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Coll. Antropol. **34** (2010) 3: 1161–1165
Review

Inadequate Face Mask Ventilation – Clinical Applications

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A B S T R A C T

Face mask ventilation is a life saving technique. This article will review aetiology and patophysiological consequences of inadequate mask ventilation. The main focus will be on circulatory changes during induction of anesthesia, before and in a short period after intubation that could be attributed to inadequate mask ventilation in humans.

Key words: *face mask ventilation, training, hypoventilation, hypercarbia, hyperventilation, hypocarbia, circulatory changes*

Introduction

Face mask ventilation is considered to be a basic life saving technique in ventilating unsecured airway. It is generally used during resuscitation, during the induction of anaesthesia, and may be used during the maintance of anaesthesia for short term procedures. In order to achieve the constant and adequate ventilation performance, performers should invest great effort. Since this goal is difficult to reach in real life, face mask ventilation is not considered to be optimal in securing the airway for the longer period. Therefore, it is performed usually only temporarly before proceeded by laryngeal mask insertion or intubation.

Face Mask Ventilation Technique

The technique of face mask ventilation is taught by practice on mannequin models[1,2] and traditionally in real time clinical situations[3]. However, nor the technique[4] nor the training of face mask ventilation have been standardized. Gender of practitioner may influence the learning process but only in an early stage of training. It was shown that the female residents have more difficulties in providing tight mask seal that is necessary for performing ventilation well[5].

The technique consists of a proper face mask holding and ventilation. The classical textbooks' text instructs the novices to lift the chin with a left hand with the fifth finger at the left mandible angle (jaw thrust) while the left index and thumb make a pressure on the dome of the mask[6]. The right hand is free for performing ventilation. This is one-hand ventilation technique. Alternatively, one can use both hand for lifting the mandible and maintaining the pressure on the mask (two-hand ventilation) with the help of second person or a respirator that perform ventilation. Ventilation of apnoic patient during induction of anaesthesia can be performed manually by squeezing a breathing bag by hands or mechanically by the aid of a respirator. Resuscitators usually have only bag mask ventilation on disposal that has certain limitations. Mechanical ventilation provides better control of the applied peak pressures[7]and provides the means of applying positive end-expiratory pressure (PEEP)[8]. The application of PEEP during induction of anesthesia is beneficial for morbidity obese patients[9]. Beneficial effect of

Received for publication July 6, 2010

PEEP during induction of anaesthesia in this population is attributed to prolonged periods of nonhypoxic apnoe by 50%[10].

Certain teaching and instruction methods can be helpful too. The group of authors found that, when combined, the written instruction and the demonstration of the identified optimal technique of face mask ventilation resulted in significantly reduced face mask leak by 24.1%[11].

Difficult Mask Ventilation

Difficult mask ventilation is recognized problematic situation clearly stated in the American Society of Anaesthesiologists (ASA) Task Force Guidelines on the Management of the Difficult Airway[12]. The ASA Task Force Guidelines define difficult mask ventilation by problems and inadequate mask ventilation by signs according to ASA Task Force Guidelines the problems in difficult mask ventilation are classified as inadequate mask seal, excessive gas leak or excessive resistance to ingress or egress of gas[12].

There are nine signs of difficult mask ventilation listed in ASA Task Force Guidelines: 1. absent or inadequate chest movement; 2. absent or inadequate breath sounds; 3. auscultatory sign of severe obstruction: 4. cyanosis: 5. gastric air entry or dilatation; 6. absent or inadequate oxygen saturation; 7. absent or inadequate exhaled carbon dioxide; 8. absent or inadequate spirometric measures of exhaled gas flow; and 9. haemodynamic changes associated with hypoxemia or hypercarbia[12]. Additional signs of inadequate ventilation were included in the published papers: necessity of increasing gas flow (greater than 6 L/min[5] or greater than 15 L/min[1]), two handed mask ventilation requiring assistance by anaesthesiologist[5,13], and oxygen flush needed more than two times[5,13,] and change of operator[13]. In 2004 Han et al. introduced the semi-quantative scale of difficult ventilation. The Han's scale includes four grades of ventilation: Grade 1-ventilated by mask; Grade 2-ventilated by mask with oral airway; Grade 3-difficult ventilation (inadequate, unstable, or requiring two practitioners); Grade 4-unable to ventilate[14].

