Alternate Airways in the Prehospital Setting (Resource Document to NAEMSP Position Statement)

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Introduction

In the United States, advanced level rescuers often use endotracheal intubation (ETI) to provide oxygenation and ventilation to apneic or hypoventilating patients. Alternate airways are devices that facilitate oxygenation and ventilation without the use of an endotracheal tube (Table 1). Other terms used to describe an alternate airway include rescue airway device, alternative airway, secondary airway, failed airway device, difficult airway device, salvage airway and backup airway, among others. Although rescuers typically use alternate airways when ETI is not feasible, these devices are occasionally used as the primary airway device. This resource document reviews the rationale and data supporting the availability and use of alternate airways in prehospital airway care.

Need and Rationale for Alternate Airway Devices

Although paramedics in the United States are trained to perform ETI, the intervention is often unsuccessful or not possible. Prior studies have described unsuccessful ETI rates ranging from 8% to over 30%.[1–4] Although unsuccessful ETI may result from inadequate relaxation, many prehospital intubation failures occur on patients in cardiac arrest or without protective reflexes. This suggests that rescuers are often not able to visualize airway structures through laryngoscopy, whether due to the nature of airway anatomy, airway injury, rescuer skill, compromised patient position, or inadequate rescuer access.

Bag-valve-mask (BVM) ventilation is often used in the event of failed ETI efforts. However, despite its perception as a fundamental skill, this technique is extremely difficult to perform both in controlled and clinical settings.[5,6] BVM ventilation performance may improve by using a two-rescuer technique, but this may be difficult during prolonged transport or when there is a limited number of rescuers.[7]

In light of these observations, all prehospital services that perform ETI should have alternate airways available for clinical application. This resource document reviews the current literature and provides recommendations regarding the use of prehospital alternate airways.

Alternate Airway Devices

Blindly Inserted Airways

Blindly inserted airways are placed in the oropharynx without directly visualizing laryngeal structures. Designed for placement in either the supraglottic or infraglottic positions, these devices use one or more inflatable balloon cuffs to establish and isolate a patent airway.

Esophageal Tracheal Combitube (Esophageal Tracheal Dual Lumen Airway, Combitube)

The Esophageal Tracheal Combitube (ETC, The Kendall Company, Mansfield, Massachusetts) is a dual-lumen airway that is inserted blindly into the oropharynx. The ETC was originally developed as an alternate airway management device for cardiopulmonary resuscitation.[8] It was designed to provide a temporary airway for providers not skilled in endotracheal intubation.[9] The ETC was first described as a prehospital alternate device by Atherton and Johnson.[10]

The ETC has both theoretical and proven features. It can be inserted blindly and may provide some protection from aspiration.[11,12] The ETC protects against aspiration via a distal esophageal balloon.[13,14] Hagberg et al. suggested that the ETC protects against aspiration better than the laryngeal mask airway (LMA).[15] Prior efforts have verified the ease of its use.[9] Complications associated with ETC use include unrecognized tracheal intubation, pneumomediastinum, pneumoperitoneum, subcutaneous emphysema, perforation of the piriform sinus and those associated with ventilation of the wrong lumen.[16–18] Preliminary evidence suggests that these complications are rare, occurring in less than 1%.[17]

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TABLE 1. Types of Alternate Airways

Blindly Inserted airways
Laryngeal Mask Airway (LMA)
Esophageal Tracheal Combitube (ETC)
King Laryngeal Tube
Cobra Perilaryngeal Airway (Cobra PLA)
Magboul (Cuffed Oropharyngeal Airway - COPA)
Pharyngeal Tracheal Lumen Airway
Esophageal Obturator Airway (EOA)
Surgical airways
Open Cricothyroidotomy
Percutaneous Cricothyroidotomy
Transtracheal Jet Ventilation

