Review
Clinical review: Management of difficult airways

Olivier Langeron, Julien Amour, Benoît Vivien and Frédéric Aubrun

Department of Anesthesiology and Critical Care, Centre Hospitalier Universitaire Pitié-Salpêtrière, Assistance Publique-Hôpitaux de Paris, Université Pierre et Marie Curie (Paris 6), Paris, France

Corresponding author: Olivier Langeron, olivier.langeron@psl.aphp.fr

Abstract

Difficulties or failure in airway management are still important factors in morbidity and mortality related to anesthesia and intensive care. A patent and secure airway is essential to manage anesthetized or critically ill patients. Oxygenation maintenance during tracheal intubation is the cornerstone of difficult airway management and is always emphasized in guidelines. The occurrence of respiratory adverse events has decreased in claims for injuries due to inadequate airway management mainly at induction of anesthesia. Nevertheless, claim reports emphasize that airway emergencies, tracheal extubation and/or recovery of anesthesia phases are still associated with death or brain damage, indicating that additional educational support and management strategies to improve patient safety are required. The present brief review analyses specific problems of airway management related to difficult tracheal intubation and to difficult mask ventilation prediction. The review will focus on basic airway management including preoxygenation, and on some oxygenation and tracheal intubation techniques that may be performed to solve a difficult airway.

Introduction

Difficulties or failure in airway management are still important factors in morbidity and mortality related to anesthesia [1-4]. The occurrence of respiratory adverse events has decreased in claims for injuries due to inadequate ventilation and, to a lesser extent, for injuries due to esophageal intubation, as a result of better monitoring with pulse oxymetry and capnography use [1]. Difficult tracheal intubation (DTI), however, remains relatively constant among anesthesia-related patient injuries, and is the third most common respiratory-related event leading to death and brain damage in the American Society of Anesthesiologists closed claims analysis [1]. Moreover, in contrast with other phases of anesthesia (intraoperative, tracheal extubation and recovery periods), induction of anesthesia is associated with a decreased incidence of claims arising from difficult airway management (DAM) during 1993–1999 compared with that during 1985–1992.

These findings suggest the beneficial impact of difficult airway guidelines mainly focused on the preoperative period and the induction of anesthesia, and suggest the need for additional recommendations and strategies for DAM during maintenance of, emergence from and recovery from anesthesia [2,3]. Moreover, emergency tracheal intubation in critically ill patients is associated with a significant frequency of major complications such as esophageal intubation, endobronchial intubation and aspiration [4]. Practice guidelines have been established to aid management of the difficult airway and to reduce poor outcomes, and several algorithms have been developed [5-9]. Maintenance of patient oxygenation is the cornerstone of DAM, and is highlighted in algorithms from these various airway management guidelines [5–9]. We shall therefore discuss specific problems of airway management related to DTI and to difficult mask ventilation (DMV) prediction. The present review will focus on basic airway management including preoxygenation, and some oxygenation and tracheal intubation techniques that may be performed to solve a difficult airway.

Prediction of difficult tracheal intubation

One component of many of these algorithms is the preoperative assessment and recognition of the difficult airway [5-9]. Prediction uses many factors associated with DTI, such as mouth opening, Mallampati classification, head and neck movement (atlanto-occipital joint assessment), receding mandible, protruding maxillary incisors (buck teeth), thyromental distance, sternomental distance, obesity and a previous history of difficult intubation [5-9].

In a meta-analysis of bedside screening tests usually performed to predict DTI, a poor to moderate discriminative power was reported when any test was used alone [10]. Combinations of individual tests or risk factors add some incremental diagnostic value in comparison with the value of each test alone; the best combination was Mallampati

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CICV = cannot intubate and cannot ventilate; DAM = difficult airway management; DTI = difficult tracheal intubation; DMV = difficult mask ventilation; FOI = fiberoptic intubation; ILMA = intubating laryngeal mask airway; LMA = laryngeal mask airway.

classification and thyromental distance [10]. Predicting DTI could therefore be quite complex and perhaps even controversial [11], but probably the most important benefit of DTI prediction is to anticipate a difficult airway.

