Percutaneous Transtracheal Ventilation: Resuscitation Bags Do Not Provide Adequate Ventilation

Edmond A. Hooker, MD;[1,2] Daniel F. Danzl, MD;[2] Daniel O'Brien, MD;[2] Michael Presley, MD;[2] Ginger Whitaker;[3] M. Keith Sharp, ScD[3]

1. Department of Health Services Administration, Xavier University, Cincinnati, Ohio USA
2. Department of Emergency Medicine, University of Louisville, School of Medicine, Louisville, Kentucky USA
3. Department of Mechanical Engineering, University of Louisville, School of Medicine, Louisville, Kentucky USA

Correspondence:
Edmond A. Hooker, MD
Department of Health Services Administration
Xavier University
3800 Victory Parkway
Cincinnati, OH 45207-7331 USA
E-mail: hookere@xavier.edu

This research was presented at the Southeastern Regional Research Meeting of the Society for Academic Emergency Medicine, 08–09 April, 2005 Chapel Hill, North Carolina

Keywords: artificial respiration; catheterization; cricoid cartilage; emergency medical services; high-frequency jet ventilation; intratracheal intubation; resuscitation; tracheostomy; tracheotomy

Abbreviations:
ID = internal diameter
JV = jet ventilator
PTJV = percutaneous transtracheal jet ventilation
PTV = percutaneous transtracheal ventilation

Received: 16 August 2005
Accepted: 19 April 2006
Revised: 10 May 2006

Web publication: 11 December 2006

Abstract

Introduction: Percutaneous, transtracheal jet ventilation (PTJV) is an effective way to ventilate both adults and children. However, some authors suggest that a resuscitation bag can be utilized to ventilate through a cannula placed into the trachea.

Hypothesis: Percutaneous transtracheal ventilation (PTV) through a 14-gauge catheter is ineffective when attempted using a resuscitation bag.

Methods: Eight insufflation methods were studied. A 14-gauge intravenous catheter was attached to an adult resuscitation bag, a pediatric resuscitation bag, wall-source (wall) oxygen, portable-tank oxygen with a regulator, and a jet ventilator (JV) at two flow rates. The resuscitation bags were connected to the 14-gauge catheter using a 7 mm adult endotracheal tube adaptor connected to a 3 cc syringe barrel. The wall and tank oxygen were connected to the 14-gauge catheter using a three-way stopcock. The wall oxygen was tested with the regulator set at 15 liters per minute (LPM) and with the regulator wide open. The tank was tested with the regulator set at 15 and 25 LPM. The JV was connected directly to the 14-gauge catheter using JV tubing supplied by the manufacturer. Flow was measured using an Ohmeda 5420 Volume Monitor. A total of 30 measurements were taken, each during four seconds of insufflation, and the results averaged (milliliters (ml) per second (sec)) for each device.

Results: Flow rates obtained using both resuscitation bags, tank oxygen, and regulated wall oxygen were extremely low (adult 215 ±20 ml/sec; pediatric 195 ±19 ml/sec; tank 358 ±13 ml/sec; wall at 15 l/min 346 ±20 ml/sec). Flow rates of 1,394 ±13 ml were obtained using wall oxygen with the regulator wide open. Using the JV with the regulator set at 50 pounds per square inch (psi), a flow rate of 1,759 ±40 was obtained. These were the only two methods that produced flow rates high enough to provide an adequate tidal volume to an adult.

Conclusions: Resuscitation bags should not be used to ventilate adult patients through a 14-gauge, transtracheal catheter. Jet ventilation is needed when percutaneous transtracheal ventilation is attempted. If jet ventilation is attempted using oxygen supply tubing, it must be connected to an unregulated oxygen source of at least 50 psi.

Hooker E, Danzl DF, O'Brien D, Presley M, Whitaker G, Sharp K: Percutaneous transtracheal ventilation: Resuscitation bags do not provide adequate ventilation. *Prehosp Disast Med* 2006;21(6):431–435.

Introduction

Ventilation of humans through a catheter placed in the trachea has been practiced for at least 50 years, although it was not until 1971 that the first study of a large series of cases was published.[1,2] In 1972, Jacobs reported a series of patients successfully resuscitated using a catheter placed through the cricoidthyroid membrane.[3] Since then, there have been many reports of successful ventilation of humans using catheters placed into the trachea.[1,3–12] This can be done by directly inserting the catheter between the tracheal rings or through the cricoid membrane. All of these investigators utilized jet ventilation with high-pressure oxygen sources of at least 50 pounds per square inch (psi) (2,585 mmHg) for adults. Pediatric patients have been resuscitated using

lower pressures between 30–40 psi (1,551–2,068 mmHg).[5,8] Low flow oxygen (4 liters per minute (LPM)) can oxygenate patients through an 18-gauge needle in patients with spontaneous respirations.[2] Catheters utilized in the successful resuscitation of apneic adults vary from 14–18-gauge catheters. Catheters used in children also have varied in size from 14–18-gauge.