The ETC is widely recognized in the United States, and its use in prehospital settings has been well described.[10,19,20,21] Ochs et al. demonstrated that EMT-Ds could successfully manage 79% of the airways in cardiac arrest cases with the ETC alone.[20] Davis et al. demonstrated the feasibility of ETC use as an alternate airway after failed neuromuscular blockade-assisted intubations.[21] Several authors have described ETC use by basic-level rescuers.[18,20]

Laryngeal Mask Airway

The laryngeal mask airway (LMA, North America, Inc., San Diego, CA, USA) was developed by Brain in 1981 as an alternative to BVM and ETI.[22,23] It was approved for use in the United States in 1991. Although the LMA is used primarily in the operating room setting, several authors have promoted its use in the emergency department and other in-hospital settings.[24–28]

The LMA is believed to cause less damage to the airway than other airway devices.[27] Because there is no balloon securing the device beneath the vocal cords, the risk of aspiration is theoretically higher with the LMA than the ETC or ETI.[15] However, there are currently no data specifically evaluating this phenomenon in the prehospital setting. The LMA may be of limited utility in patients with certain anatomic abnormalities or supraglottic airway obstruction.[24]

Limited studies have described LMA use in the prehospital setting. In a series of 470 prehospital patients, Rumball and McDonald collected arterial blood gas measurements on patients receiving prehospital ETC, pharygotracheal-laryngoscopy, and LMA; the LMA compared similarly with the other devices.[29,30] The LMA is used as a prehospital primary airway device in many countries such as the United Kingdom and Japan.[31,32] Experts have suggested the LMA as an alternate to prehospital ETI for pediatric patients, but supportive data are limited.[33–35]

King Laryngeal Tube (King LT) Airway

The King LT Airway (King Systems Corporation, Noblesville, Indiana) is a relatively new device that is similar in appearance to the ETC.[36] Like the ETC, the King LT device is placed blindly. However, the King LT has only a single lumen, and its shape facilitates more consistent placement in the correct esophageal position. The King LT was specifically designed for prehospital use. Anecdotal reports describe King LT use in prehospital and combat settings, but large-scale clinical data do not yet exist.

Surgical Airways

Surgical airways involve insertion of an airway tube or catheter into the trachea through an incision in the neck. In the United States, three types of surgical airways are commonly available in the prehospital environment: (1) open cricothyroidotomy, (2) percutaneous cricothyroidotomy, and (3) transtracheal jet ventilation.

Open Cricothyroidotomy

Open cricothyriodotomy involves the use of surgical tools (i.e., scalpel, etc.) to facilitate exposure of and insertion of a tracheal tube through the cricothyroid membrane.[37] This technique has been used for over 45 years.[38] Although described as a safe and rapid procedure, the technique requires adequate training for proper execution.[39–42] Cricothyroidotomy has been studied in the hospital and emergency department settings as both a primary and alternate airway.[43,44] Because of the plasticity of the pediatric airway, it is contraindicated in children less than 8 years old.

Several efforts have described cricothyroidotomy use in the prehospital environment.[42,45] Although widely taught, the prehospital application of cricothyroidotomy appears to be rare and associated with significant complications and poor outcomes.[37,42,46,47]

Percutaneous Cricothyroidotomy

Percutaneous cricothyroidotomy uses a modified Seldinger (guidewire) technique to facilitate location of and insertion of a tracheal tube through the cricothyroid membrane. Commercially packaged kits contain the equipment necessary to perfom the procedure.[48] The technique is believed to have fewer complications than open cricothyroidotomy.[49–51]

Percutaneous cricothyroidotomy was first described as an in-hospital alternate airway by Fischer.[52] Percutaneous cricothyroidotomy has been described in the anesthesia literature for difficult airway management.[53,54] Use of the percutaneous cricothyroidotomy was first described in the emergency department in 1992.[55]

The prehospital use of percutaneous cricothyroidotomy was proposed over a decade ago.[55] Several studies using cadavers and human simulators

have demonstrated the prehospital feasibility of this technique.[39,49,50] However, descriptions of clinical prehospital experience with percutaneous cricothyroidotomy are limited.

