Original Article

Comparison of nasal and face mask ventilation in anaesthetised obese adults: A randomised controlled study

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ABSTRACT

Background and Aims: The use of a face mask while inducing general anaesthesia (GA) in obese patients is often ineffective in providing adequate ventilation**.** Although nasal mask ventilation has demonstrated effectiveness for continuous positive airway pressure (CPAP) in obese patients with obstructive sleep apnoea (OSA), it has not yet been applied to the induction of anaesthesia. This study evaluated the efficacy of nasal mask ventilation against standard face mask ventilation in anaesthetised obese patients with body mass index (BMI)>25 kg/m^2. **Methods:** Ninety adult patients with BMI >25 kg/m^2 were randomly assigned to receive either facemask (Group FM) or nasal-mask (Group NM) ventilation during induction of GA. Expired tidal volume (Vt_E), air leak, peak inspiratory pressure (PIP), plateau pressure (P_{PLAT}), oxygen saturation (SpO_2), and end-tidal carbon dioxide ($EtCO_2$) were recorded for10 breaths, and their mean was analysed. **Results:** The mean (standard deviation) Vt_E measured was not significantly higher in Group NM [455.98 (55.64) versus 436.90 (49.50) mL, *P* = 0.08, degree of freedom (df):88, mean difference (95% confidence interval [CI]) −19.08 (−41.14, 2.98) mL]. Mean air-leak [16.44 (22.16) versus 31.63 (21.56) mL, *P* = 0.001, df: 88, mean difference 95%CI: 15.19 (6.03,24.35)], mean PIP [14.79 (1.39) versus 19.94 (3.05) cmH_2O, *P* = 0.001, df: 88, mean difference, 95%CI: 5.15 (4.16, 6.14)], and mean P_{PLAT} [12.04 (1.21) versus 16.66 (2.56) cmH_2O, *P* = 0.001, df: 88, mean difference 95% CI: 4.62 (3.78, 5.45)] were significantly lower in Group NM. $EtCO_2$, SpO_2, and haemodynamic measurements were similar between the two groups. **Conclusion:** Nasal mask ventilation is an effective ventilation method and can be used as an alternative to face mask ventilation in anaesthetised obese adults with BMI>25 kg/m^2.

Keywords: Body mass index, face mask, general anaesthesia, nasal, obese, tidal volume, ventilation

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INTRODUCTION

Mask ventilation is pivotal in the initial stages of general anaesthesia (GA) induction, serving as the primary means of ventilation before securing a definitive airway. It encompasses two critical aspects: ensuring an airtight seal between the mask and the patient's face to prevent gas leakage and maintaining an unobstructed upper airway. Patients with body mass index (BMI) exceeding 25 kg/m^2 often exhibit anatomical changes in their airways, primarily affecting the oropharynx and larynx.[1-3] Continuous positive airway pressure (CPAP), delivered via a nasal mask, prevents upper airway collapse and is a highly effective treatment for obstructive sleep apnoea (OSA).

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This mechanism bears similarities to upper airway obstruction encountered during anaesthesia induction.[4-6] Nasal mask ventilation directs inspired air through the nasal cavity, countering gravity's influence on the soft palate and tongue, thereby maintaining upper airway patency.[7] Consequently, direct nasal ventilation may offer improved ventilation efficacy and a more natural breathing pattern.

We hypothesised that nasal mask ventilation would be more effective than the conventional face mask ventilation method in anaesthetised obese patients by ensuring better mask seal and lesser airway obstruction. The present study aimed to evaluate the ventilatory effectiveness of nasal mask ventilation with face mask ventilation in obese adults with BMI >25 kg/m^2 during induction of GA.

METHODS

This randomised controlled study was performed after obtaining approval from the institutional ethics committee (vide approval number DMCH/2k21-EA/4/8-2020 dated 17 May 2021). The study protocol was registered in the Clinical Trials Registry-India (CTRI/2021/09/036901, http://ctri.nic.in/). Written informed consent was obtained from all patients to participate in the study and use patient data for research and educational purposes. The study was carried out in accordance with the principles of the Declaration of Helsinki, 2013 and good clinical practice.