There are many terms that have been used to describe these various techniques of ventilation using a catheter placed percutaneously into the tracheal lumen: (1) needle cricothyroidotomy; (2) translaryngeal ventilation; (3) transtracheal ventilation; (4) percutaneous transtracheal ventilation (PTV); (5) percutaeous transtracheal jet ventilation (PTJV); (6) tracheotomy; and (7) tracheostomy. None of these are exactly correct anatomically for what most emergency physicians and paramedics perform—a transcricoid membrane puncture and placement of a catheter. In this manuscript, the terms PTV and PTJV will be utilized.

Simple modifications using readily available equipment have been proposed when a commercially available jet ventilator (JV) is not used. Oxygen supply tubing can be coupled with a three-way stopcock, effectively creating a manual JV. This configuration was tested using a G cylinder at 50 psi with the regulator wide open in a canine model.[13] Adequate ventilation was achieved with inspiratory time between two and eight seconds. Dunlap suggested a similar setup utilizing a three-way valve and oxygen supply tubing.[14] This was used to successfully ventilate three adults. If the patient is in the operating room, modifications have been suggested to connect the anesthesia machine directly to the catheter.[15–17] All of these modifications still utilize jet ventilation by activating the oxygen flush valve.

The other modifications involve the use of a bag-valve or resuscitation bag to accomplish PTV. Attia *et al* suggest using a 3 mm pediatric, endotracheal tube adapter attached to a resuscitation bag.[18] Reich and Schwartz suggest using an 6.5–8.0 mm endotracheal tube inserted into a 10 ml disposable syringe that has the plunger removed.[19] Gildar *et al* had the same idea as Reich, except the authors utilized a 12 ml syringe barrel.[20] The only method actually tested in animals was the method proposed by Attia *et al*.[18] Cote showed that oxygenation could be maintained in a dog utilizing a 12-gauge catheter, but the level of ventilation produced was inadequate with CO_2 almost doubling.[21] It also took extreme physical effort on the part of the anesthesiologist to attempt to ventilate using a resuscitation bag, and personnel had to be changed frequently. Neff *et al* showed that sheep could be ventilated with a resuscitation bag if a catheter with internal diameter (ID) of 3 mm was used, but not if a smaller catheter was used.[22] There are no reported successful resuscitations of humans utilizing any of these configurations.

Yealy *et al* evaluated several methods of insufflation through varying size catheters.[23] Flow rates achievable with a resuscitation bag did not provide adequate tidal volumes to ventilate an adult. Even with a 4 mm ID catheter, only 850 ml of flow per second could be generated with maximal effort of the rescuer squeezing the bag. Approximately half of the oxygen insufflated through a transtracheal catheter will escape through the mouth.[4] Based on animal research, flow rates of 1,166 ml/sec would be needed to ventilate a 70 kilogram patient based on one second of ventilation every five seconds.[24]

Despite the lack of efficacy of a resuscitation bag for ventilating through a transtracheal catheter, some authors suggest that a resuscitation bag is a viable method to resuscitate via PTV.[25–27] Paramedic protocols available online contain the use of a resuscitation bag.[28]

The purpose of the current research is to expand on the previous research regarding the use of a resuscitation bag for ventilation through a 14-gauge catheter used for PTV, and to study other options for proper ventilation via PTV.

Methods

Design

The study was performed in a laboratory.

