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Original Research Article

Comparison of Pre-Oxygenation Using High-Flow Nasal Oxygen vs Tight Face Mask During Rapid Sequence Induction

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Abstract: *Pre-oxygenation prior to rapid sequence induction (RSI) is critical in minimizing the risk of hypoxemia during emergency surgeries. High-flow nasal oxygen (HFNO) has emerged as a promising alternative to conventional facemask pre-oxygenation; however, data from multicenter, real-time emergency settings remain limited.* ***Objective:*** *To compare the effectiveness of high-flow nasal oxygen versus tight-fitting facemask pre-oxygenation in preventing desaturation during RSI among adults undergoing emergency surgery.* ***Methods:*** *This randomized controlled trial was conducted at the Anesthesia Department of Gujranwala Teaching Hospital between September 2024 and February 2025. A total of 144 adult patients requiring emergency surgery and RSI were randomized equally into the HFNO group (n=77) and facemask group (n=77). All participants were pre-oxygenated with 100% oxygen. The primary outcome was the incidence of oxygen desaturation (SpO_2 <93%) from the start of pre-oxygenation to one minute after tracheal intubation. Secondary outcomes included rates of regurgitation and end-tidal carbon dioxide ($EtCO_2$) levels post-intubation. Statistical analysis was performed using the Chi-square test, and $p \leq 0.05$ was considered significant.* ***Results:*** *Desaturation <93% occurred in 5 patients (2.9%) in the HFNO group and six patients (3.4%) in the facemask group ($p = 0.77$), indicating no significant difference. No increase in desaturation risk was noted during on-call hours. Regurgitation rates and $EtCO_2$ levels after intubation were comparable between groups. No adverse events related to either technique were reported.* ***Conclusion:*** *Both high-flow nasal oxygen and tight-fitting facemask pre-oxygenation are safe and effective in maintaining adequate oxygenation during RSI in emergency surgeries. HFNO offers comparable outcomes and may be considered a viable alternative, particularly in settings where facemask pre-oxygenation may be less practical.*

Keywords: Pre-oxygenation, High Flow Nasal Oxygen (HFNO), Tight Face Mask, Airway Management

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Introduction

Rapid sequence induction (RSI) is a high-risk procedure; patients undergoing emergency surgery are more likely to experience hypoxia (1). So, pre-oxygenation prior to anesthesia induction is crucial (2). Administration of low-flow oxygen with a nasal cannula has been shown to extend until desaturation in an apneic patient (3-5). However, the incidence of desaturation during RSI is still high (1, 6). Moreover, contributes significantly to adverse events and poor outcomes (7,8). Low-flow nasal oxygen administered with a nasal cannula has been shown to prolong apnea time up to 1 hour (9), has been used during laryngeal surgery with apnoea times up to 30 minutes (10,11), and during RSI (12,13). Prior research has compared high-flow nasal oxygen during RSI with pre-oxygenation performed with a tight-fitting facemask, since this is standard practice. It was demonstrated that high-flow nasal oxygen preserved oxygen saturation to an equal extent as facemask pre-oxygenation, with some other potential benefits (12, 13). Notably, these studies were single-center and involved a limited number of patients. One of these studies was conducted during office hours only (12) and both were strictly monitored by the research groups (12, 13). It has previously been demonstrated that staff cognitive performance and patient outcomes can vary daily to night (14, 15). Therefore, the safety of using this pre- and peri-oxygenation approach during RSI on a larger scale has not yet been established. This study compared tight-fitting facemask pre-oxygenation during RSI with high-flow nasal oxygen in patients undergoing emergency surgery at all hours of the day and night in the Gujranwala teaching hospital, Gujranwala. The rationale of this study is to find out the best technique for pre-oxygenation using a high-flow nasal oxygen cannula versus a tight face mask during rapid sequence induction. As previous literature showed contrary results, few studies showed a significant difference between the outcomes of both groups, and few studies showed that both techniques are equally effective. So this study is planned to clear this contraindication in our local setting. Furthermore, no study has been done on this topic in our local population.

