Table 1) received OST in the OR, and one (5.3 %) received CTY in the ER. This study also revealed that severe facial trauma cases received ESA at a significantly higher rate than others ($p = 0.015$, odds ratio 14.1). Facial trauma can make it impossible to open the mouth fully, and makes face-mask ventilation very difficult. Face-mask ventilation in facial trauma cases can worsen hypoxia by pushing blood, debris, and tissue from the upper airway into the lower airway, and can cause further damage to facial structures [8]. Imprudent induction of general anesthesia can cause a CVCI situation, leading to a tragic outcome. Awake intubation or ESA may be considered in such situations according to ASA-DAM guidelines [1]. However, when awake intubation is attempted in severe facial trauma cases, laryngoscope manipulation can worsen upper airway edema and bleeding, and can worsen airway and breathing conditions. One of the most important functions of anesthesiologists is risk management: to prepare for worst case scenarios, to minimize risks, and to assure patient safety. Two of the four ESA procedures in the OR (cases 1 and 2) received OST as the initial approach to intubation because of high-risk facial trauma. For the reasons already mentioned, this was considered proper airway management in these cases. This study found no cases that became CVCI situations, even under challenging situations for the anesthesiologists. None of the patients who underwent OST in the OR had short-term or long-term complications, and all had positive outcomes, owing in part to the proper clinical decisions of anesthesiologists. There are no guidelines or consensus for ESA for facial trauma patients [9]. High-risk facial trauma cases should be treated at medical institutions that can provide surgical backup. We should emphasize this principle to paramedics, to decrease preventable trauma deaths associated with airway management challenges.

In some cases, such as in case 3, it may be quicker and easier to introduce a tracheostomy cannula via a wound, or to surgically extend a wound, rather than perform standard ESA procedures [8]. Penetrating wounds between the skin and trachea can make facial mask ventilation inefficient, and an endotracheal tube inserted via the upper airway can deviate to the skin wound. Of course, the temporary cannula must be replaced with a more secure route.

Case 4 could not be intubated after induction of general anesthesia and underwent an OST. Definitive airway management was necessary because of unstable vital signs and risk of aspiration. An iLMA was very useful as a bridging ventilatory device while OST was performed. Linstedt et al. [10] also reported that iLMA provided adequate ventilation and endoscopic views during endoscope-guided percutaneous dilatational tracheostomy (PDT). In this study, there were also two cases of failed ETI with standard techniques using direct and indirect laryngoscopes, which were salvaged by endoscope-guided ETI through iLMA. Several reports have described the usefulness of ventilation and intubation with iLMA [11–14], a point emphasized in the ASA-DAM guidelines [1].

This study revealed only four ESA cases occurring during 11 years in an emergency trauma surgical setting. The very rare occurrence of ESA makes it impossible for anesthesiologists to have sufficient experience of such situations through on-the-job training only. It is important to simulate such situations in training exercises to enable proper and prompt decision making in emergency situations. Kuduvalli et al. [15] reported that difficult airway education using a simulation model led to improved

performance in the management of unanticipated difficult airways for at least 6–8 weeks after training.

In this study, four OSTs were performed as ESA, and no patients received PDT. PDT is less costly and faster than OST and has an aesthetic advantage over OST [16–18]. Several meta-analyses that have examined elective tracheotomies for patients with long-term intubation in intensive care units reported that bleeding, short-term and long-term complications, mortality rate, and ventilation-dependent term were the same for PDT as for OST [18, 19]. However, the surgeon does not have direct visualization of the surgical site if PDT is performed, which is a great disadvantage in an emergency situation. Emergency trauma cases may have tracheal injury or copious bleeding from the upper airway, which could not be managed with PDT. Moreover, PDT has severe potential complications, such as peritracheal and intratracheal bleeding, cannula malposition, tracheal damage, and airway loss with sudden hypoxia [20]. We preferentially perform OST for safe and definitive airway management in emergency trauma cases. To our knowledge, there is no reliable report indicating the superiority of PDT over OST in emergency situations.

This study has several limitations. This is a retrospective observational study in a single institution. Accuracy of the data depended on medical and anesthesia records, which could increase the risk of reporting bias, including underestimation of complications. The anesthesia records were handwritten, so physiological parameters were not recorded automatically, which could have resulted in underestimation of lowest physiological parameters. Despite these limitations, this report revealed the present use of ESA for trauma patients in an emergency surgery setting, clarified risk factors, and provided important information to improve clinical practice. In summary, 4 of 554 trauma patients (0.72 %) received ESA for definitive airway management in an emergency surgery setting. No cases became CVCI situations, and there were no complications related to ESA. Patients with severe facial injury with AIS $\geq$ 3 received ESA 14 times more often than others, and these patients are considered at high risk of having difficult airways. The most important function of anesthesiologists is risk management. We should recognize risks that can cause CVCI situations, and make proper clinical decisions, including performing ESA, to assure patient safety.

Conflict of interest The authors report no conflicts of interest.

Appendix

The Injury Severity Score (ISS) is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned a value according to the Abbreviated Injury Scale (AIS), allocated to one of six body regions (head, face, chest, abdomen or pelvic contents, extremities or pelvic girdle, external). The AIS was first introduced in 1969. Since this time it has been revised and updated. The latest incarnation of the AIS score is the 1990 revision (AIS-90), and we used the AIS-90 in this study. Only the highest AIS score in each body region is used. The scores of the three most severely injured body regions are squared and added together to produce the ISS score. The ISS score includes values from 0 to 75. If an injury is assigned an AIS of 6 (unsurvivable injury), the assigned ISS score is automatically 75. The ISS score is virtually the only anatomical scoring system in use and correlates with mortality, morbidity, hospital stay, and other measures of severity.

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