Recently El Orbany reviewed this topic and emphasized the need for the standardisation of defintion of difficut mask ventilation because of the obvious difficulty in approaching the whole problem. Untill a more precise definition will be accepted, the same autor recommeded rather vaguelly the concommitant use of the Task Force definition, the use of explicit descriptions and the Han's scale[15].

Face Mask Leak

The common practice evidences that a leak at the face mask is common, though the written reports are limited. The leak is present when there is no perfect match of the mask and the face. Having in mind the human individuality, the imperfection is inevitable.

Leaks may be attributed to the design of mask. One study on adult models identified that there is great variation in satisfaction and performance of anesthesiologist with different designs of the face masks[16]. Black rubber mask showed worse performance in compare to disposable, soft designed one in adult patients[17]. The leak varied from 20–27% depending on type of mask used, but did not significantly correlated with years of experience[16]. The studies on modified neonate mannequin models showed that the leak on average was >50%[2,18] and often irrespective of operator experience[18]. A type of the face mask did not influenced ventilation performance and leaks in neonate models[2,11,18].

Beard, edentulous face and abnormal facial anatomy are most often blamed for bad mask fit and difficult mask ventilation[13,19,20]. In addition, common associated risk factors for difficult ventilation are weight, age above 55 and snoring. El-Orbany et al. found the following independent predictors of difficult mask ventilation: obesity, age older than 55 yr, history of snoring, lack of teeth, the presence of a beard, Mallampati Class III or IV, and abnormal mandibular protrusion test[15]. In their first study Kheterpal et al. showed that body mass index of 30 or greater, a beard, Mallampati classification III or IV, age of 57 year or older, severely limited jaw protrusion, and snoring were identified as independent predictors for grade 3 mask ventilation[19]. Snoring and thyromental distance of less than 6 cm were independent predictors for grade 4 mask ventilation. Limited or severely limited mandibular protrusion, abnormal neck anatomy, sleep apnea, snoring, and body mass index of 30 kg/m or greater were independent predictors of grade 3 or 4 mask ventilation[19]. In their later study of Kheterpal et al. (2009) identified neck radiation changes, male sex, sleep apnea, Mallampati III or IV, and presence of beard as independent predictors[20]. Similar results were published by Yildaz et al. who found that height, weight, age, male gender, increased Mallampati class, history of snoring, lack of teeth, and beard to be risk factors for difficult mask ventilation[21]. The risk predictor of difficult mask ventilation in children is obesity[22,23]. Children with craniofacial abnormalities in different syndromes (Treacher Collins[24], Down[25]) may be difficult to ventilate that is even more challenging, because they develop hypoxemia much faster than adults[15.]

The common practice resolves the problem of leaks with different practical maneuvers such as two hand ventilation and bilateral jaw trust or insertion of oropharyngeal (Guedel) airway. Leaving dentures in place was recommended by some authors but may be dangerous[13]. Shaving beard before operation has more than pure hygienic purpose[13,19,26]. Packing the buccal cavities with gauze may help in providing better facial support[6]. Recent study on improving performance of mask ventilation in edentulous patients with leak showed the lower lip face mask placement with two hands significantly reduced air leak[27]. In addition, respiratory monitoring reduced leak in neonates from 27% to 11%[28].