Transtracheal Jet Ventilation

Transtracheal jet ventilation involves the insertion of a large bore flexible catheter through the cricothyroid membrane to facilitate insufflation of high-pressure oxygen.[56] Although some passive exhalation of carbon dioxide occurs, the technique theoretically does not facilitate ventilation. The pressures generated from conventional oxygen regulators and BVM devices are insufficient for TTJV. Special regulators delivering oxygen at 50 psi must be used with TTJV.[57,58] TTJV is contraindicated in supraglottic obstruction, because no means of exhalation would be present.[59] It is the only form of surgical airway that can be used in small children.[60–62]

Several authors have described the use of TTJV for alternate airway management in the operating room and emergency department settings.[58,63,64] TTJV has been proposed as an alternative to prehospital cricothryoidotomy.[56,58,65] Field studies of TTJV do not exist.

Bag Valve Mask Ventilation and Other Alternate Airway Techniques

Other alternate airway management techniques merit comment. Although all prehospital rescuers are trained to use Bag-Valve-Mask (BVM) ventilation, the technique is relatively difficult. During BVM ventilation, it may be difficult for a single rescuer to simultaneously open the airway, maintain a mask seal, and deliver sufficient tidal volume. Two-rescuer BVM techniques may be more effective, but these approaches may not be practical under the constraints of the prehospital environment. Thus, while some services rely on BVM ventilation as a backup for unsuccessful ETI, because of its difficulty, the BVM is not recommended as the sole alternate airway technique.

The Esophageal Obturator Airway (EOA) was developed in the 1970s and used as a prehospital alternate device for many years. The device consists of a single lumen with a large balloon to obstruct the esophagus and indirectly ventilate the trachea. It has fallen out of favor because of significant complications, including inadvertent tracheal intubation and esophageal trauma.[69,70]

Other airway management devices include the Cuffed Oropharyngeal Airway (COPA, Mallinckrodt Inc., St. Louis, Missouri, USA), the Cobra Perilaryngeal Airway (Engineered Medical Systems, Inc., Indianapolis, Indiana, USA) and other single and multi-lumen airways such as the Pharyngeal Tracheal Lumen Airway (PTL). Descriptions of these devices in either in-hospital or prehospital application are limited.

RECOMMENDATIONS FOR PREHOSPITAL ALTERNATE AIRWAYS

Availability of Alternate Airways

Alternate airway devices should be available to all prehospital rescuers who perform ETI. In addition to the BVM device, all agencies should have at least one blindly inserted airway device available for clinical use.

The role of and need for prehospital surgical airway techniques are not clear at this time. Current data allude to significant concerns including complications and poor outcomes associated with prehospital surgical airway management. In addition, the training needed to maintain these skills is substantial. However, there may be clinical situations where surgical airway management is the only option (e.g., in cases of severe facial trauma). Medical directors must determine the need for prehospital surgical airways on an individual agency basis. Agencies should not rely on surgical airways as the sole alternate airway management technique.

Training in Alternate Airway Use

Medical directors must ensure adequate training in the use of available alternate airways. Acquisition and maintenance of alternate airway skills are important because their clinical use may occur infrequently and under emergent conditions. Training should encompass didactic, simulated, and practical experiences.[71–73] Although training on live patients in controlled settings is desirable, this may not be practical for most alternate airways. For example, operating room patients rarely receive elective cricothyroidotomy, and Combitubes are rarely used in the operating room. Although LMAs are used widely in the operating room, rescuers using LMAs should receive additional training in urgent and emergent contexts.

