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INVITED REVIEW ARTICLE

# Should anesthesiologists have to confirm effective facemask ventilation before administering the muscle relaxant?

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**Abstract** There is ongoing controversy as to whether effective facemask ventilation (FMV) should be established following induction of anesthesia before a muscle relaxant is administered. The rationale for such practice is the belief that, should FMV be ineffective, non-paralyzed patients can be woken up, and subsequently an alternative airway management can be considered. However, the chances of successfully restoring adequate spontaneous respiration before severe hypoxemia develops in an anesthetized, apneic patient who is prone to anesthetic-induced respiratory depression and airway collapse are very small. On the other hand, the overall evidence shows that muscle relaxation is likely to improve or leave unchanged, but not to worsen, the quality of FMV. Furthermore, muscle relaxation will facilitate placement of a supraglottic airway device and endotracheal intubation, interventions which may become essential should the patient become hypoxemic during failed FMV. Thus, the earliest administration of a muscle relaxant following induction of anesthesia may well be the most effective and safest practice. Insistence on demonstration of adequate FMV before administration of a muscle relaxant is more of a ritual than an evidence-based practice. It should therefore be abandoned.

**Keywords** Facemask ventilation · Muscle relaxation · Anesthesia

## Introduction

It seems to be deeply embedded in the minds of most anesthesiologists that, following induction of anesthesia, effective facemask ventilation (FMV) must be established before any neuromuscular blocking drug (NMBD) is administered. The rationale for this long-held belief is that, if FMV should prove ineffective following induction of anesthesia, non-paralyzed patients can be woken up, and subsequently an alternative airway management can be considered (typically awake fiberoptic-aided intubation). In this way, potentially life-threatening hypoxemia can supposedly be avoided. In 2008, Calder and Yentis questioned the safety of this practice [1]. They argued that the traditional practice, considered 'safe practice', actually compromises patient safety. Since then, there has been ongoing controversy about the appropriate timing of the administration and the choice of NMBD (depolarizing vs. non-depolarizing) following induction of anesthesia.

We are now confronted with principally two opposing opinions of what constitutes best practice. There are those anesthesiologists who continue arguing that, for patient safety reasons, NMBDs should only be administered after adequate FMV has been demonstrated (the 'checkers') [2–6]. On the other hand, there are those who have voiced reservations about the rationale and safety of such a practice, and who advocate the administration of a NMBD immediately after induction of anesthesia before checking the ability to ventilate (the 'non-checkers') [7–11]. This review will examine the rationale and existing evidence for each of these practices.

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## Routine practice of induction of anesthesia

Let me approach the controversy surrounding this topic by addressing two questions: (1) at present, how do most of us most of the time proceed on our way from inducing anesthesia to endotracheal intubation, and (2) what may happen on that way? Let us assume we are caring for a patient with unremarkable anesthetic history and preoperative airway assessment who requires endotracheal intubation for the procedure. When the patient has become apneic following induction of anesthesia, the 'non-checkers' will be administering the NMBD of their choice right away because they consider checking the quality of FMV before muscle relaxation to be of no benefit.

In contrast, the 'checkers' will administer a NMBD only after having established effective FMV because they consider this practice to be essential for patient safety. They will now be confronted with two possible scenarios. Either FMV proves to be effective, and they will administer a NMBD, or FMV proves to be inadequate. In such cases, there are principally four options: (1) continue trying to establish FMV under the assumption that the maximal effect of the induction drug has not yet been reached, thereby impairing FMV; (2) deepen the anesthesia by injecting additional doses of hypnotics and/or opioids in the hope that this will facilitate FMV; (3) insert an oropharyngeal airway with or without two-provider ventilation; and (4) wake up the patient. Most of the time, the various interventions will ultimately enable effective FMV, at which time the NMBD is administered. However, what action should be taken if these interventions do not result in effective FMV? As the patient will now have been apneic for some time, the peripheral oxygen saturation may well be starting to decrease, a sure sign of impending hypoxemia. The proponents of 'ventilation before paralysis' should now make every effort to 'wake up' the patient (a colloquialism for re-establishing sufficient spontaneous respiration). However, at this point the chance of restoring sufficient spontaneous respiration before severe hypoxemia develops is very small, because the additional doses of anesthetics that are likely to have just been administered in an attempt to facilitate FMV will promote upper airway collapse and respiratory depression. This explains why this option is rarely exercised in contemporary practice.