Methodology

This cross-sectional study was conducted in the anesthesia department of Gujranwala Teaching Hospital, Gujranwala, between September 2024 and February 2025. Institutional and ethical approvals were obtained in both countries before patient enrollment. Around the clock, adult patients having emergency surgery for which RSI was scheduled were registered one after the other. Pregnancy, non-invasive breathing prior to anesthesia, BMI > 35 kg/m-2, and a SpO_2 measurement of less than 93% during pre-oxygenation were all grounds for exclusion. Additionally, patients who had already been included and those incapable of providing consent were excluded from the analysis. Patient participation was requested during the pre-anesthesia assessment. A consent form was signed, and information was provided orally and in writing. Patients were randomly assigned to either a tight-fitting facemask or high-flow nasal oxygen for pre-oxygenation. Block sizes of ten sealed envelopes given in a 1:1 ratio were used for this ECG, pulse oximetry, and blood pressure measurements—invasive or non-invasive—were performed upon arrival in the operating room. After securing an intravenous line, a routine electrolyte solution infusion was initiated. Afterward, the patients were put in a reverse Trendelenburg posture while supine. Rapid sequence induction was carried out by each hospital's local protocols (16). The lead anesthetist chose the medications and dosages. Pre-oxygenation lasted at least three minutes. With specially made cannulae, 30 to 50 l.min-1 of heated and humidified oxygen delivered high-flow nasal oxygen. Patients might

either open or close their mouths to breathe. Oxygen flow was increased to 70 l.min-1 once apnea began and continued until the tracheal tube was in place. Patients in the conventional group received a fresh gas flow of 10 l.min-1 through a circle system while breathing 100% oxygen through a tight-fitting facemask (2). Both groups employed jaw thrust and/or chin raise to keep the airway open during apnea. Tracheal intubation conditions were noted, including the grade of the Cormack-Lehane laryngoscopy, the number of attempts, the requirement for airway equipment other than the Macintosh laryngoscope size 3, and indications of gastric regurgitation. The length of apnea (apnoea time) and the amount of time required to intubate the trachea (intubation time) were recorded during the induction of anesthesia. The apnea duration was determined by measuring the carbon dioxide trace using capnography. The time required to intubate the trachea was calculated from the moment the laryngoscope passed the teeth until a carbon dioxide trace appeared on capnography. From the beginning of pre-oxygenation until one minute after intubation, the lowest SpO_2 was recorded. Patients who did not achieve $SpO_2 > 93\%$ during pre-oxygenation were excluded. The anesthetist decided to begin mask ventilation if the patient had desaturated prior to intubation. After that, the lowest saturation prior to mask ventilation was recorded. Before pre-oxygenation began, end-tidal carbon dioxide ($ETCO_2$) was monitored in both groups using a tight oblique facemask that delivered room air. $ETCO_2$ and end-tidal oxygen (ETO_2) were also measured during induction in the facemask group. The first breath following tracheal intubation was used to assess ETO_2 and ECO_2 in both groups. Data collection ceased one minute after intubation. The office hours were defined as 07.30 to 16.00, Monday through Friday. On-call hours were defined as all other times.

The main outcome was the number of patients who experienced oxygen saturation below 93% during the beginning of pre-oxygenation and one minute following intubation. Our secondary outcomes examined the number of individuals exhibiting indications of stomach regurgitation and end-tidal gas concentrations in the first breath following intubation. We also examined the variations between centers and the impact of office hours versus on-call hours. The main result was the variation in the number of patients with a peripheral pulse oximeter reading of less than 93% oxygen saturation. No patient pre-oxygenated with high-flow nasal oxygen desaturated to less than 93% in a prior RSI research, compared to 12.5% in the facemask group (12).