Clinical Indications for Alternate Airway Use

Clinical indications for alternate airway use have not been formally or scientifically derived. However, a practical recommendation is that alternate airways should be used after failed ETI attempts or in situations where initial or ongoing ETI efforts are predicted to be difficult or futile. "Difficult" conditions may include situations involving difficult airway anatomy, severe airway trauma, or inadequate operator skill, among others. Difficult airway conditions may be identified before or after initial intubation attempts. In situations where airway management difficulty clearly exceeds the skill of the operator, it is recommended that rescuers defer ETI efforts and proceed directly to alternate airway insertion.

Clinical protocols should define broad guidelines for alternate airway use. Scientific and consensus guidelines suggest that ETI efforts should be abandoned (and alternate airway inserted) after no more than three ETI attempts (insertion of blade).[74,75] The prompt availability of online medical command may help to facilitate prudent airway management decision making in scenarios involving failed ETI or alternate airway use. However, because of the emergent nature of airway management efforts, clinical protocols should permit alternate airway insertion without online medical command authorization.

Primary Use of Alternate Airways

Many international EMS agencies use alternate airways in a primary capacity.[76,77] Several sources describe alternate airway use by basic level rescuers.[18,20] Current Advanced Cardiac Life Support recommendations suggest that when adequately skilled personnel are not available, ETI may be substituted with an alternate airway device.[78] Although this strategy has not been formally evaluated or compared with ETI, this approach does have many appealing features, including the simplification of airway management and the reduction of potential impact on other concurrent interventions. In a trial using human simulators, Abo et al. showed that compared with traditional ETI, ETC insertion reduced the time to airway placement as well as the time without chest compressions.[79] This area merits additional scientific study.

Quality Assurance and Quality Improvement

Alternate airway use should be monitored by a comprehensive quality assurance and quality improvement program. EMS medical directors should participate in continuous quality improvement (CQI) activities and have access to all the reviewed airway data. All uses of alternate and salvage airways should be documented as described in the NAEMSP position paper "Recommended Guidelines for Uniform Reporting of Data from Prehospital Airway Management."[80]

Collection of alternate airway data should include (1) indications for invasive airway management, (2) number of attempts at ETI and alternate airway, (3) relevant clinical and physiological factors, (4) methods and devices used, (5) outcomes (success at alternate airway placement), (6) outcomes (success of overall effort), (7) method of confirming proper placement of the airway, (8) physiological changes in patient condition during and after airway management, (9) critical complications encountered in airway management, and (10) reasons for failed ETI or primary use of the alternate airway device. Patient follow-up including linkage to in-hospital course is strongly recommended; these records often are the only indicators of prehospital airway management complications.

CONSIDERATIONS FOR FUTURE RESEARCH

Additional scientific study is needed to improve our understanding of the use of alternate and surgical airways. Specific areas requiring evaluation include (1) clinical indications for alternate airway use; (2) device monitoring, including the identification of physiological response to insertion of, and ventilation through, alternate airways; (3) clinical outcomes after alternate airway use, including morbidity and mortality; (4) education programs and training using both live patients and human simulation; and (5) comparisons of cost and operational impacts.

CONCLUSION

All prehospital agencies and rescuers that perform endotracheal intubation should have the availability of at least one blindly inserted alternate airway device. All rescuers should receive adequate training in alternate airway use. Medical directors should closely monitor the use of alternate airways.