Insertion of a supraglottic airway device or endotracheal intubation would now be alternative options. However, in the presence of complete lack of muscle relaxation and possible airway obstruction caused by preceding airway manipulations, such interventions are prone to fail. In my personal experience spanning several decades, most anesthesiologists are prepared to administer a NMBD when FMV remains impossible and the patient is at risk of becoming or is already hypoxic. The obvious question then is: why not administer the NMBD early on, irrespective of the quality of FMV, rather than delay the administration until the patient may have become hypoxic, and an initially elective situation deteriorates into an emergency?

In this context, the findings of an online survey of 136 trainee and non-trainee anesthesiologists are telling [12]. Forty-three percent replied that they did not check ('non-checkers'), and 57 % replied that they did check ('checkers') FMV before administering a NMBD. The most common reason given for the latter practice was the ability to 'enable escape wake-up'. Both groups held equally strong views in support of their respective practice. However, in a hypothetical 'cannot ventilate' scenario, even the majority of 'checkers' stated they would administer suxamethonium. Although the authors tried to explain this obvious paradox by "well-recognized psychological mechanisms", I would submit that there was the subconscious belief that muscle relaxation may at times be the solution rather than the cause of airway problems.

## Muscle relaxation and quality of facemask ventilation

In the awake state, the upper airway is maintained by physiologic reflexes and neural activity of the upper airway muscles [13]. In the unconscious state, neuromuscular control of the upper airway muscles is reduced or abolished [13]. Opioids [14], benzodiazepines [15] and barbiturates [16] inhibit neural activity of upper airway muscles, thereby contributing to upper airway narrowing and collapse [17–19]. In addition, immediately following induction of anesthesia, upper airway reflexes may increase, which can lead to laryngospasm [20]. Thus, difficult or impossible FMV following induction of anesthesia may be caused by soft tissue obstruction at the pharyngeal or laryngeal level, and/or by laryngospasm. The effect of muscle relaxation on the quality of FMV will depend on the predominant forces at the time of administration of the NMBD. Muscle relaxation can improve FMV by blunting or abolishing laryngospasm [21, 22], by reducing chest wall rigidity, and by facilitating optimal sniffing position, jaw thrust, and insertion of oro- or nasopharyngeal airways. Muscle relaxation can worsen FMV by relaxation-induced collapse of the oropharyngeal cavity [23, 24].

Several studies have shown that administration of a NMBD following induction of anesthesia facilitated FMV. In patients with mostly normal airways, administration of rocuronium following induction of anesthesia improved FMV in 28 of 42 patients (67 %) without worsening in any of them [25]. During pressure-controlled FMV at 15 $cmH_2O$ of 125 anesthetized patients, following the administration of rocuronium the expired tidal volume (a

surrogate marker of ease of mask ventilation) significantly increased by a mean of 61 ml (12 %) [26]. Mean expired tidal volumes also increased significantly in patients with a body mass index (BMI) ≥30 kg/m$^2$. A decrease was not observed in any of the patients. At first glance, a mean increase in expired tidal volume of 61 ml may seem clinically irrelevant. However, as the average oxygen consumption in a healthy subject is ~250 ml/min [27], an increase in minute volume of 61 ml at 12 breaths/min amounts to 732 ml/min, which is equivalent to three times the oxygen consumption.

During pressure-controlled FMV of 67 anesthetized non-paralyzed patients presenting with at most two of five predictors of difficult FMV [28], gastric insufflation (determined by epigastric auscultation and real-time ultrasonography) was observed in 19 and 35 % of patients at inspiratory pressures as low as 10 and 15 cm$H_2O$, respectively [29]. At those inspiratory airway pressures, the mean probabilities of acceptable ventilation were merely 19 and 65 %, respectively. At inspiratory pressures of 20 and 25 cm$H_2O$ (which are not infrequently observed in routine clinical practice during attempts at establishing FMV in the non-paralyzed patient), the mean probabilities of gastric insufflation were 41 % according to auscultation, and 53 and 59 % according to ultrasonography, respectively. In contrast, during manual, volume- and pressure-controlled FMV of 90 anesthetized paralyzed patients, auscultation-determined gastric insufflation occurred in only seven patients (7.8 %) [30]. The low incidence of gastric insufflation might have been related to the low mean peak airway pressures (between 11.4 and 14.3 cm$H_2O$) which, in turn, might have been due to muscle relaxation. At these low airway pressures, ventilation was highly effective.