We recruited 90 adults from the American Society of Anesthesiologists (ASA) physical status classification I–III patients with BMI>25 kg/m^2, age>18 years, scheduled for elective surgeries under GA. Patients with maxillofacial trauma, beard, prognathia, retrognathia, pregnancy, and any patient having a contraindication to study drugs were excluded.

A thorough pre-anaesthetic check-up comprising a detailed history, physical examination, and relevant investigations was conducted. Patients were randomly allocated to either Group FM (face mask ventilation) or Group NM (nasal mask ventilation) by computer-generated random numbers concealed using sequentially numbered opaque envelopes to be opened by the anaesthesiologist managing the airway. The patient and the investigator were not blinded to the group allocated.

Standard monitoring was instituted in the operating room, which included electrocardiography, heart rate, non-invasive blood pressure measurement, oxygen saturation (SpO_2), and capnography. The patient's head was placed in a neutral position on a pillow and elevated 10 cm from the operating room table. Patients were pre-oxygenated with 100% oxygen at a flow rate of 10 L/min for 3 minutes using a tightly held face mask of appropriate size. This was determined by keeping the upper end of the mask at the nasal bridge and the lower end below the lower border of the lower lip. Subsequently, anaesthesia was induced using an intravenous (IV) fentanyl 2µg/kg and propofol 1–2 mg/kg body weight titrated to loss of verbal response. After verifying the ability to ventilate, IV atracurium besylate 0.5 mg/kg was administered, and the lungs were ventilated using the technique based on group allocation. In Group FM, ventilation was performed by placing the transparent silicon facemask (Drägerwerk AG and Co.KGaA, Lübeck, Germany) between the nasal bridge and below the lower border of the lower lip using the two-handed CE grip. In Group NM, ventilation was performed by placing the transparent silicon Rendell Baker Saucek mask (Rusch, Teleflex Medical Pvt Ltd, Germany) between the nasal bridge and the upper border of the upper lip using the two-handed CE grip. A trained anaesthesia practitioner with over five years of experience performed mask ventilation. After induction of anaesthesia, ventilation was achieved through the ventilator (Dräger Fabius®Plus, Drägerwerk AG and Co.KGaA, Lübeck, Germany) set to a volume-controlled mode (VCV) of ventilation at a pre-set fresh gas flow of 10 L/min, tidal volume of 7 mL/kg (of adjusted body weight), respiratory rate of 10 breaths/min, and pressure limit of 40 cmH_2O. After 3 minutes of ventilation and verification of positive capnography tracing, all the ventilator settings and parameters, including set tidal volume, expired tidal volume (Vt_E), air leak (defined as difference in set and expired tidal volume), peak inspiratory pressure (PIP), plateau pressure (P_{PLAT}), SpO_2, and end-tidal carbon dioxide ($EtCO_2$), were noted for 10 breaths in each case. A mean value of all these parameters for 10 breaths was calculated. Adequacy of mask ventilation was assessed, and ventilation was considered inadequate if there was no visible chest rise or capnography trace showed low amplitude wave with $EtCO_2$ <20 mmHg. If the lungs were not ventilated adequately for three breaths, other airway adjuncts were used as rescue airways, and the participant was excluded from the study. Upon completion of the study, the participant's airway was secured normally by placing either an endotracheal tube or a laryngeal mask airway.

Our primary outcome was the mean expired tidal volume in both groups. Mean air leak, mean PIP, mean P_{PLAT}, mean SpO_2 and mean $EtCO_2$ were the secondary outcomes.

Adjusted body weight (AjBW) is calculated as AjBW = IBW + 0.4(ABW − IBW) where ABW is actual body weight, IBW is estimated ideal body weight (IBW = 50 kg + 2.3 kg for each inch over 5 feet in males; IBW = 45.5 kg + 2.3 kg for each inch over 5 feet in females).[8]

The sample size was calculated using the formula, $n = (Z_{\alpha/2}+Z_{\beta})^2 * 2 * \sigma^2/d^2$, based on the results of a previous study using expired tidal volume as the primary outcome,[9] σ (assumed standard deviation [SD]) = 214.2, and d (mean difference) = 199.2, the sample size calculated was 45 for each group at a power of 0.99 with α error = 0.05 for 95% confidence level.