Observations

A 14-gauge intravenous catheter 1.75 in, 45 mm long (ID = 1.5 mm) was selected for the experiments. Five different devices for insufflation were tested: (1) adult resuscitation bag (Vital Signs; Code Blue II); (2) pediatric resuscitation bag (Vital Signs; Pedi Blue); (3) wall-source (wall) oxygen; (4) portable-tank (tank) oxygen (E cylinder (682 l)) with a regulator (Life Support Products Inc., St. Louis, MO) Model #270–060); and (5) a JV (BE 183-SUR, Instrumentation Industries, Inc., Bethel Park, PA). The resuscitation bags were connected to the 14-gauge catheter using a 7 mm adult endotracheal tube adapter connected to a 3 ml syringe (Figure 1). The wall and tank oxygen were connected to the 14-gauge catheter using a three-way stopcock (Figure 2). The wall oxygen was tested with the flow regulator (Ohmeda flowmeter, GE Healthcare) set at 15 LPM or with the regulator wide open. The manufacturer's product specifications indicate that flow rates of 65 LPM can be obtained when the regulator is set at "wide open". The tank was tested with a regulator set at 15 and 25 LPM (25 LPM is the highest possible setting for the regulator). The JV was connected directly to the 14-gauge catheter using JV tubing supplied by the manufacturer (Figure 3). The JV connected to the wall oxygen source.

Flow was measured using an Ohmeda 5420 Volume Monitor (Datex-Ohmeda, Louisville, KY) (Figure 4). A total of 30 measurements were taken, each for four seconds of insufflation. The results were averaged (ml/sec) for each device. When using the adult and pediatric resuscitation bags, a 180-pound emergency physician compressed the bag with maximum effort for the entire four seconds.

Statistics

Descriptive statistics were utilized including mean values and standard deviation. All calculations were done utilizing Statistical Package for the Social Sciences (SPSS) version 11.5 (SPSS Inc., Chicago, IL).

Results

The flow rates and the estimated tidal volumes for the various methods of insufflation are listed in Table 1. The highest flow rates were obtained utilizing a JV set at 50 psi

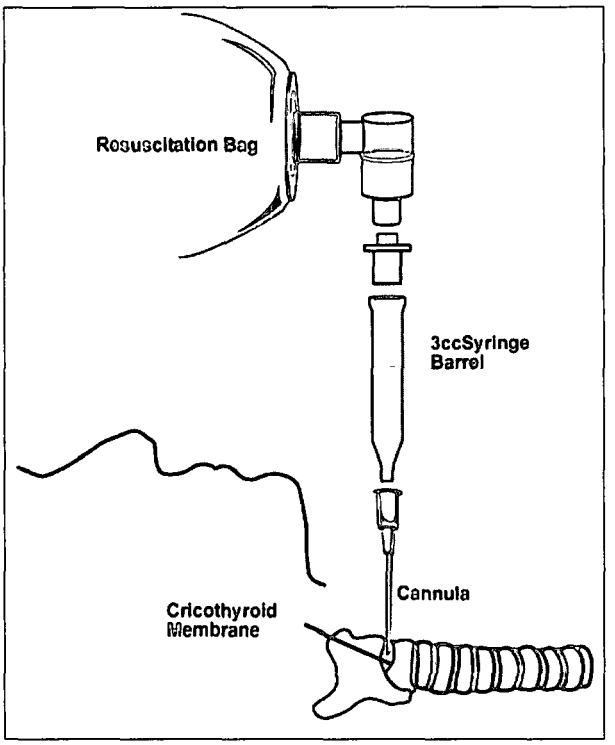

Figure 1—Schematic of resuscitation bag (bag-valve) connected to a needle cricothyroidotomy

(1,759 ±40 ml/sec) and unregulated wall oxygen (1,394 ±13 ml/sec). Flow rates obtained using both resuscitation bags, tank oxygen, and regulated wall oxygen were lower. Flow rates obtained using both resuscitation bags, tank oxygen, and regulated wall oxygen were extremely low (adult 215 ±20 ml/sec; pediatric 195 ±19 ml/sec; tank 358 ±13 ml/sec; wall at 15 l/min 346 ±20 ml/sec).

Discussion

Using wall oxygen with the regulator wide open and the JV with the regulator set at 50 psi were the only two methods that produced a flow rate high enough to provide an adequate tidal volume to an adult when utilizing a 14-gauge catheter. The tidal volume achievable with resuscitation bags would be inadequate. In addition to generating inadequate tidal volumes, the effort required by the rescuer to continue to compress the resuscitation bag could not be maintained for more than a brief period.