Alternative Approaches to Face Mask Ventilation Problems

Nowadays due to improved airway devices and new drugs there is trend to overcome the problems of any suboptimal standard mask ventilation, not necessarily preoperatively recognized difficult mask ventilation. Firstly, some authors advocate the development of ergonomic face masks[4]. The ergonomic face mask are designed to adapt for asymmetrical left hand grip with a dome larger on the left side and the posterior part higher than the anterior[4]. Secondly, initial ventilation via face mask can effectively and safely be replaced by initial laryngeal mask insertion. The usefulness of laryngeal mask was proved even in circumstances that are more difficult to control such as out-hospital environment[29] and for near term newborns[30,31]. Thirdly, the period during induction for the mask ventilation, in which the patient has no spontaneous breathing, has been shorten due to the introduction of rapid sequence induction dose of rocuronium (muscle relaxant)[32–34]. This means that in addition to succinylcholine, that provides optimal intubation conditions in 30 seconds, the clinicians have another rapid muscle relaxant on disposal. When rocuronium is used in high doses (1.2 mg/kg), it provides optimal conditions in one minute, still sparing the patient for side effects that accompany the use of succinylcholine. Moreover, rocuronium, in compare to succinylcholine, has a faster, more effective and safer antidote, sugammadex, that can abolish its effect in approximately two minutes and return patient's spontaneous breathing[35,36].

Inadequate Mask Ventilation in Adults

Inadequate mask ventilation is generally defined in terms of poor gas exchange of carbon dioxide (CO_2). Hypoventilation leads to retention of CO_2 and hypercarbia ($PaCO_2$ ≥45 mmHg); while hyperventilation leads to hypocarbia ($PaCO_2$ <35 mmHg). Hypoventilation leads to hypoxemia too, but adding extra oxygen (O_2) in gas mixture resolves it quickly[37], and that is the case with controlled ventilation as featuring during induction of anesthesia.

Standard monitoring during anaesthesia, that includes pulse oximetry and capnography, should warn the practitioner to apply corrective measures if parameters range out of normal values. Few recent studies showed the greater importance of monitoring end-tidal CO_2 to pulse oximetry in recognizing early signs of hypoventilation[38–40].

However, more alarming results were recently claimed by one retrospective analysis studying the admission arterial to end-tidal carbon dioxide gradient in intubated major trauma patients at a major Australian trauma centre[41]. The authors demonstrated that 49% intubated major trauma patients arrived with potentially deleterious hypercapnia due to hypoventilation. The study involed, indeed, 80% patients with head injury in whom physiological dead space could be partially explanation for hypercapnia. The authors themselves emphasized the greater need to care for detecting and correcting hypercapnia[41].

However, there is little evidence about how we actually perfom ventilation. There is only one study on the incidence of unintended hypercapnia/hypocapnia during induction of anaesthesia before intubation and immediate after securing the airway by an endotracheal tube and sporadically published case reports. This is rather surprising because nowadays the end-tidal CO_2 monitoring is considered to be the integral part of the standard equipment in operation theaters and is routinely used in all recent anaesthesia studies.

One study dated from 1999 on adult maxillofacial surgical patients during induction period showed that arrhythmias during intubation were rare (0.9%) but when occurred significantly associated with elevated $PaCO_2$ values (+14.0 mmHg)[42]. Therefore the authors concluded that the importance of more adequate ventilation coupled with skillful intubation in a shorter period to avoid hypercapnia and arrhythmias[42]. Karlin et al. reported a case of a 2-year old child, scheduled for open bilateral hernia repair, who developed tachycardia with hypercarbia. Obvious cause of this incidence was the addition of a heat and moisture exchanger in a breathing system, that led to increased dead space and hypoventilation[43]. Two cases of arrhythmia were reported as a result from the faulty Bain circuit breathing system[44].

In addition, it may be presumed that all difficult mask ventilation situations carry risk for hypercapnia. Incidence of difficult mask ventilation varies between 0.08–15% depending on the definition of difficult mask ventilation used in a study[13,15,19,20,21,45,46]. In some of these studies difficult ventilation was only considered in worst cases graded as 4 according to Han's scale.

However, inadequate ventilation has a broader meaning. Hypothetically it may occur even in situations categorized as easy ventilation, but for some reason the performer ventilates the patient with too high or too low rate/volume. It is identified that a lay person on a mannequin model[47]and after one year training[48] tend to hyperventilate patients that can produce hypocapnia. This may be attributed to novice anaesthetists, too. Surprisely, face mask ventilation performance of anaesthesia residents was only studied by one Japanese study which identified gender influence on holding face mask early during training. The incidence of loose mask hold was reported to be in 29.8% female residents and 20% of male residents[5]. The frequency of difficult mask ventilation to the sixth procedures was above 40%. Unfortunately, the study design did not included collecting data on CO_2 though reported incidence hypoxemia (spO_2 <92%) during the period of mask ventilation in 1.2% patients.