The most dangerous situation in DAM, however, occurs when tracheal intubation is difficult or impossible and when mask ventilation is, or becomes, inadequate, thereby creating a cannot intubate and cannot ventilate (CICV) scenario. Indeed, the risk of difficult or impossible mask ventilation is increased after three unsuccessful tracheal intubation attempts [12]. We shall consequently focus on the recognition and management of difficult or impossible mask ventilation to avoid a CICV scenario.

Prediction of difficult mask ventilation

The incidence of DMV has been rarely assessed in studies related to airway management [3,13-15]. Low rates of DMV have been reported in prospective studies by Asai and colleagues (1.4%) [3], by Rose and Cohen (0.9%) [13] and by El-Ganzouri and colleagues (0.07%) [14]. In contrast, in a retrospective study of 2,000 incident reports during anesthesia, the incidence of DMV was 15% when intubation was difficult [15]. In most studies, DMV was not precisely defined [3,13-15]. The difficulty of definition probably increases the difficulty of recognition.

The incidence and associated risk factors for DMV have been studied prospectively in a large general adult population, and a DMV incidence of 5% was reported [16]. Moreover, difficult intubation was more likely when DMV was present (30% in patients with DMV compared with 8% patients without associated DMV) [16]. Five features (age >55 years, body mass index $>26\,kg/m^2$, lack of teeth, presence of beard, history of snoring) were independent risk factors for DMV, and the presence of two of these criteria indicated, at best, a DMV [16]. Another work involving a study on a large sample population (14,369 patients) supports these results by confirming the DMV risk factors of the previous study except for the lack of teeth, and provides another risk factor in predicting DMV – limited mandibular protrusion [17].

These stated risk factors were related to DMV for the following reasons. Obesity is associated with decreased posterior airway space behind the base of the tongue and impaired airway patency during sleep, and is a risk factor for obstructive sleep apnea syndrome [18]. Upper airway obstruction can occur after induction of general anesthesia with posterior displacement of the soft palate, the base of the tongue and the epiglottis. Attempts at inspiration during anesthesia cause collapse of the pharynx with obstruction at several sites, similar to obstructive sleep apnea [19]. In patients with unsuspected abnormal anatomy of the upper airway related to obstructive sleep apnea, DMV may occur during general anesthesia and tracheal intubation may also be difficult [20]. In obese patients and morbidly obese

patients (body mass index $>30\,kg/m^2$ and $>40\,kg/m^2$, respectively), the risk of oxygen desaturation at induction of anesthesia [21] and the risk of difficult intubation [22,23] are increased. On the other hand, obesity alone could not predict DTI so easily, probably because the body mass index is not an independent risk factor for DTI [22,24]. These patients, however, are definitely at high risk for oxygen desaturation and should be considered in this manner to anticipate DAM [16,17,22-25]. Age is closely related to increased pharyngeal resistance to airflow (from choanae to epiglottis) in men but not in women [26], supporting the predominance of obstructive sleep apnea in men. Finally, progressive difficulty in ventilating via a mask can develop because of persistent and prolonged failed intubation attempts [12]. An unexpected difficult airway caused by lingual tonsillar hyperplasia may occur in an asymptomatic patient [27], and could even lead to the death of the patient [28]. Because of the serious consequences of unsuspected CICV, such as in patients in which attempts to intubate the trachea failed and mask ventilation becomes difficult, urgent oxygenation is mandatory and is supported by guidelines [5-9].