This study confirms previous research by Yealy and Neff *et al* that showed that a resuscitation bag does not produce adequate flow of oxygen to ventilate an adult through a 14-gauge catheter, placed for PTV.[22,23] All previous reports of successful PTV of adult patients utilized 14–18-gauge catheters and the patients were ventilated by jet ventilation with 50–60 psi oxygen sources.[1,3–5,7] While it seems appropriate to suggest modification with readily available equipment, none of the suggested modifications utilizing resuscitation bags have been evaluated on humans prior to their publication in the literature.[18,19,29] There have been no subsequent reports of their successful use in humans. Despite this evidence, authors continue to recommend modifications utilizing a resuscitation bag.[27]

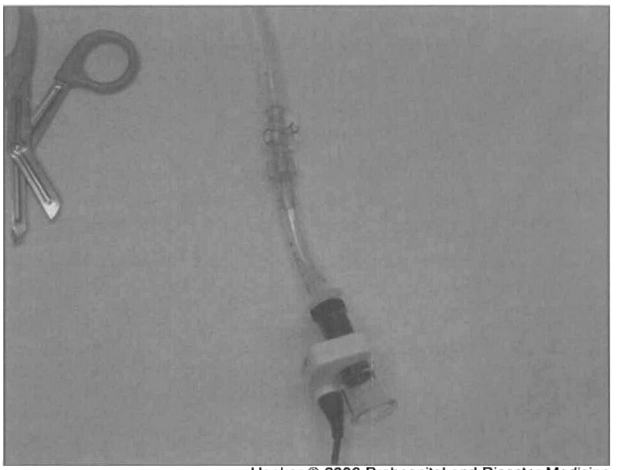

Figure 2—Experimental setup: Wall and tank oxygen connected to three-way stopcock that was connected to a 14-gauge catheter

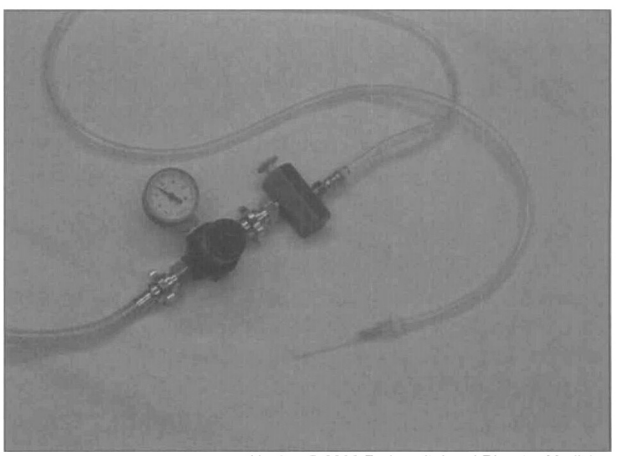

Figure 3—Experimental set-up: Jet ventilator connected directly to a 14-gauge catheter using jet ventilator tubing supplied by the manufacturer

Figure 4—Experimental set-up: Bag valve connected to a 7 mm adult endotracheal tube adaptor connected to a 3 cc syringe that was connected to a 14-gauge catheter syringe and then to the flow meter

https://doi.org/10.1017/S1049023X00004155 Published online by Cambridge University Press

Insufflation Method	Flow Rate ±SD (ml/sec)	Expected Tidal Volume* (ml)
Adult resuscitation bag	215 ±20	113
Pediatric resuscitation bag	195 ±19	98
Tank oxygen at 15 liters/min	358 ±13	179
Tank oxygen at 25 liters/min	558 ±20	279
Wall Oxygen at 15 liters/min	346 ±20	173
Wall oxygen at wide open	1,394 ±13	697
JV (25 psi)	1,000 ±20	500
JV (50 psi)	1,759 ±40	880

Table 1—Flow rates and expected tidal volume through 14-gauge catheter (JV = jet ventilator; min = minutes)
*Based on one second of insufflation and 50% air leak

After reviewing the literature, it seems inappropriate to suggest that PTV be done without utilizing jet ventilation. This can be achieved with commercially available automatic and manual JVs. If these are unavailable, the use of oxygen supply tubing and a stopcock should achieve the same results.[13,14] The unregulated, wall oxygen should provide jet ventilation at around 65 psi. Regulated oxygen at 15 LPM, or even 25 LPM, is unlikely to produce adequate tidal volume and ventilation for adults. The suggestion by some emergency medical services that low flow oxygen at 15 LPM can be used is not supported by the literature or the current research.[30] By utilizing the jet ventilation, the patient actually is being ventilated and not just oxygenated. The high flow rates force the CO_2 out of the lungs.[3–5] Manual JVs can be purchased for <(US)$200. These are supplied with all of the necessary attachments and eliminate the need to look for additional equipment.