Circulatory Effects of Inadequate Ventilation in Clinical Practice

Short-termed cardiovascular effects of CO_2 were evaluated in humans in very early publications[49,50]. In awake patients the effect of hypercarbia was related to the sympathic response[51]. Wattiwil et al. showed on nine ASA II and ASAIII patients scheduled for major surgery that the addition of carbon dioxide resulted in increases in cardiac output, systemic and pulmonary arterial blood pressures, and right and left ventricular stroke work[52]. The addition of isoflurane during hypercapnia decreased systemic arterial blood pressure, but pulmonary arterial blood pressure was unaffected, cardiac output and stroke volume did not change, and left but not right ventricular stroke work decreased. The authors finally concluded that acute pulmonary hypertension induced by hypercapnia was not affected by isoflurane but, despite increased right ventricular stroke work, there were no signs of right ventricular failure[52].

Kazmaier et al. showed that short-term modulation of ventilation rate induced significant haemodynamic changes in ten anaesthetised patients with coronary artery disease undergoing cardiac bypass grafting procedure[53]. During hypercapnia, the mean cardiac index and stroke volume index were increased by 13% and 15%, respectively. Heart rate was not significantly altered by variations of level of CO_2[53]. The mean systemic vascular resistance index increased during hypocapnia by 9% and decreased during hypercapnia by the same amount. Because of the concommitant changes in cardiac index, mean arterial pressure remained constant during the entire study. Similarly, pulmonary capillary wedge pressure, end-diastolic left ventricular pressure, and central venous pressure remained unchanged[53].

In a recent study of Kim et al. studied the effect of different mask ventilation rate on 40 ASA I and ASA II adult patients. The authors showed that hypercarbia due to hypoventilation during induction period resulted in significant increase in systolic arterial pressure to laryngoscopy irrespective of the used anaesthtic drugs[54]. The heart rate and diastolic arterial pressure remained unchanged[54].

Choiniere et al. showed that, voluntary hyperventilation before the induction of general anesthesia in a rapid sequence induction protocol, that included still face mask with 100% oxygen, in intention to prevent hypercapnia after intubation was not effective[55].

Potential benefit of inadequate ventilation to counteract cardiac depression induced by anaesthetics was explored by Enoki et al. The authors evaluated the effectiveness of intentional hypercapnia against hypotension after induction of anaesthesia with thiopental and isoflurane or propofol. Mild hypercapnia was effective in the prevention of hypotension in patients receiving thiopental followed by 0.6% end-expiratory isoflurane, but not in patients receiving 6 mg/kg/h propofol[56].

Conclusion

In our daily practice we are often faced with inadequate face mask ventilation performance leading to hypoventilation or hyperventilation of patients. None of these situations fulfills the patients' needs. Moreover, unwanted circulatory disturbances may occur. Good performer seeks for the state of adequate ventilation. The alternative devices may help in improving our performance, and should be encouraged to use whenever judged to give extra benefit for the patient. However, the proper face mask training should not be skipped. Face mask ventilation is a fundamental skill and a life saving technique. We should spend more time on teaching, evaluating and upgrading it.

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NEZADOVOLJAVAJUĆA VENTILACIJA MASKOM – KLINIČKA PRIMJENA

S A Ž E T A K

Ventilacija maskom je važna tehnika koja u ključnim trenucima spašava ljudski život. Ovaj članak pregledno iznosi etiologiju i moguće patofiziološke posljedice nezadovoljvajuće ventilacije maskom. Glavno težište članka je prikaz cirkulacijskih promjena u ljudi tijekom uvoda u anesteziju, neposredno prije i poslije intubacije, koje se mogu pripisati neodgovarajućoj ventilacijii.