The continuous variables (age, height, actual and adjusted body weight, neck circumference, set and expired tidal volume, air leak, plateau and peak inspiratory airway pressures, SpO_2, $EtCO_2$) were described as mean (SD). The categorical variables (gender, STOP-BANG score, ASA physical status) were expressed as frequency. For comparison of continuous variables (height, body weight, set and expired tidal volume, air leak, plateau and peak inspiratory airway pressures, SpO_2, and $EtCO_2$), between the two groups, z-test was used. Age and BMI were analysed using a t-test. For comparison of gender, ASA physical status, and STOP-BANG score between both groups, Chi-Square test was applied. All the data were analysed using Statistical Package for the Social Sciences (SPSS) statistics software version 20.0 (Armonk, NY: International Business Machines Corp, USA) statistical software. A value of $P < 0.05$ was considered statistically significant.

RESULTS

A total of 90 adults were recruited for the study, and data of all the recruited participants were analysed. There was no case of inability to ventilate [Figure 1]. The comparison of demographic characteristics for both groups indicated no significant difference [Table 1]. The mean (SD) expired tidal volume was marginally higher in Group NM than in Group FM, with no statistically significant difference [455.98 (55.64) versus

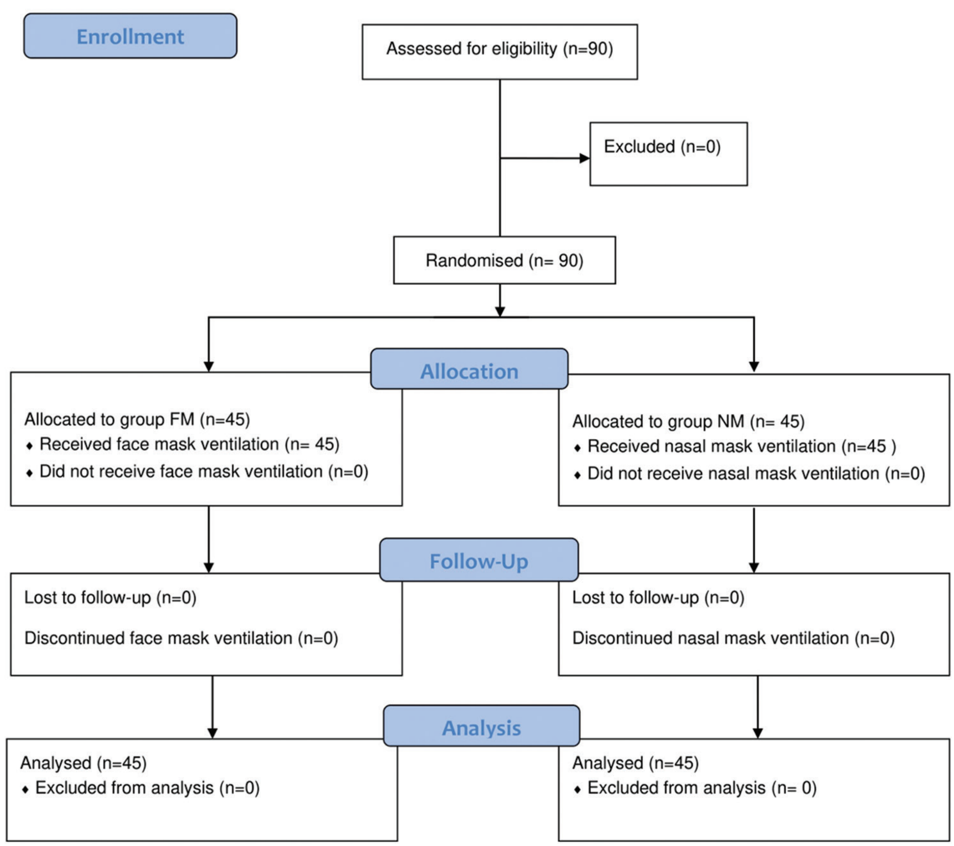

Figure 1: Consolidated standards of reporting trials (CONSORT) flow diagram of the study. n = number of patients