Another important reason to utilize jet ventilation is to prevent aspiration. In an animal model, manual translaryngeal jet ventilation offered protection from aspiration equivalent to that obtained with ventilation through a cuffed endotracheal tube.[31]

The choice of a catheter for PTJV is somewhat problematic. Jacobs *et al* utilized a specially designed 14-gauge catheter, not a standard intravenous catheter.[3,4] In a multicenter study with 643 patients reported by Bourgain *et al*, specialized catheters were utilized.[7] Smith *et al*, in his two series with a combined total of 170 patients, utilized standard 14-gauge intravenous catheters.[5,32] There have been reports of kinking and inability to ventilate patients when standard 14-gauge intravenous catheters are utilized.[33] Smith suggested that the 14-gauge catheter be held manually at the hub to prevent kinking.[32] Newer catheters designed for intravenous insertion have been made safer in order to prevent needle sticks of providers. However, some of these designs may not allow these catheters to have a syringe attached to aid in insertion.[34]

The major limitation of the study was the laboratory design. The resuscitation bag attached to a cannula in either an animal or human model was not tested. Another limitation is that different sizes of catheters were not used. The results with the 14-gauge catheter are similar to those found by Yealy *et al* (205 ml/sec).[23] They showed that the use of larger catheters could result in increased flow. With the use of a 4 mm ID catheter, a flow rate of 850 ml/sec could be achieved using a resuscitation bag.[35] Assuming a 50% air leak, this would provide an estimated 425 ml of tidal volume. Since there are no case reports or case series that report successful resuscitation utilizing resuscitation bags attached to catheters, it is unclear if this produces adequate ventilation or oxygenation in an adult to ensure neurologically intact survival. However, when a resuscitation bag is the only available equipment, authors of current textbooks recommend the use of large catheters (10-gauge).[36]

The current study did not address the issue of training. It is unclear how often there must be retraining for the use of a JV or a resuscitation bag for transtracheal ventilation. The potential advantage of the JV is that multiple pieces of equipment do not need to be assembled when a "can't intubate, can't ventilate" problem occurs. Utilizing the JV also does not require special, larger catheters. Routinely available 14-gauge catheters can be utilized and the ventilator can be attached directly onto the catheter.

Conclusions

Resuscitation bags should not be used to ventilate patients through a 14-gauge transtracheal catheter. Jet ventilation is needed when percutaneous transtracheal ventilation is attempted using a 14-gauge catheter. Jet ventilation can be accomplished via commercially available JVs or by utilizing oxygen supply tubing connected to an unregulated oxygen source of at least 50 psi.

Acknowledgements

Thank you to Instrumentation Industries, Inc. for supplying the authors with a jet ventilator for the study.