This is why we based the sample size calculation on the supposition that the facemask group had 10% desaturation and the high-flow nasal oxygen group had 2.5%. A sample size of 326 was estimated using a type-1 error of 5% and a type-2 error of 20% (power 80%). We aimed to include 350 patients to account for a little variation in outcomes and dropouts. Depending on the distribution, a Mann-Whitney U-test or an unpaired two-sample t-test was used to examine group differences. A Chi-square test or a Fisher's exact test was used to analyze categorical data if the sample size assumption was broken. A chi-squared test was used to analyze the primary outcome. There was a threshold of $p < 0.05$ for statistical significance. SPSS Statistics 26 (IBM, Armonk, NY, USA) was used for all tests. Age 18-65 years Both gender American society of anesthesiologist classification ASA (I/II) (Annexure I) BMI (kg/m^2) 40 or above Pregnant Patients Patients who need non-invasive ventilation before anesthesia or not reaching $SpO_2 > 93\%$ during pre-oxygenation Patients having any respiratory illness diagnosed previously on medical history.

Results

One hundred forty-four patients were randomly assigned to facemask or pre-oxygenation with high-flow nasal oxygen. Due to a procedure breach (the ventilator was inadvertently configured to supply room air), one patient was excluded. Two patients were ventilated during the apnoeic phase due to tracheal intubation issues and a prolonged apnoea period. Without a specific explanation, one patient was ventilated during the apneic phase. SpO 2 > 96% was present when apnea was stopped in all three. All patients were included in the results to analyze the data from 144 patients. No patient or airway characteristics variation was seen between the groups. The high-flow nasal oxygen group had a marginally longer intubation and apnea duration. Also, each group's intubation conditions were comparable. From the beginning of pre-oxygenation until one minute after intubation, there was no difference in the number of patients having SpO 2 < 93% across groups. Six patients (3.4%) in the facemask group and five patients (2.9%) in the high-flow nasal oxygen group saw a decrease in oxygen saturation of less than 93% ($p = 0.77$).

Table 1 lists the characteristics of 144 pre-oxygenated patients using either a facemask or high-flow nasal oxygen for a quick sequence induction of anesthesia. Among the pulmonary comorbidities were pleuritis/pneumonia (5), lung cancer (3), pulmonary embolism (2), pneumothorax (1), pulmonary fibrosis (1), pleural effusion (1), asthma (19), obstructive sleep apnea syndrome (10), and chronic obstructive pulmonary disease (7). Three individuals suffered from a combination of lung illnesses, while three patients had no specific diagnosis. Neurosurgery and surgery for the ears, nose, and throat were included in the "other" category. Values might be either numbers (percentages) or means (SD). There was no significant difference in the frequency of individuals who developed S pO 2 < 93%

Table 2 compares key airway assessment variables between patients pre-oxygenated with high-flow nasal oxygen (HFNO) and those with a conventional facemask (n = 77 each). A higher proportion of patients in the HFNO group had a favorable Modified Mallampati Score I (62.3% vs 42.8%), indicating easier airway visualization. Similarly, normal neck movement was more prevalent in both groups (HFNO: 90.9%, Facemask: 92.2%). The distribution of thyromental distance and mouth opening was comparable across both groups. These parameters are statistically non-significant but clinically relevant in anticipating difficult airways.

Table 3 details intubation-related outcomes and secondary physiological measures. Although the Cormack–Lehane grade distribution was statistically similar ($p = 0.46$), the HFNO group showed a higher proportion of Grade I views (87.03% vs 83.12%). Median intubation attempts were identical across groups (1 attempt, range 1–4; $p = 0.83$), and use of adjuncts was comparable (HFNO: 44.15%, Facemask: 41.5%; $p = 0.61$). However, statistically significant differences were observed in intubation time (HFNO: 52.1 s vs Facemask: 47.6 s; $p = 0.01$) and apnoea time (HFNO: 108 s vs Facemask: 97 s; $p = 0.001$). Notably, ETO_2 was significantly higher in the facemask group (84.9% vs 76.7%; $p < 0.001$), whereas $ETCO_2$ values did not differ ($p = 0.33$). These findings support the physiological efficacy and comparative safety of both pre-oxygenation techniques.