In the context of this debate, the findings of a prospective evaluation of an algorithm for difficult airway management in a total of 12,225 patients deserve special attention because they provide clinically highly relevant information [31]. Patients with established indications for awake fiberoptic intubation (limited mouth opening, severe fixed deformity of the cervical spine, history of impossible tracheal intubation) were excluded from the study. Participating patients were prospectively subdivided into those with <3 and those with ≥3 risk factors for difficult airway management (risk factors being men aged >50 years, obesity with BMI > kg/m$^2$, sleep apnea syndrome, Mallampati classes III and IV, mouth opening or intergingivial distance <35 mm, thyroid to mentum distance <65 mm, severely limited jaw protrusion, neck circumference >40 cm in women and 45 cm in men). The algorithm required that patients with ≥3 risk factors for difficult airway management were to receive suxamethonium without prior assessment of quality of FMV right after induction of anesthesia. This approach is by itself remarkable because it clearly runs against the traditional view that especially those patients at increased risk for airway problems should not be paralyzed before effective FMV has been demonstrated. Obviously, the design of the algorithm reflected the investigators' belief that the advantages of early effective relaxation by far outweigh its potential disadvantages, particularly so in patients with risk factors for difficult airway management.

Amongst the entire population of 12,225 patients, there were 188 patients with ≥3 risk factors for difficult airway management who (in accordance with the algorithm) received suxamethonium right after induction of anesthesia. The quality of subsequent FMV was of grade I (ventilation without need for an oral airway) and grade II (ventilation requiring oropharyngeal airway) in 175 of these patients (93 %), of grade III (difficult and variable ventilation requiring an oral airway and two providers; or an oral airway and one provider using pressure-controlled mechanical ventilation requiring 25 cm$H_2O$) in 12 patients (6.4 %), and of grade IV (ventilation inadequate with no end-tidal carbon dioxide measurement and no perceptible chest wall movement during attempts at positive pressure) in 1 patient (0.5 %).

In those 12,003 patients with <3 risk factors for difficult airway management, the algorithm required assessment of quality of FMV before administration of a NMBD. In accordance with the algorithm, patients with grade I or II difficulty of FMV received a non-depolarizing NMBD ($n$ = 11,943); patients with grade III ($n$ = 90) difficulty of FMV received suxamethonium without any attempt at first improving the quality of FMV by whatever means or waking up the patient. This, again, is remarkable in itself because by administering a NMBD in the presence of difficult FMV, the option to 'wake up the patient' is effectively abolished. No case of FMV difficulty grade IV was observed after induction of anesthesia before administration of a NMBD. Most relevant in the context of this discussion, in 56 of the 90 patients (62 %) with FMV difficulty grade III, the quality of FMV improved by one grade following administration of suxamethonium. Equally important, in none of the 12,003 patients did the quality of FMV worsen following administration of the NMBD.

All of the 12,225 patients admitted to the study and routinely paralyzed, irrespective of the quality of FMV, could ultimately be successfully orotracheally intubated (using additional gum elastic bougie, video-laryngoscope or intubating laryngeal mask airway). In the entire population of 12,225 patients, there were 17 episodes of severe hypoxemia [peripheral oxygen saturation ($SpO_2$) of less than 80 % until the time of endotracheal intubation]. Only three of the 17 episodes of severe hypoxemia were attributable to difficult FMV. In general, desaturations occurred mostly during attempts at intubation in morbidly obese patients. This implies that it is not necessarily the quality of FMV

which primarily predicts the incidence of hypoxemia, but rather subsequent intubating conditions. This, in turn, argues for early muscle relaxation, independent of the quality of FMV, because this will definitely establish optimal intubating conditions as quickly as possible.