Basic airway management

While preparations for airway control are made, basic maneuvers are implemented: preoxygenation techniques, including relief of airway obstruction by chin lift and jaw thrust, and insertion of a nasal airway or an oral airway. Bag mask ventilation with the use of an oropharyngeal or nasopharyngeal airway can be a difficult skill to master, best performed by two individuals with a more efficient mask seal and jaw thrust, but it can easily inflate the stomach [29]. Moreover, techniques that use one hand to squeeze the bag give significantly smaller tidal volumes than two-handed techniques, with no significant difference in peak airway pressure or average airway pressure [29]. The second component of optimal mask ventilation is the use of large oral or nasal pharyngeal airways. Finally, ventilation-pressure-controlled mask ventilation reduced the inspiratory peak flow rates and airway pressures in comparison with the manual circle system with bag-valve-mask ventilation devices, providing additional patient safety by decreasing the risk of regurgitation and subsequent pulmonary aspiration [30].

Preoxygenation is a prerequisite for endotracheal intubation in any patient. Preoxygenation in a patient with an anticipated difficult airway provides the maximum length of time for which a patient can tolerate apnea and provides time for the anesthesia provider to solve a DAM issue [31]. One of the usual preoxygenation techniques, such as tidal breathing of 100% oxygen for 3–5 minutes, is recommended and is effective in delaying arterial desaturation during a tracheal intubation procedure [31,32]. Various preoxygenation techniques have been advocated before induction of anesthesia, including tidal volume breathing of 100% oxygen for 3–5 minutes, four deep vital capacity breaths of oxygen taken within 30 seconds or eight deep vital capacity breaths

Table 1

Examples of simple predefined strategies used in difficult airway management

	Anticipated difficult tracheal intubation	Unanticipated difficult tracheal intubation
Questions	Is difficult mask ventilation anticipated?	None: use of a predefined algorithm
	Are oxygenation maintenance techniques available? (consider intubating laryngeal mask airway or laryngeal mask use, or invasive airway access)	
	Anesthesia technique: spontaneous ventilation or not?	
Actions	Consider awake or general anesthesia intubation techniques	Consider oxygenation as first priority
		Consider tracheal intubation as second priority
		Call for help

of oxygen taken within 60 seconds [32-34]. Comparisons of these different preoxygenation techniques have often been conflicting, because of the various regimens of preoxygenation depending on the oxygen flow and the type of anesthetic system, and because of various endpoints such as the maximum arterial oxygen tension, the maximum end-tidal oxygen fraction and the time taken for hemoglobin to desaturate [31-34]. Nevertheless, the time to desaturation is more directly related to the available body stores for oxygen than the maximum arterial oxygen tension, suggesting the former is a more suitable endpoint for preoxygenation studies [31-33].

Preoxygenation is also essential for critically ill patients, but the usual preoxygenation technique appeared marginally effective in these patients regarding minimal improvement in the blood oxygen tension, as a surrogate marker of effective preoxygenation [12]. Preoxygenation in hypoxemic patients using noninvasive ventilation, with a pressure support mode adjusted to obtain an expired tidal volume of 7–10 ml/kg with a positive end-expiratory pressure level of $5\ cmH_2O$ during 3 minutes, was recently reported in a prospective randomized study to be significantly more effective at reducing arterial oxygen desaturation during tracheal intubation than the usual method [35]. Finally, the preoxygenation efficiency in morbidly obese patients may be improved by a 25° head-up position. This position achieves better gas exchange by reducing atelectasis and reducing ventilation/perfusion mismatch related to a less reduced functional residual capacity, and increases the desaturation safety period (time to reach an oxygen saturation of 92%: 201 ± 56 s and 155 ± 70 s in a 25° head-up position and a supine position, respectively) [36]. When the positive end-expiratory pressure (+10 cmH_2O) was applied during anesthesia induction, a greater safety margin to control the airway in morbidly obese patients was observed in comparison with induction without the positive end-expiratory pressure, increasing the nonhypoxic apnea duration [37].