References

1. Wang HE, Sweeney TA, O'Connor RE, Rubinstein H. Failed prehospital intubations: an analysis of emergency department courses and outcomes. Prehosp Emerg Care. Apr-Jun 2001;5(2):134–141.
2. Wang HE, Kupas DF, Paris PM, Bates RR, Yealy DM. Preliminary Experience with a Prospective Multi-centered Evaluation of Out-of-Hospital Endotracheal Intubation. Resuscitation 2003;58:49–58.
3. Krisanda TJ, Eitel DR, Hess D, Ormanoski R, Bernini R, Sabulsky N. An analysis of invasive airway management in a suburban emergency medical services system. Prehospital Disaster Med. Apr-Jun 1992;7(2):121–126.
4. Wang HE, O'Connor RE, Schnyder ME, Barnes TA, Megargel RE. Patient Status and Time to Intubation in the Assessment of Prehospital Intubation Performance. Prehospital Emergency Care. 2001;5:10–18.
5. Kurola J, Harve H, Kettunen T, et al. Airway management in cardiac arrest–comparison of the laryngeal tube, tracheal intubation and bag-valve mask ventilation in emergency medical training. *Resuscitation.* May 2004;61(2):149–153.
6. Kurola JO, Turunen MJ, Laakso JP, Gorski JT, Paakkonen HJ, Silfvast TO. A comparison of the laryngeal tube and bag-valve mask ventilation by emergency medical technicians: a feasibility study in anesthetized patients. Anesth Analg. Nov 2005;101(5):1477–1481.
7. Davidovic L, LaCovey D, Pitetti RD. Comparison of 1- versus 2-person bag-valve-mask techniques for manikin ventilation of infants and children. Ann Emerg Med. Jul 2005;46(1):37–42.
8. Frass M, Frenzer R, Ilias W, Lackner F, Hoflehner G, Losert U. [The esophageal tracheal Combitube (ETC): animal experiment results with a new emergency tube]. Anasth Intensivther Notfallmed. Jun 1987;22(3):142–144.