In the context of the debate on the need for checking FMV before administration of a NMBD, the most relevant findings of this prospective study can be summarized as follows: (1) administration of a NMBD irrespective of the existing quality of FMV never worsened, but in several cases improved, the quality of FMV; (2) all of the 12,225 patients admitted to the study and routinely paralyzed, irrespective of the quality of FMV, could ultimately be successfully orotracheally intubated; (3) in no case of difficult FMV was any attempt made to wake up the patient; and (4) episodes of severe hypoxemia were more often associated with difficult intubation than difficult FMV.

During 53,041 attempts at FMV in patients undergoing general anesthesia, 77 cases of unexpected impossible FMV occurred [32]. All but four of these 77 received NMBDs. It is not stated whether this was before or after FMV was found to be impossible. Of those 77 patients with impossible FMV, 65 received suxamethonium and eight a non-depolarizing NMBD in the process of induction or management of the airway. In most of them (58/77), intubation was without difficulty; in 15 patients intubation was difficult or required additional equipment, two patients were woken up, and two had an emergency cricothyrotomy. In this study, the 95 % intubation success rate (73/77) following impossible FMV was possibly due to the administration of a NMBD in all but four of the 77 patients. It is questionable whether endotracheal intubation could have been that successfully performed in the absence of muscle relaxation, or that these patients could safely have been woken. "These data may undermine some anesthetists' practice of awakening a patient or avoiding neuromuscular blockade in the case of impossible mask ventilation" [32].

To my knowledge, there is only one previous study in which no significant improvement in FMV occurred after neuromuscular blockade [33]; neither was worsening of FMV observed. However, the lungs were manually ventilated, so tidal volumes were uncontrolled. Furthermore, the efficacy of FMV was assessed by the ratio of expired and inspired tidal volumes ($VT_E/VT_I$), which can be affected by leaks in the ventilatory system.

The ongoing controversy on this topic is reflected by the differing views on the value of NMBDs in the presence of airway problems expressed in the report of the 4th National Audit Project (NAP4) [34, 35]. Whereas some local auditors judged avoidance of a NMBD in the presence of difficult airway management as something 'that went well', the review panel considered delayed or absent administration of NMBD in such situations as contributing to the adverse events. The NAP4 report includes the following statements: (1) "Where facemask or laryngeal mask anaesthesia is complicated by failed ventilation and increasing hypoxia the anaesthetist should consider early administration of further anaesthetic agent and/or a muscle relaxant to exclude and treat laryngospasm"; (2) "No anaesthetist should allow airway obstruction and hypoxia to develop to the stage where an emergency surgical airway is necessary without having administered a muscle relaxant".

The latter statement reflects the combined evidence which suggests that in patients without indication for awake fiberoptic intubation, the administration of a NMBD following induction of anesthesia can be expected to improve FMV in the majority of patients with little risk of worsening it. It adds considerable weight to the argument that routine confirmation of effective FMV is unnecessary. Furthermore, as the presence of neuromuscular blockade facilitates endotracheal intubation [36–38], the chances of successful life-saving endotracheal intubation in the presence of impossible FMV can be expected to be higher in the paralyzed than in the non-paralyzed patient.

## Quality of facemask ventilation and choice of muscle relaxant

It has been argued that checking FMV following induction of anesthesia is important for choosing the appropriate NMBD [39–41]. The reasoning is that suxamethonium should be administered when FMV is difficult, and a long-acting non-depolarizing NMBD when FMV is easy. The rationale behind this recommendation is the belief that the administration of suxamethonium preserves the option to 'wake up the patient' before severe hypoxemia develops.

I disagree with this generalized recommendation because existing data do not necessarily support the assumption that the option to 'wake up the patient' before severe hypoxemia develops will reliably be preserved. Following the administration of suxamethonium 1 mg/kg, it took as long as 10.5 min [42] and 11.2 min [43] for the recovery of the first train-of-four twitch ($T_1$) to 10 %, and as long as 8.5 min from tracheal intubation to the return of spontaneous respiration [43]. Thus, although there have been reports showing that patients may be successfully woken up following muscle relaxation [32], these findings nevertheless re-emphasize the view that after suxamethonium-induced apnea "achievement of functional recovery before significant desaturation is not a realistic possibility" [44].