At this stage, it is important to distinguish the two main clinical situations of DAM: anticipated DTI and unanticipated

DTI (Table 1). Some issues are raised as regards anticipated DTI – is mask ventilation anticipated to be difficult?, how can one maintain the patient's oxygenation? (consider using an intubating laryngeal mask airway (ILMA) or a laryngeal mask, or invasive airway access) and, finally, at induction of anesthesia, should we preserve spontaneous ventilation or is apnea possible? After considering these points, awake or general anesthesia intubation techniques could be decided depending upon the answers to the previous issues (Table 1).

Unanticipated DTI could occur in various clinical settings, and a predefined algorithm should be used to minimize improvisation, considering oxygenation as the main goal of the DAM (Table 1). In a recent study during scheduled surgery, for example, a predefined algorithm – including the gum elastic bougie and the ILMA as the first and second steps, respectively, of DAM – was prospectively validated and reported to be effective in solving most problems occurring during unexpected DAM [38]. Many guidelines with algorithms were developed and proposed to solve DAM, but maintenance of the patient's oxygenation is the cornerstone of all of these recommendations [5-9].

Finally, the CICV scenario often results from an inappropriate airway management with repeated unsuccessful and traumatic tracheal intubation attempts. This should be prevented by changing the operator and/or the technique of tracheal intubation, reminding the operator of the possibility to wake the patient if there is no life-threatening situation. The CICV scenario is consequently the one that should be predicted and managed with a predefined strategy or with algorithms [5-9]. In contrast, when a CICV situation is encountered, the effective recommendations are to implement oxygenation techniques [5-9].

Advanced airway management
The fiberoptic intubation technique
Fiberoptic intubation (FOI) is a well-documented technique in a patient with an anticipated difficult airway. Guidelines on anticipated DAM [5,6,9] emphasize the importance of the

FOI technique when a difficult airway is predicted. Awake intubation then has to be considered to maintain oxygenation of the patient, and the FOI technique remains a 'gold standard' for this scenario. The FOI technique may be used for both oral and nasal approaches to the larynx. The FOI is an interesting technique because of the minimal cervical movement required to achieve DTI in cervical spine disease or trauma, enabling a postintubation neurologic assessment in cooperative patients when an awake tracheal intubation technique is performed [39]. The FOI technique has an important role in the management of patients who present a small interincisor distance or ear, nose and throat cancer. The acquisition of skills in this technique is an essential part of anesthetic training [5,9].

In contrast, oxygenation is the very first priority in an unanticipated difficult airway. The use of oxygenation devices is therefore mandatory initially, and the FOI may be considered a second-line technique when oxygenation is already ensured [5-9].

The laryngeal mask and the intubating laryngeal mask

The laryngeal mask airway (LMA) represents a major advance in airway management and has been incorporated into difficult airway algorithms [5-9,40]. The LMA allows ventilation and oxygenation, although it does not completely protect against aspiration. The ILMA is a device specifically designed to allow effective ventilation and to act as a guide for blind intubation in patients with normal and abnormal airways [41]. The ILMA has several potential advantages compared with the LMA, to overcome difficulties in intubation with the LMA [41]. The efficacy of the ILMA for ventilation and blind intubation has been reported in emergency patients with normal airways, and its use could be learnt quickly [42]. The ILMA has been used successfully in patients with difficult airways [38,41,43,44] and in obese patients [45]. Moreover, a comparably high success rate for tracheal intubation was observed with the ILMA in comparison with the fiberscope technique, but the ILMA was found to be associated with less adverse events than the fiberscope – in particular, oxygen desaturation [44]. The ILMA is consequently a valuable tool in the CICV scenario or in an unanticipated DTI patient to maintain oxygenation, and the impact of the device is emphasized in algorithms and guidelines from many anesthetic societies [5-9].

Cricothyroidotomy

When the airway is compromised and attempts at intubation have failed, cricothyroidotomy should be considered. This technique involves different methods, including surgical cut-down to the cricothyroid membrane and insertion of an appropriately sized tracheal tube. The technique allows effective ventilation and overcomes the limitations of percutaneous transtracheal needle ventilation. Several cricothyroidotomy kits are available. Possible complications such as intratracheal bleeding, pneumothorax, pneumo-mediastinum or esophageal puncture are reduced if the Seldinger technique is used, in contrast to direct puncture [5].