9. Frass M, Frenzer R, Mayer G, Popovic R, Leithner C. Mechanical ventilation with the esophageal tracheal combitube (ETC) in the intensive care unit. Arch Emerg Med. Dec 1987;4(4):219–225.
10. Atherton GL, Johnson JC. Ability of paramedics to use the Combitube in prehospital cardiac arrest. Ann Emerg Med. Aug 1993;22(8):1263–1268.
11. Agro F, Frass M, Benumof JL, Krafft P. Current status of the Combitube: a review of the literature. J Clin Anesth. Jun 2002;14(4):307–314.
12. Mercer MH. An assessment of protection of the airway from aspiration of oropharyngeal contents using the Combitube airway. Resuscitation. Nov 2001;51(2):135–138.
13. Hartmann T, Krenn CG, Zoeggeler A, Hoerauf K, Benumof JL, Krafft P. The oesophageal-tracheal Combitube Small Adult. Anaesthesia. Jul 2000;55(7):670–675.
14. Urtubia RM, Carcamo CR, Montes JM. Complications following the use of the Combitube, tracheal tube and laryngeal mask airway. Anaesthesia. Jun 2000;55(6):597–599.
15. Hagberg CA, Vartazarian TN, Chelly JE, Ovassapian A. The incidence of gastroesophageal reflux and tracheal aspiration detected with pH electrodes is similar with the Laryngeal Mask Airway and Esophageal Tracheal Combitube–a pilot study. Can J Anaesth. Mar 2004;51(3):243–249.
16. Richards CF. Piriform sinus perforation during Esophageal-Tracheal Combitube placement. J Emerg Med. Jan-Feb 1998;16(1):37–39.
17. Vezina D, Lessard MR, Bussieres J, Topping C, Trepanier CA. Complications associated with the use of the Esophageal-Tracheal Combitube. Can J Anaesth. Jan 1998;45(1):76–80.
18. Lefrancois DP, Dufour DG. Use of the esophageal tracheal combitube by basic emergency medical technicians. Resuscitation. Jan 2002;52(1):77–83.
19. Deakin CD. Prehospital management of the traumatized airway. Eur J Emerg Med. Dec 1996;3(4):233–243.
20. Ochs M, Vilke GM, Chan TC, Moats T, Buchanan J. Successful prehospital airway management by EMT-Ds using the combitube. Prehosp Emerg Care. Oct-Dec 2000;4(4):333–337.
21. Davis DP, Valentine C, Ochs M, Vilke GM, Hoyt DB. The Combitube as a salvage airway device for paramedic rapid sequence intubation. Ann Emerg Med. Nov 2003;42(5):697–704.
22. Brain AI. The laryngeal mask–a new concept in airway management. Br J Anaesth. Aug 1983;55(8):801–805.
23. Brain AI. The laryngeal mask airway–a possible new solution to airway problems in the emergency situation. Arch Emerg Med. Dec 1984;1(4):229–232.
24. Pollack CV, Jr. The laryngeal mask airway: a comprehensive review for the Emergency Physician. J Emerg Med. Jan 2001;20(1):53–66.
25. Dob DP, Shannon CN, Bailey PM. Efficacy and safety of the laryngeal mask airway vs Guedel airway following tracheal extubation. Can J Anaesth. Feb 1999;46(2):179–181.
26. Verghese C, Brimacombe JR. Survey of laryngeal mask airway usage in 11,910 patients: safety and efficacy for conventional and nonconventional usage. Anesth Analg. Jan 1996;82(1):129–133.
27. Springer DK, Jahr JS. The laryngeal mask airway. Safety, efficacy, and current use. Am J Anesthesiol. Mar-Apr 1995;22(2):65–69.
28. Reardon RF, Martel M. The intubating laryngeal mask airway: suggestions for use in the emergency department. Acad Emerg Med. Aug 2001;8(8):833–838.
29. Rumball CJ, MacDonald D. The PTL, Combitube, laryngeal mask, and oral airway: a randomized prehospital comparative study of ventilatory device effectiveness and cost-effectiveness in 470 cases of cardiorespiratory arrest. Prehosp Emerg Care. Jan-Mar 1997;1(1):1–10.
30. Barbieri S, Michieletto E, Di Giulio M, et al. Prehospital airway management with the laryngeal mask airway in polytraumatized patients. Prehosp Emerg Care. Jul-Sep 2001;5(3):300–303.