The findings of a previous investigation [45] have been interpreted [41] as showing a superior effect of suxamethonium over non-depolarizing NMBDs on the quality of FMV. However, the study was non-randomized, FMV

had been successful even before the administration of any NMBD, baseline values for nasal and oral ventilatory volumes had differed between patients receiving rocuronium or suxamethonium, and statistical testing had not been optimal. The data can thus only be interpreted as showing that administration of a NMBD does not worsen pre-existing effective FMV. They certainly do not support the conclusion of differential effects of suxamethonium and non-depolarizing NMBDs on the quality of FMV.

## Conclusion

The overall evidence suggests that following the administration of a NMBD, the quality of FMV either remains unchanged or improves, but never worsens, irrespective of the initial quality of FMV. No airway technique under general anaesthesia is guaranteed to work always, but in airway management NMBDs seem to be much more often the answer than the problem. An underdosing of the anesthetic induction drug with the aim of maintaining the option of waking up the patient in the event of difficult FMV, may by itself render FMV more difficult. Lack of effective muscle relaxation will considerably reduce the chance of successful endotracheal intubation which may be required when hypoxemia develops during failed FMV. In a way, the reluctance to provide early effective muscle relaxation may actually cause rather than prevent a 'can't intubate, can't ventilate' situation. Moreover, early relaxation may reduce the risk of hypoxemia and pulmonary aspiration by shortening the time interval between anesthesia-induced apnea and intubation.

Administration of a NMBD has been compared with 'crossing the Rubicon' [41]. This idiom does not only mean passing a point of no return, but also implies irrevocable commitment to a risky or revolutionary course of action. It is a potentially dangerous misconception to consider the administration of a NMBD to be the Rubicon. Rather, the Rubicon is the administration of a hypnotic at a dose that abolishes spontaneous respiration. The chances are very small of successfully restoring adequate spontaneous respiration before severe hypoxemia develops in the presence of difficult or impossible FMV in an anesthetized, apneic patient who is prone to airway collapse because of reduced pharyngeal muscle tone. Thus, once we have crossed that Rubicon (i.e., have abolished spontaneous respiration), our goal must not be to 'consider preserving a way back over the bridge' (i.e., wake up the patient) [13], but to concentrate all our efforts on putting up camp quickly and safely on the other side of the river (i.e., provide effective ventilation).

These are no longer the 1960s or 1970s when effective airway devices were rare or non-existent and 'preserving a way back over the bridge' (i.e., wake up the patient) was clearly a safety issue. In 2015, the required airway equipment to successfully provide effective ventilation is available. It has become an extremely rare event that effective oxygenation and securing the airway cannot be achieved by any of these devices in the fully paralyzed patient. For obvious reasons, similar effectiveness of these devices cannot be expected in non-paralyzed patients. The initial crossing of the Rubicon (i.e., abolishing spontaneous respiration) is usually easy and guaranteed. However, a safe 'way back over the bridge' (i.e., wake up the patient) is predictably not easy and definitely not guaranteed. Thus, provided that conditions which forbid crossing the Rubicon to start with have been ruled out (i.e., indications for awake fibreoptic intubation), following induction of anesthesia we must aim at establishing, as quickly as possible, optimal conditions for FMV, endotracheal intubation, or the placement of a supraglottic airway device, rather than keeping open options with no proven success. As muscle relaxation facilitates establishing such conditions, the earliest administration of a NMBD following induction of anesthesia may well be the most effective tactic in routine clinical practice and, thus, in the interest of patient safety. Insistence on FMV before administration of a NMBD is more of a ritual than an evidence-based safe practice. In my opinion, this practice should thus be abandoned.