Transtracheal jet ventilation

Percutaneous transtracheal jet ventilation can allow effective ventilation and oxygenation of the lungs by a transtracheal route. The technique involves percutaneous puncture of the cricothyroid membrane and passing a large-bore intravenous catheter into the trachea. This technique may be performed with various devices such as a venous or arterial catheter, or a specific needle like the Ravussin needle (CHUV® catheter), and requires a jet injector powered by regulated oxygen source. This technique has to be incorporated into DAM, and, like cricothyroidotomy, may solve a glottic or subglottic problem such as a tumor, an abscess or a hematoma [5-9].

Conclusion

A patent and secure airway is essential to manage anesthetized or critically ill patients. Whatever the clinical setting (that is, scheduled surgery or emergency airway management), oxygenation maintenance during tracheal intubation is the cornerstone of DAM and is always highlighted in algorithms and guidelines. The occurrence of respiratory adverse events has decreased in claims for injuries due to inadequate ventilation mainly at the induction of anesthesia, but claim reports emphasize that airway emergencies or tracheal extubation and recovery of anesthesia phases are still associated with death or brain damage, indicating that additional educational support and management strategies to improve safety patient are required.

Management of anticipated difficult airways has to consider several points, including the anesthesia technique with maintenance or not of spontaneous ventilation, the available oxygenation technique in the case of anticipated DMV, and the appropriate tracheal intubation technique according to the patient status and the clinical setting. In an unexpected difficult airway, the very first priority is oxygenation and a predefined strategy or algorithm has to be implemented. Finally, the last step of DAM is tracheal extubation requiring a strategy depending, in part, on the condition of the patient and on the surgery, the skills and the preference of the medical team.

Competing interests

The authors declare that they have no competing interests.

References

1. Cheney FW: **The American Society of Anesthesiologists Closed Claims Project: what have we learned, how has it affected practice, and how will it affect practice in the future?** *Anesthesiology* 1999, **91:**552-556.
2. Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW: **Management of the difficult airway: a closed claims analysis.** *Anesthesiology* 2005, **103:**33-39.
3. Asai T, Koga K, Vaughan RS: **Respiratory complications associated with tracheal intubation and extubation.** *Br J Anaesth* 1998, **80:**767-775.

