EGYPTIAN JOURNAL OF ANAESTHESIA
2022, VOL. 38, NO. 1, 656–664
https://doi.org/10.1080/11101849.2022.2143175

High flow nasal cannula effect on pulmonary complications after major elective upper abdominal surgeries: A randomized control study

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ABSTRACT

Background: Postoperative pulmonary complications (PPCs) are a challenge for anesthesiologists, especially following major surgeries. Using a high-flow nasal cannula (HFNC) postoperatively may decrease this challenge.

Purpose: The study aimed to assess the clinical effect of HFNC after extubation compared with simple face mask oxygen following major elective upper abdominal surgeries regarding PPCs, the need to escalate the respiratory support, days of intensive care unit stay, and days of hospital stay.

Methods: Eighty adult patients were randomly assigned to two groups (each with 40 patients): group I received HFNC, while group II received a standard oxygen face mask. Five days later, postoperative pulmonary problems were evaluated.

Results: There was statistically significantly less lung atelectasis in the HFNC group than in the face mask group. The p-value was 0.029. There was no statistically significant difference concerning the need to escalate the respiratory support. The length of hospital and ICU stay days for the HFNC group was statistically significantly lower than for the face mask group.

Conclusion: HFNC is more efficient than a simple oxygen face mask in lowering lung atelectasis following major upper abdominal procedures, improving oxygenation with decreasing respiratory rate and reducing ICU and hospital days of stay.

ARTICLE HISTORY
Received 6 October 2022
Revised 20 October 2022
Accepted 30 October 2022

KEYWORDS
HFNC; PPCs; upper major abdominal surgeries

1. Introduction

Postoperative pulmonary complications (PPCs) are a typical dangerous consequence following upper abdominal surgeries. PPCs are closely related to greater postoperative morbidity and prolonged hospitalization. [1]

Upper abdominal incisions have been considered more challenging for PPCs than lower incisions. Diaphragmatic dysfunction is meant to be the cause as the diaphragm is responsible for ventilation of the lower part of the lung where atelectasis and infection occur. [2]

High-flow nasal cannula (HFNC) is an oxygen supply system capable of delivering 100% heated humidified flow up to 60 L/min. It provides a kind of positive end-expiratory pressure that decreases pharyngeal dead space and nasopharyngeal airway resistance. [3]

2. Aim of the work

Primary outcome: To compare the effect of the application of HFNC and simple face mask oxygen on pulmonary complications within 5 days after major elective upper abdominal surgeries.

Secondary outcome: To detect the need for escalation of respiratory support, intensive care unit days of stay, and hospital days of stay.

Patients and methods

After the approval of The Local Ethical Committee at Alexandria Main University Hospital, written informed consent was received from 80 adult patients of both genders, aged 50 to 70 (Table 1), with ASA physical status I–III, who were intended for major elective upper abdomen procedures (Table 2). Patients with pre-existing lung disease (pleural effusion, pneumothorax, or pulmonary atelectasis), obstructive sleep apnea, or a body mass index of 35 kg/m^2 were not eligible. ClinicalTrials.gov Identifier: NCT05548309, IRB NO: 00012098.

Postoperatively, at the intensive care unit using the closed-envelope technique, patients were randomly allocated into two groups with 40 patients each (The Department of Biomedical Informatics and Medical Statistics, Medical Research Institute, University of Alexandria approved the sample size to be sufficient). [4]

Group I: HFNC was applied using nasal prongs (Fisher & Paykel Healthcare, Auckland, New Zealand). FiO_2 was detected by (AIRVO™ 2; Fisher & Paykel Healthcare, Auckland, New Zealand) system connected to the HFNC. Starting with the flow rate of 35 L/min and temperature of 31°C [5], the flow was titrated up to 60 L/min with a target SpO_2 of ≥94%.

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Table 1. Comparison between the two studied groups according to demographic data.

	HFNC (n = 40)		Face mask (n = 40)			
	No.	%	No.	%	Test of Sig.	P
Gender						
Male	19	47.5	20	50.0	χ^2 = 0.050	0.823
Female	21	52.5	20	52.6		
Age (years)						
Mean ± SD	59.20 ± 5.0		59.20 ± 4.77		t = 0.0	1.000
Median (Min.–Max.)	60.0(50.0–70.0)		59.0(51.0–69.0)			

SD: Standard deviation; t: Student's t-test;HT
χ^2: Chi-square test
p: p value for comparing between the two studied groups

Table 2. Comparison between the two studied groups according to the type of surgical procedure.