436.90 (49.50) mL, $P = 0.08$, degree of freedom (df):88, mean difference (95% CI) −19.08(−41.14, 2.98)]. The mean (SD) air leak was significantly lower in Group NM than in Group FM [16.44 (22.16) versus 31.63 (21.56) mL, $P = 0.001$, df: 88, mean difference (95% CI) 15.19 (6.03, 24.35)]. The mean (SD) PIP was significantly lower in Group NM than in Group FM [14.79 (1.39) versus 19.94 (3.05) cmH_2O, $P = 0.001$, df: 88, mean difference (95% CI) 5.15 (4.16, 6.14)]. Similarly, the mean (SD) P_{PLAT} in Group NM was significantly lower than in Group FM [12.04 (1.21) versus 16.66 (2.56) cmH_2O, $P = 0.001$, df: 88, mean difference (95% CI) 4.62 (3.78, 5.45)]. In both groups, other ventilation parameters, such as $EtCO_2$ and SpO_2, remained within normal limits with no statistically significant difference [Table 2]. Hypotension did not occur in either of the groups.

DISCUSSION

The present study investigated the ventilatory effectiveness of nasal and facemask ventilation in anaesthetised and paralysed obese patients. We observed that nasal mask ventilation is more effective than conventional face mask ventilation in an anaesthetised obese patient with BMI >25 kg/m^2.

Asian Indians have distinct obesity traits, including excess body fat, abdominal fat, increased subcutaneous and intra-abdominal fat, and fat in unusual places. Due to lower normal BMI limits based on body fat and health data compared to Caucasians, we defined obesity in our set population as BMI ≥25 kg/m^2 as per the consensus guidelines for diagnosing obesity in Asian Indians.[10] In our study, we used the two-handed CE technique for holding the mask, which is reported to be superior to the one-handed CE technique.[11] For ventilation in obese individuals, calculating tidal volume based on their actual weight may lead to overestimation, requiring higher airway pressures and risking lung injury. Thus, our study used adjusted body weight to set tidal volume targets.[12]

Both mask interfaces provided adequate ventilation to the patients when evaluated with the ventilator's predetermined tidal volume. However, Group NM demonstrated a slightly higher average expired tidal volume and a narrower gap between the set and expired tidal volume, suggesting a reduced level of air leak. Nasal mask ventilation required lower airway pressures (PIP and P_{PLAT}) for effective ventilation compared to a face mask. Other study parameters, $EtCO_2$ and SpO_2, showed no significant difference between the two groups. They were within the normal range in both groups.

Our study demonstrated higher expired tidal volume in the nasal mask group, though it was not statistically significant. Our study shows agreement with a study conducted on a similar group of patients, which also observed no significant difference in expired tidal volume between nasal mask and facemask ventilation.[13] On the contrary, nasal mask ventilation delivered a greater tidal volume in edentulous patients than face mask ventilation.[14] Facemask ventilation of edentulous patients is often inefficient due to a lack of facial support. Nasal mask ventilation may be more effective in these patients due to reduced air leaks and better contact with the maxillary plane. Higher expired tidal volume was reported with nasal mask ventilation than combined oro-nasal mask

Table 1: Demographic data

Variable	Group FM (*n*=45)	Group NM (*n*=45)
Age (years)	41.67 (10.54)	43.16 (12.88)
Gender (Male/Female)	20/25	19/26
Actual body weight (kg)	80.84 (9.12)	82.22 (8.87)
Adjusted body weight (kg)	66.93 (7.46)	67.49 (7.57)
Height (cm)	164.16 (7.11)	164.28 (6.80)
Body mass index (kg/m^2)	29.97 (2.77)	30.40 (2.40)
Neck circumference (cm)	35.44 (3.56)	36.23 (3.43)
STOP-BANG score 0/1/2/3/4	14/11/13/4/3	8/10/9/15/3
ASA physical status 1/II/III	16/26/3	26/53/11