4.   Schwartz DE, Matthay MA, Cohen NH: **Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations.** *Anesthesiology* 1995, **82:**367-376.
5.   Boisson-Bertrand D, Bourgain JL, Camboulives J, Crinquette V, Cros AM, Dubreuil M, Eurin B, Haberer JP, Pottecher T, Thorin D, *et al.*: **Intubation difficile. Société française d'anesthésie et de réanimation. Expertise collective.** *Ann Fr Anesth Réanim* 1996, **15:**207-214.
6.   American Society of Anesthesiologists Task Force: **Practice Guidelines for Management of the Difficult Airway. An updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway.** *Anesthesiology* 2003, **98:**1269-1277.
7.   Crosby ET, Cooper RM, Douglas MJ, Doyle DJ, Hung OR, Labrecque P, Muir H, Murphy MF, Preston RP, Rose DK, Roy L: **The unanticipated difficult airway with recommendations for management.** *Can J Anaesth* 1998, **45:**757-776.
8.   Henderson JJ, Popat MT, Latto IP, Pearce AC: **Difficult Airway Society guidelines for management of the unanticipated difficult intubation.** *Anaesthesia* 2004, **59:**675-694.
9.   Petrini F, Accorsi A, Adrario E, Agro F, Amicucci G, Antonelli M, Azzeri F, Baroncini S, Bettelli G, Cafaggi C, *et al.*, Gruppo di Studio SIAARTI 'Vie Aeree Difficili', IRC e SARNePI, Task Force: **Recommendations for airway control and difficult airway management.** *Minerva Anestesiol* 2005, **71:**617-657.
10. Shiga T, Wajima Z, Inoue T, Sakamoto A: **Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance.** *Anesthesiology* 2005, **103:**429-437.
11. Yentis SM: **Predicting difficult intubation – worthwhile exercise or pointless ritual?** *Anaesthesia* 2002, **57:**105-109.
12. Mort TC: **Preoxygenation in critically ill patients requiring emergency tracheal intubation.** *Crit Care Med* 2005, **33:**2672-2675.
13. Rose DK, Cohen MM: **The airway: problems and predictions in 18,500 patients.** *Can J Anaesth* 1994, **41:**372-383.
14. El-Ganzouri AR, McCarthy RJ, Tuman KJ, Tanck EN, Ivankovich AD: **Preoperative airway assessment: predictive value of a multivariate risk index.** *Anesth Analg* 1996, **82:**1197-1204.
15. Williamson JA, Webb RK, Szekely S, Gillies ERN, Dreosti AV: **Difficult intubation: an analysis of 2000 incident reports.** *Anaesth Intens Care* 1993, **21:**602-607.
16. Langeron O, Masso E, Huraux C, Guggiari M, Bianchi A, Coriat P, Riou B: **Prediction of difficult mask ventilation.** *Anesthesiology* 2000, **92:**1229-1236.
17. Kheterpal S, Han R, Tremper KK, Shanks A, Tait AR, O'Reilly M, Ludwig TA: **Incidence and predictors of difficult and impossible mask ventilation.** *Anesthesiology* 2006, **105:**885-891.
18. Partinen M, Guilleminault C, Quera-Salva MA, Jamieson A: **Obstructive sleep apnea and cephalometric roentgenograms: the role of anatomic upper airway abnormalities in the definition of abnormal breathing during sleep.** *Chest* 1988, **93:**1199-1205.
19. Nandi PR, Charlesworth CH, Taylor SJ, Nunn JF, Doré CJ: **Effect of general anaesthesia on the pharynx.** *Br J Anaesth* 1991, **66:**157-162.
20. Hiresmath AS, Hillman DR, James AL, Noffsinger WJ, Platt PR, Singer SL: **Relationship between difficult tracheal intubation and obstructive sleep apnoea.** *Br J Anaesth* 1998, **80:**606-611.
21. Jense HG, Dubin SA, Silverstein PI, O'Leary-Escolas U: **Effect of obesity on safe duration of apnea in anesthetized humans.** *Anesth Analg* 1991, **72:**89-93.
22. Juvin P, Lavaut E, Dupont H, Lefevre P, Demetriou M, Dumoulin JL, Desmonts JM: **Difficult tracheal intubation is more common in obese than in lean patients.** *Anesth Analg* 2003, **97:**595-600.
23. Wilson ME, Spiegelhalter D, Robertson JA, Lesser P: **Predicting difficult intubation.** *Br J Anaesth* 1988, **61:**211-216.
24. Brodsky JB, Lemmens HJ, Brock-Utne JG, Vierra M, Saidman LJ: **Morbid obesity and tracheal intubation.** *Anesth Analg* 2002, **94:**732-736.
25. Berthoud MC, Peacock JE, Reilly CS: **Effectiveness of preoxygenation in morbidly obese patients.** *Br J Anaesth* 1991, **67:**464–466.