31. Ridgway S, Hodzovic I, Woollard M, Latto IP. Prehospital airway management in Ambulance Services in the United Kingdom. Anaesthesia. Nov 2004;59(11):1091–1094.
32. O'Malley RN, O'Malley GF, Ochi G. Emergency medicine in Japan. Ann Emerg Med. Oct 2001;38(4):441–446.
33. Patterson MD. Resuscitation update for the pediatrician. Pediatr Clin North Am. Dec 1999;46(6):1285–1303.
34. McNiece WL, Dierdorf SF. The pediatric airway. Semin Pediatr Surg. Aug 2004;13(3):152–165.
35. Berry AM, Brimacombe JR, Verghese C. The laryngeal mask airway in emergency medicine, neonatal resuscitation, and intensive care medicine. Int Anesthesiol Clin. Spring 1998;36(2):91–109.
36. Hagberg C, Bogomolny Y, Gilmore C, Gibson V, Kaitner M, Khurana S. An evaluation of the insertion and function of a new supraglottic airway device, the King LT, during spontaneous ventilation. Anesth Analg. Feb 2006;102(2):621–625.
37. Xeropotamos NS, Coats TJ, Wilson AW. Prehospital surgical airway management: 1 year's experience from the Helicopter Emergency Medical Service. Injury. Apr 1993;24(4):222–224.
38. Nelson TG, Rumer GF, Nicholas TH. Cricothyroidotomy in complete airway obstruction. Am J Nurs. Nov 1961;61:74–76.
39. Wong DT, Prabhu AJ, Coloma M, Imasogie N, Chung FF. What is the minimum training required for successful cricothyroidotomy?: a study in mannequins. Anesthesiology. Feb 2003;98(2):349–353.
40. Chang RS, Hamilton RJ, Carter WA. Declining rate of cricothyrotomy in trauma patients with an emergency medicine residency: implications for skills training. Acad Emerg Med. Mar 1998;5(3):247–251.
41. O'Connor D, Longhorn R, Heard A. Emergency surgical airway training in Western Australia. Anaesthesia. Sep 2004;59(9):919.
42. Salvino CK, Dries D, Gamelli R, Murphy-Macabobby M, Marshall W. Emergency cricothyroidotomy in trauma victims. *J Trauma.* Apr 1993;34(4):503–505.
43. Bair AE, Panacek EA, Wisner DH, Bales R, Sakles JC. Cricothyrotomy: a 5-year experience at one institution. J Emerg Med. Feb 2003;24(2):151–156.
44. Jones I, Roberts K. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. To stab or slash: the percutaneous dilatation or standard surgical approach to cricothyroidotomy in prehospital care. Emerg Med J. Sep 2002;19(5):434.
45. Granholm T, Farmer DL. The surgical airway. Respir Care Clin N Am. Mar 2001;7(1):13–23.
46. Bulger EM, Copass MK, Maier RV, Larsen J, Knowles J, Jurkovich GJ. An analysis of advanced prehospital airway management. J Emerg Med. Aug 2002;23(2):183–189.
47. Fortune JB, Judkins DG, Scanzaroli D, McLeod KB, Johnson SB. Efficacy of prehospital surgical cricothyrotomy in trauma patients. J Trauma. May 1997;42(5):832–836; discussion 837–838.
48. Melker JS, Gabrielli A. Melker cricothyrotomy kit: an alternative to the surgical technique. Ann Otol Rhinol Laryngol. Jul 2005;114(7):525–528.
49. Keane MF, Brinsfield KH, Dyer KS, Roy S, White D. A laboratory comparison of emergency percutaneous and surgical cricothyrotomy by prehospital personnel. Prehosp Emerg Care. Oct-Dec 2004;8(4):424–426.
50. Johnson DR, Dunlap A, McFeeley P, Gaffney J, Busick B. Cricothyrotomy performed by prehospital personnel: a comparison of two techniques in a human cadaver model. Am J Emerg Med. May 1993;11(3):207–209.
51. Schaumann N, Lorenz V, Schellongowski P, et al. Evaluation of Seldinger technique emergency cricothyroidotomy versus standard surgical cricothyroidotomy in 200 cadavers. Anesthesiology. Jan 2005;102(1):7–11.
52. Fisher JA. A "last ditch" airway. Can Anaesth Soc J. May 1979;26(3):225–230.

