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Difficult mask ventilation: does it matter?

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Summary

We discuss the relevance of finding a patient's lungs difficult to ventilate by facemask during the course of anaesthetic induction. In particular, we discuss the issue of whether it is advisable or unnecessary to check the ability to ventilate by facemask before administering a neuromuscular blocking agent. In the light of advances in supraglottic airway technology it has become possible to insert these devices very soon after induction and in a wider variety of patients. Similarly, the development of videolaryngoscopes and rapidly acting drugs such as rocuronium have raised the possibility of earlier, and possibly more successful, tracheal intubation, with the potential result that mask ventilation becomes redundant. However, we conclude by reaffirming its value in airway management strategies.

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Abraham Lincoln is credited with the saying *''The dogmas of the quiet past are inadequate to the stormy present''*, a quote that we will modify as follows: *''The dogmas of the stormy past are inadequate to the quiet present''*. The greatest challenge to evidence-based evaluation of any airway technique is the extremely low incidence of severe adverse events directly attributable to inadequate ventilation. In addition, it is not known whether any observed improvement in the incidence of airway-related morbidity is a consequence of increased focus on airway management, improved respiratory monitoring, or both.

Two fundamental dogmas have shaped airway management research and strategies over the ages. On the one hand, the importance of securing the airway with invasive devices has been explored in various cultures since approximately 2000 BC, long before the advent of modern medicine. For example, one section of the voluminous *Rig Veda* describes a tracheostomy as a way to sustain life [1]. The majority of the world's literature to date has focused on techniques and equipment to secure the airway with a variety of airway devices. A second essential development occurred in the 1990s – the recognition that repeated attempts to secure the airway led to anaesthesia-related brain injury or death (in the American Society of Anesthesiologists' Closed Claims database [2]).

In part from these retrospective outcomes analyses, a newfound respect for the virtues of ventilation by facemask was born. Possibly as a consequence, the confirmation of the ease of mask ventilation gained respectability as a threshold test before administering neuromuscular blocking drugs (NBDs). Significant improvements in intra-operative respiratory monitoring were introduced during this period, with a dramatic concurrent reduction in mortality and severe morbidity from airway disasters [3]. Most recently, robust research on the optimal mask ventilation technique has gained prominence [4, 5].

Since those lofty days of 'airway success', a more sophisticated discussion has arisen about the actual value of pre-NBD mask ventilation in a milieu of improved technology. Thus, we are now confronted with two divergent views of what constitutes best practice: whether or not to check mask ventilation before NBD administration [6]. Broomhead et al. surveyed UK anaesthetists [7] and found that the majority of those who checked mask ventilation before NBD administration ('checkers') did so out of clinical habit, perceived best practice and their potential to 'bail out' of a difficult mask ventilation by 'waking up' the patient. Yet the majority (71%) of these 'checkers' also admitted that they would use suxamethonium as a response strategy to difficult or failed mask ventilation.

This apparent dichotomy of thought and practice is explained by the authors as a tendency to collect non-instrumental information during the act of mask ventilation. Although this is an attractive theory, its weakness is that it remains speculative. Broomhead et al. did not understand the logic of checkers, citing arguments that even short-acting NBDs, e.g. suxamethonium, do not allow 'wake-up' (i.e. restoration of spontaneous ventilation) in sufficient time. Furthermore, Warters et al. have recently reported that NBDs improve mask ventilation (in contrast to an earlier study suggesting that they had no effect) [8]. Although the authors argue that NBDs should in fact be given as early as possible, the study was small and included no patients who were impossible to ventilate before NBDs, therefore the findings should be interpreted cautiously.

Defining the problem

Difficult mask ventilation occurs as a result of two primary mechanisms: inadequate seal between the face and the mask; or upper airway collapse. Consequently, airway difficulty manifests (respectively) either as an inability to generate adequate airway pressure to drive gases into the lungs or the inability to move air into the lungs despite adequate driving pressures. The simplest structured mask ventilation scale in contemporary literature was probably described by Han et al. in 2004, where difficult mask ventilation was defined as 'inadequate, unstable, or requiring two providers' with or without neuromuscular blockade [9]. Through successive publications in 2006 and 2009, Kheterpal et al. demonstrated several important benchmark data [10, 11]. First, the incidence of difficult mask ventilation is $\sim$ 1.4% (95% CI 1.2–1.5%; $\sim$ 1 in 64 patients), lower than the 5% rate seen in Langeron et al.'s previous study in 2000 [12]. This difference was possibly related to the practice of using the oropharyngeal airway in Han et al.'s scale. Second, combined difficult mask ventilation and difficult intubation were encountered once in every 270 patients ($\sim$ 0.4% incidence, 95% CI 0.3–0.5%). Third, the incidence of impossible mask ventilation was shown to be $\sim$ 0.2% (95% CI 0.1–0.2; $\sim$ 1 in 625 patients). Finally, the incidence of a 'cannot ventilate – cannot intubate' scenario was a tiny 0.008% (1 in 12 500 patients). Most crucially, these numbers were derived from a single quaternary care institution whose anaesthesia providers were familiar with awake airway intubation techniques and equipment. Although the large patient cohort and caregiver experience make the data robust, caution needs to be exercised before generalising these results.