References

1. Spoerel WE, Narayanan PS, Singh NP: Transtracheal ventilation. *Br J Anaesth* 1971;43(10):932–939.
2. Jacoby JJ, Hamelberg W, Ziegler CH, *et al*: Transtracheal resuscitation. *JAMA* 1956;162(7):625–628.
3. Jacobs HB: Emergency percutaneous transtracheal catheter and ventilator. *J Trauma* 1972;12(1):50–55.
4. Jacobs HB, Smyth NP, Witorsch P: Transtracheal catheter ventilation: Clinical experience in 36 patients. *Chest* 1974;65(1):36–40.
5. Smith RB, Schaer WB, Pfaeffle H: Percutaneous transtracheal ventilation for anaesthesia and resuscitation: A review and report of complications. *Can Anaesth Soc J* 1975;22(5):607–612.
6. Patel RG: Percutaneous transtracheal jet ventilation: A safe, quick, and temporary way to provide oxygenation and ventilation when conventional methods are unsuccessful. *Chest* 1999;116(6):1689–1694.
7. Bourgain JL, Desruennes E, Fischler M, Ravussin P: Transtracheal high frequency jet ventilation for endoscopic airway surgery: A multicentre study. *Br J Anaesth* 2001;87(6):870–875.
8. Smith RB, Myers EN, Sherman H: Transtracheal ventilation in paediatric patients: Case reports. *Br J Anaesth* 1974;46(4):313–314.
9. Ravussin P, Bayer-Berger M, Monnier P, *et al*: Percutaneous transtracheal ventilation for laser endoscopic procedures in infants and small children with laryngeal obstruction: Report of two cases. *Can J Anaesth* 1987;34(1):83–86.
10. Erasmus FR, Ungerer MJ: Transtracheal ventilation during microsurgery of the larynx. *S Afr Med J* 1973;47(18):764–766.
11. Singh NP: Transtracheal Jet Ventilation as a New Technique and Experiences with Ketamine and Propanidid in India. In: Miyazaki M, Iwatsuki K, Fujita M, Lunn JN, (eds). *Anesthesiology: Proceedings of the Fifth World Congress of Anesthesiologists*, Kyoto, September 19–23, 1972. Amsterdam: Excerpta Medica; 1973:p 160.
12. Weymuller EAJ, Pavlin EG, Paugh D, Cummings CW: Management of difficult airway problems with percutaneous transtracheal ventilation. *Ann Otol Rhinol Laryngol* 1987;96(1Pt1):34–37.
13. Levinson MM, Scuderi PE, Gibson RL, Comer PB: Emergency percutaneous transtracheal ventilation (PTV). *JACEP* 1979;8(10):396–400.
14. Dunlap LB, Oregon E: A modified, simple device for the emergency administration of percutaneous transtracheal ventilation. *JACEP* 1978;7(2):42–46.
15. Aye LS: Percutaneous transtracheal ventilation. *Anesth Analg* 1983;62(6):619.
16. Scuderi PE, McLeskey CH, Comer PB: Emergency percutaneous transtracheal ventilation during anesthesia using readily available equipment. *Anesth Analg* 1982;61(10):867–870.
17. deLisser EA, Muravchick S: Emergency transtracheal ventilation. *Anesthesiology* 1981;55(5):606–607.
18. Attia RR, Battit GE, Murphy JD: Transtracheal ventilation. *JAMA* 1975;234(11):1152–1153.
19. Reich DL, Schwartz N: An easily assembled device for transtracheal oxygenation. *Anesthesiology* 1987;66(3):437–438.
20. Gildar JS: A simple system for transtracheal ventilation. *Anesthesiology* 1983;58(1):106 (Letter).
21. Cote CJ, Eavey RD, Todres ID, Jones DE: Cricothyroid membrane puncture: Oxygenation and ventilation in a dog model using an intravenous catheter. *Crit Care Med* 1988;16(6):615–619.
22. Neff CC, Pfister RC, Van Sonnenberg E: Percutaneous transtracheal ventilation: Experimental and practical aspects. *J Trauma* 1983;23(2):84–90.
23. Yealy DM, Stewart RD, Kaplan RM: Myths and pitfalls in emergency translaryngeal ventilation: Correcting misimpressions. *Ann Emerg Med* 1988;17(7):690–692.
24. Hauswald M, Ong G, Yeoh E: Percutaneous needle cricothyroidotomy with repetitive airway obstruction. *Am J Emerg Med* 1995;13(6):623–625.
25. Gens DR: Surgical Airway Management. In: Tintinalli JE, Kelen GD, Stapczynski JS, Tintinalli JE, eds. *Emergency medicine: A Comprehensive Study Guide*. 6th ed. New York: McGraw-Hill, Medical Pub. Division; 2004:119.
26. Orebaugh SL: Difficult airway management in the emergency department. *J Emerg Med* 2002;22(1):31–48.
27. Chong C, Wang T, Chang H: Percutaneous transtracheal ventilation without a jet ventilator. *Am J Emerg Med* 2003;21(6):507–508.
28. Simon JE: *Georgia Emergency Medical Services for Children Pediatric Life Support*. 2003:p 103.
29. Stinson TW: A simple connector for transtracheal ventilation. *Anesthesiology* 1977;47(2):232 (Letter).
30. Contra Costa County Prehospital Care Manual. 2005:118. Available at http://www.cchealth.org/groups/ems/pdf/care_manual_dec_2003_changes.pdf. Accessed 01 August 2005.
31. Yealy DM, Plewa MC, Reed JJ, *et al*: Manual translaryngeal jet ventilation and the risk of aspiration in a canine model. *Ann Emerg Med* 1990;19(11):1238–1241.
32. Smith RB, Albin MS, Williams RL: Percutaneous transtracheal jet ventilation. *J Clin Anesth* 1996;8(8):689–690.
33. Metz S, Parmet JL, Levitt JD: Failed emergency transtracheal ventilation through a 14-gauge intravenous catheter. *J Clin Anesth* 1996;8(1):58–62.
34. Soto R, Mesa A: New intravenous catheter not suitable for trans-tracheal jet ventilation. *Anesth Analg* 2001;92(4):1074.
35. Yealy DM, Stewart RD, Kaplan RM: Clarifications on translaryngeal ventilation. *Ann Emerg Med* 1988;17(10):1130 (Letter).
36. Marx JA, Hockberger RS, Walls RM, *et al*: *Rosen's Emergency Medicine: Concepts and Clinical Practice*. 6th ed. Philadelphia: Mosby/Elsevier; 2006.