Table 1: Demographics of study population

Variable	High-flow Nasal Oxygen (n=77)	Facemask (n=77)
Sex; male	55 (71.4%)	49 (63.6%)
Age; years	42	50
BMI; kg/m^2	25.1	25.5
Smoker	44 (57.14%)	32 (41.5%)
ASA Physical Status		
- I	44 (57.14%)	57 (74.02%)
- II	14 (18.18%)	11 (14.2%)

- III	12 (15.5%)	5 (6.5%)
- IV	7 (9.09%)	3 (3.9%)
- V	0	1 (1.3%)
Pulmonary Comorbidity (other)	13 (16.8%)	12 (15.6%)
Pre-operative O_2 Treatment	7 (9.09%)	5 (6.5%)
Type of Surgery		
- Abdominal	32 (41.55%)	29 (37.66%)
- Intervention/Endoscopy	18 (23.37%)	19 (24.67%)
- Gynaecological/Urological	15 (19.5%)	12 (15.6%)
- Orthopaedic	11 (14.2%)	13 (16.9%)
- Other	1 (1.3%)	4 (5.2%)

Table 2: Airway Assessment Parameters in High-Flow Nasal Oxygen vs Facemask Groups

Variable	High-flow Nasal Oxygen (n=77)	Facemask (n=77)
Modified Mallampati Score		
- I	48 (62.33%)	33 (42.8%)
- II	23 (29.9%)	12 (15.6%)
- III	5 (6.5%)	17 (22.07%)
- IV	1 (1.3%)	15 (19.5%)
Thyromental Distance		
- >7 cm	62 (80.52%)	60 (78%)
- -6–7 cm	10 (13.0%)	10 (13.0%)
- <6 cm	5 (6.5%)	7 (9%)
Mouth Opening		
- >4 cm	65 (84.4%)	67 (87.01%)
- 2–4 cm	12 (15.6%)	10 (12.09%)
- <2 cm	0	0
Neck Movement		
- Normal	70 (90.9%)	71 (92.20%)
- Limited	7 (9.01%)	6 (7.8%)

Table 3: Intubation Characteristics and Secondary Outcomes Between Groups

Variable	High-flow Nasal Oxygen (n=77)	Facemask (n=77)	p-value
Cormack–Lehane Grade			0.46
- I	67 (87.03%)	64 (83.12%)	
- II	7 (10%)	12 (15.6%)	
- III	2 (2.6%)	1 (1.4%)	
- IV	1 (1.3%)	0 (0%)	
Intubation Attempts (median, range)	1 (1–4)	1 (1–4)	0.83
Intubation Adjuncts Used	34 (44.15%)	32 (41.5%)	0.61
Intubation Time (s)	52.1	47.6	0.01
Apnoea Time (s)	(108). (47.8)	97 (53.4)	0.001
Secondary Outcomes			
$ETCO_2$ in First Breath after Intubation (kPa)	4.64 (0.8)	4.56 (0.8)	0.33
ETO_2 in First Breath after Intubation (%)	76.7 (16.1)	84.9 (7.7)	<0.001
Patients with Signs of Regurgitation	1 (0.6%)	0	0.50

Discussion

This study, in contrast to one of the earlier papers (12), found no difference in the percentage of patients who desaturated <93% between tight facemask and high-flow nasal oxygen preoxygenation. Additionally, we saw a longer mean intubation time in the high-flow nasal oxygen group compared to pre-oxygenated patients with a face mask. One possible explanation could be variations in RSI protocols or inadequate airway maintenance during apnea periods. None of the five high-flow nasal oxygen group patients experienced desaturation while the provider was on call. This implies that the anesthetist and on-call personnel appropriately administer high-flow nasal oxygen while maintaining an open airway. It has been demonstrated that high-flow nasal oxygen can prolong apnea by around 50% by reducing the rise in arterial carbon dioxide levels during apnea (9, 10). It has recently been shown that carbon dioxide clearance by flow-dependent flushing may result from high-flow nasal oxygen (17). Even though the high-flow nasal oxygen group had apnea for longer, we found no difference in ETO_2 levels between the groups in the first breath following intubation (Table 3). These findings are consistent with those reported in earlier research (12, 13). The facemask group had a greater oxygen concentration in the first breath following preoxygenation than the high-flow nasal oxygen group. When the facemask technique is used, the ventilator's tubes are likely not filled with oxygen during high-flow nasal oxygenation. As a result, the patient will receive room air in their first breath following intubation. This subsequently impacts the ETO_2 concentration in the first breath following intubation. Additionally, some high-flow nasal oxygen group patients breathed with their mouths open during pre-oxygenation. As