## References


1. Calder I, Yentis SM. Could 'safe practice' be compromising safe practice? Should anaesthetists have to demonstrate that face mask ventilation is possible before giving a neuromuscular blocker? Anaesthesia. 2008;63:113–5.
2. Xue FS, Liao X, Wang Q, Yuan YJ, Xiong J, Liu JH. Is it unnecessary to confirm successful face mask ventilation before administration of a neuromuscular blocking agent? Anaesthesia. 2011;66:519–20.
3. Pandit JJ. Checking the ability to mask ventilate before administering long-acting neuromuscular blocking drugs. Anaesthesia. 2011;66:520–2.
4. Cook T. What about patients whose lungs cannot be ventilated? Anaesthesia. 2011;66:522–3.
5. Ramachandran SK, Kheterpal S. Difficult mask ventilation: does it matter? Anaesthesia. 2011;66(Suppl. 2):40–4.
6. Richardson MG, Litman RS. Ventilation before paralysis: crossing the Rubicon, slowly. Anesthesiology. 2012;117:456–8.
7. Calder I, Yentis SM. Could 'safe practice' be compromising safe practice? Should anaesthetists have to demonstrate that face mask ventilation is possible before giving a neuromuscular blocker? Anaesthesia. 2008;63:113–5.
8. Priebe H-J. Could 'safe practice' be compromising safe practice? Should anaesthetists have to demonstrate that face mask ventilation is possible before giving a neuromuscular blocker? Anaesthesia. 2008;63:671–2.
9. Calder I, Yentis S, Patel A. Muscle relaxants and airway management. Anesthesiology. 2009;111:216–7.
10. Gordon RJ. Anesthesia dogmas and barriers to patient safety? Anesth Analg. 2012;114:694–9.