Influence of neuromuscular blockade on ease of mask ventilation

A large body of work supports the view that opioid medications [13], benzodiazepines [14], other induction agents [15] and NBDs [16] reduce upper airway muscle tone, resulting in upper airway narrowing and collapse [17]. It is also well established that the immediate post-induction period of anaesthesia is associated with an increase in upper airway reflexes including laryngospasm [18]. The effect of muscle relaxation on the upper airway will therefore be dependent on the predominant forces at the time of administration of the NBD. There are five significant studies that describe pertinent points to consider while discussing the interaction of NBDs and mask ventilation. First, Bennett and Abrams described the beneficial effect of NBDs on ease of mask ventilation by comparing upper airway images before and after administration of the drugs [18]. They concluded that the airway closure seen soon after induction of anaesthesia with sufentanil is related to vocal cord closure in > 90% of patients. Second, Goodwin et al. compared the efficiency of mask ventilation between pre- and post-NBD using the ratio of inspired to expired tidal volumes [19]. Although the study demonstrated no relationship between NBDs and ease of mask ventilation, there were significant differences in individual patient responses. On closer examination of the published data, one quarter of patients were observed to have worse ventilation ratios after the NBD. Considering that this study was performed on normal healthy males with no markers of difficult airway, the results are interesting and provocative. Third, Kheterpal et al.'s data clearly demonstrated that all patients with impossible mask ventilation were rescued even though they had received a NBD either electively or as a rescue medication [10, 11]. Calder and Yentis declared subsequently that this in itself was sufficient proof-of-concept that use of NBDs does not influence the incidence of impossible mask ventilation [6]. In a subsequent study, Kheterpal et al. showed that only 2 of 50 000 patients with failed mask ventilation attempts (0.004%) needed to be awoken for fibreoptic intubation, and all the remaining patients were managed by alternative airway management techniques

[11]. Finally, Warters et al. have reported (in contrast to Goodwin et al.'s study) that NBDs actually improve the ability to mask ventilate [8].

In summary, clinical evidence to support a policy of checking mask ventilation before administering a NBD is weak. Calder and Yentis suggested that the avoidance of NBDs may indeed be harmful, by significantly affecting the ease and success of laryngoscopy [6]. Yet there remain a significant number of 'checkers', whose behaviour warrants explanation. Recently, Pandit [20] noted that NBDs can make mask ventilation both easier (e.g. when there is underlying laryngeal spasm or chest muscle rigidity) [17] or more difficult (e.g. if relaxation-induced collapse of the upper airways worsens obstruction) [21]. The problem is that we cannot predict which of these effects will predominate in any given case. The only prediction models that do exist in the literature evaluate risk factors for difficult and impossible mask ventilation. Taking the view that predicting the latter is the most relevant part of this pre-operative assessment, the following independent predictors should alert anaesthetists of increased risk: neck irradiation (e.g. radiotherapy for head and neck cancer); male sex; history of sleep apnoea; Mallampati 3–4; and presence of a beard [11]. The presence of two, three and four concurrent risk factors increases the odds of impossible mask ventilation 5.8, 8.9 and 25.9 times, respectively. The challenge with this approach is the low ($\sim$ 5%) incidence of failed direct or videolaryngoscopy among patients with impossible mask ventilation, which in itself has a 0.2% incidence. This low incidence of airway failure, without doubt, seriously affects the positive predictive value of the screening system [22] in the setting of a mature quaternary care institution (where the majority of the 'anticipated difficult airways' are managed by awake techniques). Conversely, the low incidence rate also means a near-perfect negative predictive value, given the rarity of true impossible mask ventilation. Thus, in a broader sense, such screening tools are more likely than not to help anaesthetists identify which patients to focus our efforts on.

Even when mask ventilation proves difficult, we can never be certain which specific factor is contributing. Pandit offered a logical hypothesis to explain the behaviour of 'checkers'. Mask ventilation maintains oxygenation from the earliest opportunity while anaesthesia is deepened, and short-acting NBDs must be distinguished from long-acting ones. Using the former in difficult mask ventilation resembles their use during rapid sequence induction: if tracheal intubation fails then waking the patient remains an option (albeit not a certainty) [23]. Rocuronium, with sugammadex if needed, might be assumed to be akin to a short-acting NBD, although some evidence suggests that it may not be [24]. It is only by checking routinely that two patient subgroups can be identified: (A) those initially easy; and (B) those initially difficult. For Group A *all* anaesthetists would readily administer a long-acting NBD. However, Pandit argued that for Group B it was irrational to administer a long-acting NBD (e.g. it is unclear how oxygenation would be maintained while the NBD works). Very curiously, Broomhead et al. found that 18% of anaesthetists (including checkers) would follow this irrational route [7].