Data expressed as mean (standard deviation) or frequency. STOP-BANG=Snoring, Tiredness, Obesity, Hypertension, BMI >35 kg/m^2, Age >50 years, Neck circumference >40 cm, Male Gender; ASA=American Society of Anesthesiologists, *n*=number of patients

Table 2: Comparison of parameters of ventilation between both groups

Parameters	Group FM (*n*=45)	Group NM (*n*=45)	Mean difference (95% Confidence interval)	*P*
Set tidal volume (mL)	468.53 (52.22)	472.42 (53.01)	−3.89 (−25.93, 18.16)	0.56
Expired tidal volume (mL)	436.90 (49.50)	455.98 (55.64)	−19.08 (−41.14, 2.98)	0.08
Air leak (mL)	31.63 (21.56)	16.44 (22.16)	15.19 (6.03, 24.35)	0.001
Peak inspiratory pressure (cmH_2O)	19.94 (3.05)	14.79 (1.38)	5.15 (4.16, 6.14)	0.001
End-tidal carbon dioxide (mmHg)	30.16 (2.27)	29.89 (1.84)	0.27 (−0.59, 1.14)	0.16
Oxygen saturation (%)	99.61 (0.97)	99.64 (1.04)	−0.03 (−0.45, 0.39)	0.46
Plateau pressure (cmH_2O)	16.66 (2.56)	12.04 (1.21)	4.62 (3.78, 5.45)	0.001

Data expressed as mean (standard deviation) ventilation (P < 0.05).[9] The investigators used oral and nasal masks for oro-nasal ventilation in this study. They kept the mouth partially opened in both ventilation methods, unlike our study, where the mouths of all participants were kept closed. We encountered significantly lower airway pressures (PIP and P_{PLAT}) in Group NM compared to Group FM. This is because it necessitates lower ventilation pressures and a more patent airway. Thus, according to our study's results, using nasal mask ventilation could reduce the possibility of gastric insufflation, lowering the risk of aspiration of gastric contents. Furthermore, observation of lower airway pressure with adequate ventilation suggests that nasal mask ventilation provides a more direct path for positive pressure ventilation to the lungs. As a result, the likelihood of barotrauma is also reduced. Consistent with our study, Aghadavoudi *et al.* found lower airway pressures with nasal masks than face masks.[13] They reported that the face mask group had significantly higher maximum airway pressures than nasal mask group (P < 0.001), suggesting that the increased pressure is used to overcome airway obstruction due to tongue and soft palate displacement.[13] With nasal mask ventilation, positive pressure is applied only in the nasopharynx, which moves the tongue and soft palate forward, thus relieving upper airway obstruction and allowing ventilation with lower airway pressures. Similar results were demonstrated by Liang's study on the adult population, where nasal mask ventilation had significantly lower airway pressures than combined oral nasal mask ventilation (P < 0.05).[9] In contrast to our study, Kapoor *et al*.[14] found higher peak inspiratory pressures with nasal mask ventilation compared with face mask ventilation (P < 0.001). This finding may be attributed to small intraoral passage due to reduced maxillary height in edentulous patients.

Other quantitative measures related to the quality of ventilation, like, $EtCO_2$ and SpO_2 recorded in both groups, remained within the normal range, indicating the adequacy of ventilation by both the mask interfaces. It is important to note that no patients experienced significant hypotension during that phase, and there were no instances of oxyhaemoglobin desaturation in either group.

There are a few limitations in our study worth mentioning. The results of our research cannot be translated directly to all unconscious patients who need mask ventilation in emergencies. We administered muscle relaxants to our study population in the controlled setting of operating rooms. As our study involved experienced airway managers, we cannot predict if our results can be reproduced with novice operators with the same methods. The mean BMI of our participants was 30 kg/m^2. Thus, our findings may not predict the effectiveness of nasal mask ventilation in obese patients with BMI >35 kg/m^2.

CONCLUSION

We conclude that nasal mask ventilation is more effective than conventional face mask ventilation in an anaesthetised obese patient with BMI >25 kg/m^2. The nasal mask can be an alternative to a facemask in such patients.

Statement on data sharing

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' Institution policy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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