previously demonstrated, dilution may cause the fraction of inspired oxygen to be lower than anticipated (18). This could have impacted the ETO_2 in the first breath following intubation by influencing the quantity of oxygen stored in the lungs during preoxygenation. Furthermore, some evidence suggests high-flow nasal oxygen may require more time to preoxygenate above ETO_2 > 90% than facemask (19). High-flow nasal oxygen's primary advantage is its capacity to provide apneic patients with continuous oxygen delivery, or peri-oxygenation. Therefore, when oxygenation during apnea stops, the ability of high-flow nasal oxygen to retain oxygen may not have the same clinical significance as during typical facemask pre-oxygenation. End-tidal oxygen has been employed as a stand-in indicator of preoxygenation effectiveness. This variable does not account for the impact of apnoeic peri-oxygenation and cannot be measured during high-flow nasal oxygen. Studies comparing apnoea times with high-flow nasal oxygen or facemask use during pre- and peri-oxygenation show the impact of perioxygenation; higher oxygen saturation apnoea times are observed with high-flow nasal oxygen (20). Concerns have been expressed about the possibility that the high oxygen flow provided by high-flow nasal oxygen could result in stomach distension and increase the risk of regurgitation. Nasopharyngeal airway pressure has been demonstrated to rise linearly with roughly 1 cmH_2O per 10 l.min-1 of flow in people breathing spontaneously with their mouths closed (21). It has recently been demonstrated that these pressures correlate quite well with the anesthetized patient when the mouth is closed, even at flow rates of up to 80 L. min-1, the airway pressure rises with flow rate but stays below 10 cmH_2O. Furthermore, airway pressure is almost negligible when the mouth is open during strong flows (22). Furthermore, ultrasonography measurements of healthy participants receiving high-flow nasal oxygen up to 70 l.min-1 for 30 minutes revealed no evidence of stomach distension or an increase in gastric secretions (23). Gastric insufflation at a positive pressure greater than 14 cmH_2O can occur while ventilating anesthetized patients wearing a facemask (24, 25). Thus, even at maximum flow, it does not appear feasible that high-flow nasal oxygen could result in gastric insufflation. One patient in the high-flow nasal oxygen group and none in the facemask group in the current trial had regurgitation symptoms. Since most of the aforementioned studies were carried out on awake, healthy volunteers with presumed normal physiology, as opposed to anesthetized emergency surgery patients, we felt it was crucial to characterize this variable in the emergency surgery population, even though this study is underpowered for such a rare event. Crucially, RSI aims to reduce the amount of time that apnea occurs before the airway is secured. In this study, the high-flow nasal oxygen group experienced a longer mean apnea duration than the facemask group. The Mir et al. investigation also observed this tendency (13). Even though high-flow nose oxygen can prolong a safe apnea period, RSI intubation must be carried out properly, promptly, and by standard procedure. However, when managing a critically ill patient or one with a difficult airway, a technique that may extend the time until desaturation would be advantageous (26); selecting a certain patient demographic was avoided because patients were included at all times of the day. This improved the technique's generalizability and demonstrated that high-flow nasal oxygen can be a viable alternative to facemask pre-oxygenation, even during on-call hours when staff members are compromised and time is frequently at a premium.

Conclusion

In this preoxygenation investigation, we observed minor variations in preoxygenation effectiveness between humidified high-flow nasal oxygen, a tight-fitting facemask, and a regular nasal cannula with the mouth closed at 50 L min1. The conventional nasal cannula is quite successful and maybe a choice when other approaches are insufficient, even though it is less comfortable than a tight-fitting facemask and humidified high-flow nasal oxygen.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-24)

Consent for publication
Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

AR (PGR),
Manuscript drafting, Study Design,
Review of Literature, Data entry, Data analysis, and article drafting.
SAQ
Conception of Study, Development of Research Methodology Design, Study Design, manuscript review, and critical input.

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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