In conclusion, although there is dearth of *evidence* regarding checking, there is some *logic* in its support. Whereas giving a short-acting NBD (suxamethonium) may not guarantee a return to early spontaneous ventilation as rescue, the contrary is certainly true: administering a long-acting NBD before checking guarantees this rescue option is impossible if subsequent difficulties are encountered (Fig. 1).

Facemask ventilation in the era of supraglottic airways

In the Fourth National Audit Project of the Royal College of Anaesthetists and Difficult Airway Society (NAP4), Cook and colleagues reported that >75% of reported events and 80% of deaths related to airway compromise under anaesthesia had elements of poor management [25], mirroring the finding of 90% incidence of substandard care from a US closed claims database [2].

The last decade has seen a virtual explosion of supraglottic airways (SADs), prompting significant changes in airway management strategies. Second generation SADs can facilitate positive pressure ventilation with pharyngeal leak pressures of more than 25–27 cmH_2O whilst maintaining an effective oesophageal seal. Despite individual limitations, SADs collectively offer an improved routine and emergency airway management technique and have reduced the use of emergency surgical airway access in the management of patients with difficult airways [26]. But questions remain over the definition and magnitude of difficult insertion rates. Using a loose definition of failure to achieve a satisfactory SAD position within three attempts of insertion, summary data from existing literature suggest a 0–13% difficult insertion rate (mean $\sim$ 2%) [27]; quite a large variation in the data for a

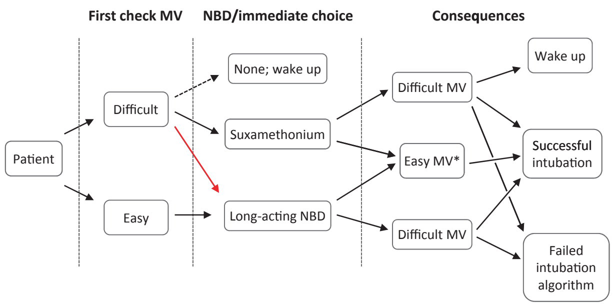

Figure 1 Possible sequences of events relating to mask ventilation during anaesthetic induction. There are three broad phases after induction, delineated by vertical dotted lines: first check of mask ventilation (MV); then a choice of three options depending upon the ability to mask ventilate (NBD/immediate choice); then several consequences of those choices. *Failed intubation may still be possible with easy mask ventilation. NBD, neuromuscular blocking drug. The dotted arrow indicates the route followed by very few anaesthetists, and the red arrow indicates the step that may lead to a potentially dangerous situation. Note that waking the patient in the third phase is only an option if suxamethonium is given. Redrawn from [20], with permission.

device purported to be an alternative to tracheal intubation (and also data that may apply only to the Pro-Seal device examined). If SADs are more difficult to insert than we think, then they may not be superior to facemask ventilation. Remarkably, unlike the studies of mask ventilation referred to above, there have been no large observational studies of failed SAD management. The recent NAP4 study noted that 42% of all patients who died or suffered brain injury received a SAD as the primary airway plan [25] (a SAD was used in ~ 50% of all anaesthetics), and there was an implication they were overused in some patient subgroups, such as the obese.

Facemask ventilation and videolaryngoscopy

Videolaryngoscopic technology presents another challenge to the traditional approach of anaesthesia induction, facemask ventilation and tracheal intubation. If these devices are universally successful and easy to use, then this may make the 'mask ventilation step' redundant in the process. Large observational studies of these newer devices are forthcoming. As an example, Aziz et al. described the two-centre experience of the GlideScope [28]. Interestingly, the device had a 3% failure rate when used in patients with anticipated difficult airways and a 6% failure rate when used to rescue failed direct laryngoscopy. In other words, the GlideScope failed once every 33 patients with a difficult airway and once every 16 patients with failed direct laryngoscopy. Ovassapian had previously demonstrated a failed fibreoptic intubation rate of between 1.4% and 2.1% in awake and anaesthetised patients, respectively, with equal distribution of a poor view and inability to advance the tracheal tube [29]. Even if subsequent studies demonstrate a halving of these failure rates, these are substantial concerns for anaesthetists who consider videolaryngoscopy as a 'complete' airway management tool.

So does difficult mask ventilation matter?

In this article, we have focussed on difficult/impossible mask ventilation in the context of induction of anaesthesia (which is the scenario for which there is most evidence). There is also the context of a difficult airway that has been instrumented and subsequently deteriorates, or the post-extubation scenario in which mask ventilation is always the first option. We do not know the extent to which research findings at induction automatically extend to considerations in these scenarios. Successful airway management relies in large part upon knowing early when things are not going according to plan. The demonstration of ease of mask ventilation is therefore an important step to take that sets the scene for later management options (Fig. 1). It is at this point that the finding of difficult mask ventilation should alert the anaesthetist to the possibility of a need to deviate from the primary airway management plan. Earlier demonstration of the ability to mask ventilate may serve to reassure if laryngoscopy later proves unexpectedly difficult. Although the availability of SADs offers further security, and videolaryngoscopes may indeed have a high success rate, proof of efficacy is not at a stage where mask ventilation can be dispensed with as an integral part of the airway management plan.

Competing interests

No external funding or competing interests declared.

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