	HFNC (n = 40)		Face mask (n = 40)	
Type of surgical procedure	No.	%	No.	%
Small intestinal resection	4	10.0	4	10.0
Total gastrectomy	6	15.0	5	12.5
Total pancreatectomy	4	10.0	3	7.5
Whipple operation	4	10.0	8	20.0
Distal pancreatectomy	4	10.0	2	5.0
Hepatectomy	6	15.0	3	7.5
Hepatojejnostomy	0	0.0	1	2.5
Choledochojejnostomy	1	2.5	1	2.5
Hydatid cyst removal	2	5.0	0	0.0
Open fundoplication	1	2.5	1	2.5
Partial gastrectomy	5	12.5	5	12.5
Retroperitoneal mass excision	1	2.5	3	7.5
Cholangiocarcinoma with caudate lobectomy	1	2.5	2	5.0
Choledochal cyst excision	0	0.0	1	2.5
Liver abscess drainage	1	2.5	1	2.5

Gradual weaning was started after 6 hours when satisfactory arterial blood gases (ABG) were obtained, with a decreased flow rate of 5 L/h, aiming at the final wean-off goal of 20 L/min, FiO_2 less than 50% targeting SpO_2 ≥94% [6].

Group II: A simple oxygen face mask was applied to the patients, starting with a flow rate of 6 L/min and titration of flow rate up to 10 L/min was done to target peripheral oxygen saturation of ≥94%. Gradual weaning was started after 6 hours when satisfactory ABG was obtained, with a decreased flow rate of 1 L/h, aiming at the final wean-off goal of 5 L/min, targeting SpO_2 ≥94%.

For all patients, epidural catheter was inserted preoperatively at levels T7–T9, loading dose 1–1.5 ml/segment of 0.125% bupivacaine with fentanyl and 1 mic/ml, and was continued as an infusion intraoperatively combined with general anesthesia with an infusion rate of 5 ml/hour and continued at same concentration postoperatively in ICU. [7] Induction of anesthesia was done using intravenous fentanyl 1 mic/kg, intravenous lidocaine 1% 1 mg/kg, intravenous propofol (1 to 1.75 mg/kg), and intravenous cisatracurium 0.2 mg/kg.

Mechanical ventilation was initiated immediately after tracheal intubation using volume control mode with an inspiratory-to-expiratory time ratio of 1:2 and inspired oxygen fraction (FiO_2) of 0.5, ventilator settings were adjusted with tidal volume (VT) of 6–8 ml/kg ideal body weight, and a PEEP of 5 cm H_2 O respiratory rate was adjusted to keep Etco2 35–45 mmHg.

At the end of the surgery, lung recruitment was done by closing an adjustable pressure-limiting valve (APL valve) at continuous positive airway pressure (CPAP) of 30 cmH_2O_2 for 30 seconds. Extubation was done after patients fulfilling the criteria of extubation (recovery of spontaneous ventilation with an expired tidal volume between 5 and 8 ml/kg, respiratory rate between 12 and 25 breaths/min, absence of residual neuromuscular blockade (assessed by a T4/T1 ratio ≥90%), peripheral oxygen saturation ≥95%, body temperature ≥36°C, and stable hemodynamics with mean arterial blood pressure more than 65 mmHg and absence of vasopressor support). [8]

3. Measurements

Age of the patient, gender, type of planned surgery, duration of the surgery, and units of packed red blood cells transfused during the surgery were recorded and statistically analyzed.

Mean arterial blood pressure and heart rate were recorded hourly from the observation chart, and a mean figure was calculated at 6-hour interval for 48 hours post ICU admission.

Peripheral oxygen saturation and respiratory rate were recorded (basal on ICU admission, 5 minutes after starting O_2 therapy, 5 minutes after every increase in O_2 flow, 5 minutes after every decrease in O_2 flow, 5 min, 10 min, 1 hour after weaning O_2 therapy, and then every 6-hour interval for 48 hours).

Assessment of patient respiratory comfort: Subjective dyspnea was measured using numerical rating scale ranging from 0 to 10 (0 = no shortness of breath to 10 = worst possible), 30 min after application of O_2 therapy, 30 min after every increase in oxygen flow, 30 min after every decrease in O_2 flow, and 1 hour after weaning O_2 therapy [9].