11. Priebe H-J. Ventilation before paralysis. Anesthesiology. 2013;118:992–3.
12. Broomhead RH, Marks RJ, Ayton P. Confirmation of the ability to ventilate by facemask before administration of neuromuscular blocker: a non-instrumental piece of information? Br J Anaesth. 2010;104:313–7.
13. Tsuiki S, Isono S, Ishikawa T, Yamashiro Y, Tatsumi K, Nishino T. Anatomical balance of the upper airway and obstructive sleep apnea. Anesthesiology. 2008;108:1009–15.
14. Hajiha M, DuBord MA, Liu H, Horner RL. Opioid receptor mechanisms at the hypoglossal motor pool and effects on tongue muscle activity in vivo. J Physiol. 2009;587:2677–92.
15. Claeys MA, Camu F. Efficacy of lorazepam and lormetazepam as intravenous premedicants for anesthesia and surgery. Acta Anaesthesiol Belg. 1986;37:113–20.
16. Eikermann M, Eckert DJ, Chamberlin NL, Jordan AS, Zaremba S, Smith S, Rosow C, Malhotra A. Effects of pentobarbital on upper airway patency during sleep. Eur Respir J. 2010;36:569–76.
17. Eastwood PR, Szollosi I, Platt PR, Hillman DR. Comparison of upper airway collapse during general anaesthesia and sleep. Lancet. 2002;359:1207–9.
18. Hillman DR, Platt PR, Eastwood PR. The upper airway during anaesthesia. Br J Anaesth. 2003;91:31–9.
19. Eastwood PR, Platt PR, Shepherd K, Maddison K, Hillman DR. Collapsibility of the upper airway at different concentrations of propofol anesthesia. Anesthesiology. 2005;103:470–7.
20. Bennett JA, Abrams JT, Van Riper DF, Horrow JC. Difficult or impossible ventilation after sufentanil-induced anesthesia is caused primarily by vocal cord closure. Anesthesiology. 1997;87:1070–4.
21. Fink BR. The etiology and treatment of laryngeal spasm. Anesthesiology. 1956;17:569–77.
22. Abrams JT, Horrow JC, Bennett JA, Van Riper D, Storella RJ. Upper airway closure: a primary source of difficult ventilation with sufentanil induction of anesthesia. Anesth Analg. 1996;83:629–32.
23. Odeh M, Schnall R, Gavriely N, Oliven A. Effect of upper airway muscle contraction on supraglottic resistance and stability. Respir Physiol. 1993;92:139–50.
24. Isono S, Kochi T, Ide T, Sugimori K, Mizuguchi T, Nishino T. Differential effects of vecuronium on diaphragm and geniohyoid muscle in anaesthetized dogs. Br J Anaesth. 1992;68:239–43.
25. Warters RD, Szabo TA, Spinale FG, DeSantis SM, Reves JG. The effect of neuromuscular blockade on mask ventilation. Anaesthesia. 2011;66:163–7.
26. Sachdeva R, Kannan TR, Mendoca C, Patteril M. Evaluation of changes of tidal volume during mask ventilation following administration of neuromuscular blocking drugs. Anaesthesia. 2014;69:826–32.
27. Pandit JJ, Duncan T, Robbins PA. Total oxygen uptake with two maximal breathing techniques and the tidal volume breathing technique: a physiologic study of preoxygenation. Anesthesiology. 2003;99:841–6.
28. Langeron O, Masso E, Huraux C, Guggiari M, Bianchi A, Coriat P, Riou B. Prediction of difficult mask ventilation. Anesthesiology. 2000;92:1229–36.
29. Bouvet L, Albert M-L, Augris C, Boselli E, Ecochard R, Rabilloud M, Chassard D, Allaouchiche B. Real-time detection of gastric insufflation related to facemask pressure-controlled ventilation using ultrasonography of the antrum and epigastric auscultation in nonparalyzed patients: a prospective, randomized, double-blind study. Anesthesiology. 2014;120:326–34.
30. Seet MM, Soliman KM, Sbeih ZF. Comparison of three modes of positive pressure mask ventilation during induction of anaesthesia: a prospective, randomized, crossover study. Eur J Anaesthesiol. 2009;26:913–6.
31. Amathieu R, Combes X, Abdi W, Housseini LE, Rezzoug A, Dinca A, Slavov V, Bloc S, Dhonneur G. An algorithm for difficult airway management, modified for modern optical devices (Airtraq laryngoscope; LMA CTrach™): a 2-year prospective validation in patients for elective abdominal, gynecologic, and thyroid surgery. Anesthesiology. 2011;114:25–33.
32. Kheterpal S, Martin L, Shanks AM, Tremper KK. Prediction and outcomes of impossible mask ventilation: a review of 50,000 anesthetics. Anesthesiology. 2009;110:891–7.
33. Goodwin MW, Pandit JJ, Hames K, Popat MT, Yentis SM. The effect of neuromuscular blockade on the efficiency of mask ventilation of the. Anaesthesia. 2003;58:60–3.
34. Frerk C, Pearce A. Induction and maintenance of anaesthesia. In: Cook T, Woodall N, Frerk C, editors. 4th National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Major Complications of Airway Management in the United Kingdom. London: RCoA; 2011:55-61.
35. http://www.rcoa.ac.uk/nap4.. Accessed 5 Aug 2015.
36. Lieutaud T, Billard V, Khalaf H, Debaene B. Muscle relaxation and increasing doses of propofol improve intubating conditions. Can J Anesth. 2003;50:121–6.
37. Combes X, Andriamifidy L, Dufresne E, Suen P, Sauvat S, Scherrer E, Feiss P, Marty J, Duvaldestin P. Comparison of two induction regimens using or not using muscle relaxant: impact on postoperative upper airway discomfort. Br J Anaesth. 2007;99:276–81.
38. Davis DP, Ochs M, Hoyt DB, Bailey D, Marshall LK, Rosen P. Paramedic-administered neuromuscular blockade improves prehospital intubation success in severely head-injured patients. J Trauma. 2003;55:713–9.
39. Ramachandran SK, Kheterpal S. Difficult mask ventilation: does it matter? Anaesthesia. 2011;66(Suppl. 2):40–4.
40. Pandit JJ. Checking the ability to mask ventilate before administering long-acting neuromuscular blocking drugs. Anaesthesia. 2011;66:520–2.
41. Richardson M, Litman R. Ventilation before paralysis: crossing the Rubicon, slowly. Anesthesiology. 2012;117:456–8.
42. Lee C, Jahr JS, Candiotti KA, Warriner B, Zornow MH, Naguib M. Reversal of profound neuromuscular block by sugammadex administered three minutes after rocuronium: a comparison with spontaneous recovery from succinylcholine. Anesthesiology. 2009;110:1020–5.
43. Sørensen MK, Bretlau C, Gätke MR, Sørensen AM, Rasmussen LS. Rapid sequence induction and intubation with rocuronium–sugammadex compared with succinylcholine: a randomized trial. Br J Anaesth. 2012;108:682–9.
44. Benumof JL, Dagg R, Benumof R. Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1 mg/kg intravenous succinylcholine. Anesthesiology. 1997;87:979–82.
45. Ikeda A, Isono S, Sato Y, Yogo H, Sato J, Ishikawa T, Nishino T. Effects of muscle relaxants on mask ventilation in anesthetized persons with normal upper airway anatomy. Anesthesiology. 2012;117:487–93.