26. White DP, Lombard RM, Cadieux RJ, Zwillich CW: **Pharyngeal resistance in normal humans: influence of gender, age, and obesity.** *J Appl Physiol* 1985, **58:**365-371.
27. Ovassapian A, Glassenberg R, Randel GI, Klock A, Mesnick PS, Klafta JM: **The unexpected difficult airway and lingual tonsil hyperplasia: a case series and a review of the literature.** *Anesthesiology* 2002, **97:**124-132.
28. Jones DH, Cohle SD: **Unanticipated difficult airway secondary to lingual tonsillar hyperplasia.** *Anesth Analg* 1993, **77:**1285-1288.
29. Augustine JA, Seidel DR, McCabe JB: **Ventilation performance using a self-inflating anaesthesia bag: effect of operator characteristics.** *Am J Emerg Med* 1987, **5:**267-270.
30. von Goedecke A, Voelckel WG, Wenzel V, Hormann C, Wagner-Berger HG, Dorges V, Lindner KH, Keller C: **Mechanical versus manual ventilation via a face mask during the induction of anesthesia: a prospective, randomized, crossover study.** *Anesth Analg* 2004, **98:**260-263.
31. Benumof JL: **Preoxygenation: best method for both efficacy and efficiency.** *Anesthesiology* 1999, **91:**603-605.
32. Baraka AS, Taha SK, Aouad MT, El-Khatib MF, Kawkabani NI: **Preoxygenation: comparison of maximal breathing and tidal volume breathing techniques.** *Anesthesiology* 1999, **91:**612-616.
33. Pandit JD, Duncan TB, Robbins PA: **Total oxygen uptake with two maximal breathing techniques and the tidal volume breathing technique: a physiologic study of preoxygenation.** *Anesthesiology* 2003, **99:**841-846.
34. Nimmagadda U, Chiravuri SD, Salem MR, Joseph NJ, Wafai Y, Crystal GJ, El-Orbany MI: **Preoxygenation with tidal volume and deep breathing techniques: the impact of duration of breathing and fresh gas flow.** *Anesth Analg* 2001, **92:**1337-1341.
35. Baillard C, Fosse JP, Sebbane M, Chanques G, Vincent F, Courouble P, Cohen Y, Eledjam JJ, Adnet F, Jaber S: **Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients.** *Am J Respir Crit Care Med* 2006, **174:**171-177.
36. Dixon BJ, Dixon JB, Carden JR, Burn AJ, Schachter LM, Playfair JM, Laurie CP, O'Brien PE: **Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study.** *Anesthesiology* 2005, **102:**1110-1115.
37. Gander S, Frascarolo P, Suter M, Spahn DR, Magnusson L: **Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients.** *Anesth Analg* 2005, **100:**580-584.
38. Combes X, Le Roux B, Suen P, Dumerat M, Motamed C, Sauvat S, Duvaldestin P, Dhonneur G: **Unanticipated difficult airway in anesthetized patients: prospective validation of a management algorithm.** *Anesthesiology* 2004, **100:**1146-1150.
39. Crosby ET: **Airway management in adults after cervical spine trauma.** *Anesthesiology* 2006, **104:**1293-12318.
40. Benumof JL: **Laryngeal mask airway and the ASA difficult airway algorithm.** *Anesthesiology* 1996, **84:**686-699.
41. Brain AI, Verghese C, Addy EV, Kapila A, Brimacombe J: **The intubating laryngeal mask. II: a preliminary clinical report of a new means of intubating the trachea.** *Br J Anaesth* 1997, **79:**704-709.
42. Baskett PJ, Parr MJ, Nolan JP: **The intubating laryngeal mask. Results of a multicentre trial with experience of 500 cases.** *Anaesthesia* 1998, **53:**1174-1179.
43. Ferson DZ, Rosenblatt WH, Johansen MJ, Osborn I, Ovassapian A: **Use of the intubating LMA-Fastrach in 254 patients with difficult-to-manage airways.** *Anesthesiology* 2001, **95:**1175-1181.
44. Langeron O, Semjen F, Bourgain JL, Marsac A, Cros AM: **Comparison of the intubating laryngeal mask airway with the fiberoptic intubation in anticipated difficult airway management.** *Anesthesiology* 2001, **94:**968-972.
45. Frappier J, Guenoun T, Journois D, Philippe H, Aka E, Cadi P, Silleran-Chassany J, Safran D: **Airway management using the intubating laryngeal mask airway for the morbidly obese patient.** *Anesth Analg* 2003, **96:**1510-1515.