53. Dob DP, McLure HA, Soni N. Failed intubation and emergency percutaneous tracheostomy. Anaesthesia. Jan 1998;53(1): 72–74.
54. Wong DT, Lai K, Chung FF, Ho RY. Cannot intubate-cannot ventilate and difficult intubation strategies: results of a Canadian national survey. Anesth Analg. May 2005;100(5):1439–1446, table of contents.
55. Ciaglia P, Brady C, Graniero KD. Emergency percutaneous dilatational cricothyroidostomy: use of modified nasal speculum. Am J Emerg Med. Mar 1992;10(2):152–155.
56. Rich JM, Mason AM, Bey TA, Krafft P, Frass M. The critical airway, rescue ventilation, and the combitube: Part 1. Aana J. Feb 2004;72(1):17–27.
57. Yealy DM, Stewart RD, Kaplan RM. Myths and pitfalls in emergency translaryngeal ventilation: correcting misimpressions. Ann Emerg Med. Jul 1988;17(7):690–692.
58. Smith RB, Babinski M, Klain M, Pfaeffle H. Percutaneous transtracheal ventilation. Jacep. Oct 1976;5(10):765–770.
59. Yealy DM, Menegazzi JJ, Ward KR. Transtracheal jet ventilation and airway obstruction. Am J Emerg Med. Mar 1991;9(2): 200.
60. Auble TE, Menegazzi JJ, Nicklas KA. Comparison of automated and manual ventilation in a prehospital pediatric model. Prehosp Emerg Care. Apr-Jun 1998;2(2):108–111.
61. Yealy DM, Plewa MC, Stewart RD. An evaluation of cannulae and oxygen sources for pediatric jet ventilation. Am J Emerg Med. Jan 1991;9(1):20–23.
62. Wheeler M. Management strategies for the difficult pediatric airway. Middle East J Anesthesiol. Jun 2004;17(5):845–873.
63. Benumof JL. Management of the difficult airway. Ann Acad Med Singapore. Jul 1994;23(4):589–591.
64. Depierraz B, Ravussin P, Brossard E, Monnier P. Percutaneous transtracheal jet ventilation for paediatric endoscopic laser treatment of laryngeal and subglottic lesions. Can J Anaesth. Dec 1994;41(12):1200–1207.
65. Vitberg DA, Reed DB. Crackdown on crics. Needle cricthryotomy & percutaneous transtracheal jet ventilation explained. Jems. Mar 2001;26(3):58–62, 64–55, 78–59 passim.
66. Elling R, Politis J. An evaluation of emergency medical technicians' ability to use manual ventilation devices. Ann Emerg Med. Dec 1983;12(12):765–768.
67. Cummins RO, Austin D, Graves JR, Litwin PE, Pierce J. Ventilation skills of emergency medical technicians: A teaching challenge for emergency medicine. Ann Emerg Med. Oct 1986;15(10):1187–1192.
68. Seidelin PH, Stolarek IH, Littlewood DG. Comparison of six methods of emergency ventilation. Lancet. Nov 29 1986;2(8518):1274–1275.
69. Hankins DG, Carruthers N, Frascone RJ, Long LA, Campion BC. Complication rates for the esophageal obturator airway and endotracheal tube in the prehospital setting. Prehospital Disaster Med. Apr-Jun 1993;8(2):117–121.
70. Smith JP, Bodai BI, Seifkin A, Palder S, Thomas V. The esophageal obturator airway. A review. JAMA. Aug 26 1983;250(8):1081–1084.
71. Schaefer JJ, 3rd. Simulators and difficult airway management skills. Paediatr Anaesth. Jan 2004;14(1):28–37.
72. Berridge PD, Pollock KM, Longhorn RK, Heard AM. Emergency airway equipment and training. Anaesthesia. Mar 2005;60(3):291; author reply 292.
73. Zirkle M Blum R, Raemer DB, Healy G, Roberson DW. Teaching emergency airway management using medical simulation: a pilot program. Laryngoscope. Mar 2005;115(3):495–500.
74. Wang HE, Kupas DF, Greenwood MJ, et al. An algorithmic approach to prehospital airway management. Prehosp Emerg Care. Apr-Jun 2005;9(2):145–155.
75. Wang HE, Yealy DM. How many attempts are required to accomplish out-of-hospital endotracheal intubation? Acad Emerg Med. Apr 2006;13(4):372–377.
76. Staudinger T, Brugger S, Roggla M, et al. [Comparison of the Combitube with the endotracheal tube in cardiopulmonary resuscitation in the prehospital phase]. Wien Klin Wochenschr. 1994;106(13):412–415.
77. Tanigawa K, Shigematsu A. Choice of airway devices for 12,020 cases of nontraumatic cardiac arrest in Japan. Prehosp Emerg Care. Apr-Jun 1998;2(2):96–100.
78. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care: Part 7.1: Adjuncts for Airways Control and Ventilation. *Circulation.* December 13, 2005. 2005;112(24_suppl):IV-51–57.
79. Abo BN, Hostler D, Wang HE. Does the Type of Out of Hospital Airway Interfere with Other Cardiopulmonary Resuscitation Tasks? Resuscitation (in press). Resuscitation. 2006.
80. Wang HE, Domeier RM, Kupas DF, Greenwood MJ, O'Connor RE. Recommended Guidelines for Unifrom Reporting of Data from Out-of-Hospital Airway Management: Position Statement of the National Association of EMS Physicians. Prehospital Emergency Care. 2004;8:58–72.