Arterial blood gases were recorded (immediate on admission to ICU, 30 min after application of O_2 therapy, and after every increase in oxygen flow or acidosis in previous ABG). [6]

The incidence of PPCs was also detected by chest X-ray and daily lung ultrasound assessment; a chest X-ray was done on day 1, day 3, and day 5 and was recorded according to the European Perioperative Clinical Outcome definitions (EPCO). [10] Daily lung ultrasound assessment has been done using Bed Side Lung Ultrasound in Emergency protocol (BLUE) [11] on postoperative days (day 0, day 1, day 2, day 3, day 4, day 5) using (Sonosite M-Turbo® Ultrasound System) linear transducer (L38Xi 10–5 MHZ).

Moreover, the need to escalate respiratory support was recorded as the need for noninvasive ventilation or endotracheal intubation for both groups. [6] Days of ICU and hospital stay days were also recorded.

4. Statistical analysis of the data

The IBM SPSS software program version 20.0 (IBM Corporation, Armonk, New York) was used to analyze the data. Data were input numerically and categorically as needed. Numbers and percentages were used to describe qualitative characteristics. The Shapiro–Wilk test was performed to demonstrate the normality of the distribution. Minimum, maximum, mean, standard deviation, and median were used to describe quantitative data. The test's significance was detected at the 5% level. The chi-square test was used to compare categorical variables between groups, Fisher's Exact or Monte Carlo correction for chi-square (when more than 20% of the cells had a predicted count less than 5), Student's t-test to describe normally distributed quantitative variables between the two groups, and Mann–Whitney test to describe abnormally distributed quantitative variables between the two groups.

5. Results

Ninety-four patients were screened for eligibility to participate in this study, seven patients were excluded for not meeting the inclusion criteria, and there were seven dropouts during the study. Eighty patients continued the trial until the end (Figure 1).

There were no significant differences between the two groups in the following data: age, gender (Table 1), type of surgery (Table 2), duration of surgery, units of packed red blood cells transfused during the surgery, hemodynamic parameters, peripheral oxygen saturation, and the need to escalate respiratory support (Table 5).

The mean respiratory rate for the HFNC group 5 min after starting oxygen therapy on 35 L was statistically less than that for the face mask group on 6 L oxygen (18.13 ± 1.96 and 19.68 ± 1.80, respectively). P-value was less than 0.001. Moreover, after weaning of oxygen at different intervals (5 min, 10 min, 1 h, 6 h, 12 h, 18 h, 24 h, 30 h, 36 h, 42 h, 48 h), there were no statistically significant differences between the two groups (Figure 2).

Moreover, in terms of the numerical rating scale for respiratory comfort, the HFNC group had a statistically significantly lower scale than the face mask group, and the p-value was 0.043 (Figure 3).

When comparing the two groups, there was no significant difference in the mean of partial pressure of carbon dioxide ($PaCO_2$) on ICU admission between the two groups and the p-value was 0.596, but when comparing the mean of $PaCO_2$ 30 min after starting oxygen between the two groups, the mean for the HFNC group was less than that for the face mask group (31.43 ± 3.72 and 35.75 ± 3.10, respectively), and the p-value was less than 0.001 which was statistically significant (Figure 4).

The mean arterial oxygen partial pressure (PaO_2) for HFNC and face mask groups was 77.03 ± 6.31 and 77.0 ± 6.36, respectively, on ICU admission; it increased for both groups 30 minutes after application of oxygen therapy but the increase in the mean of PaO_2 for HFNC group was greater than those for face mask group, which was 191.3 ± 14.26 for HFNC group and 156.1 ± 31.0 for face mask and the p-value was less than 0.001 which was statistically significant (Figure 5).

The HFNC group showed a statistically significant higher hypoxic index than face the mask group. The p-value was 0.023 (Table 3).

For PPCs, there was statistically significantly less lung atelectasis in the HFNC group than in the face mask group (Table 4).

There was no statistical significant difference between the two groups as regards the need to escalate the respiratory support (Table 5).

For the HFNC group, the ICU stay days were statistically lower than for the face mask group. The mean was 2.18 ± 0.59 and 2.73 ± 1.41, respectively. p-value was 0.036 (Table 6).

Regarding hospital stay days, there was a statistically significantly shorter length of stay for the HFNC group than for the face mask group; the mean was 7.73 ± 1.55 and 10.28 ± 2.90, respectively. P-value was less than 0.001 (Table 6).

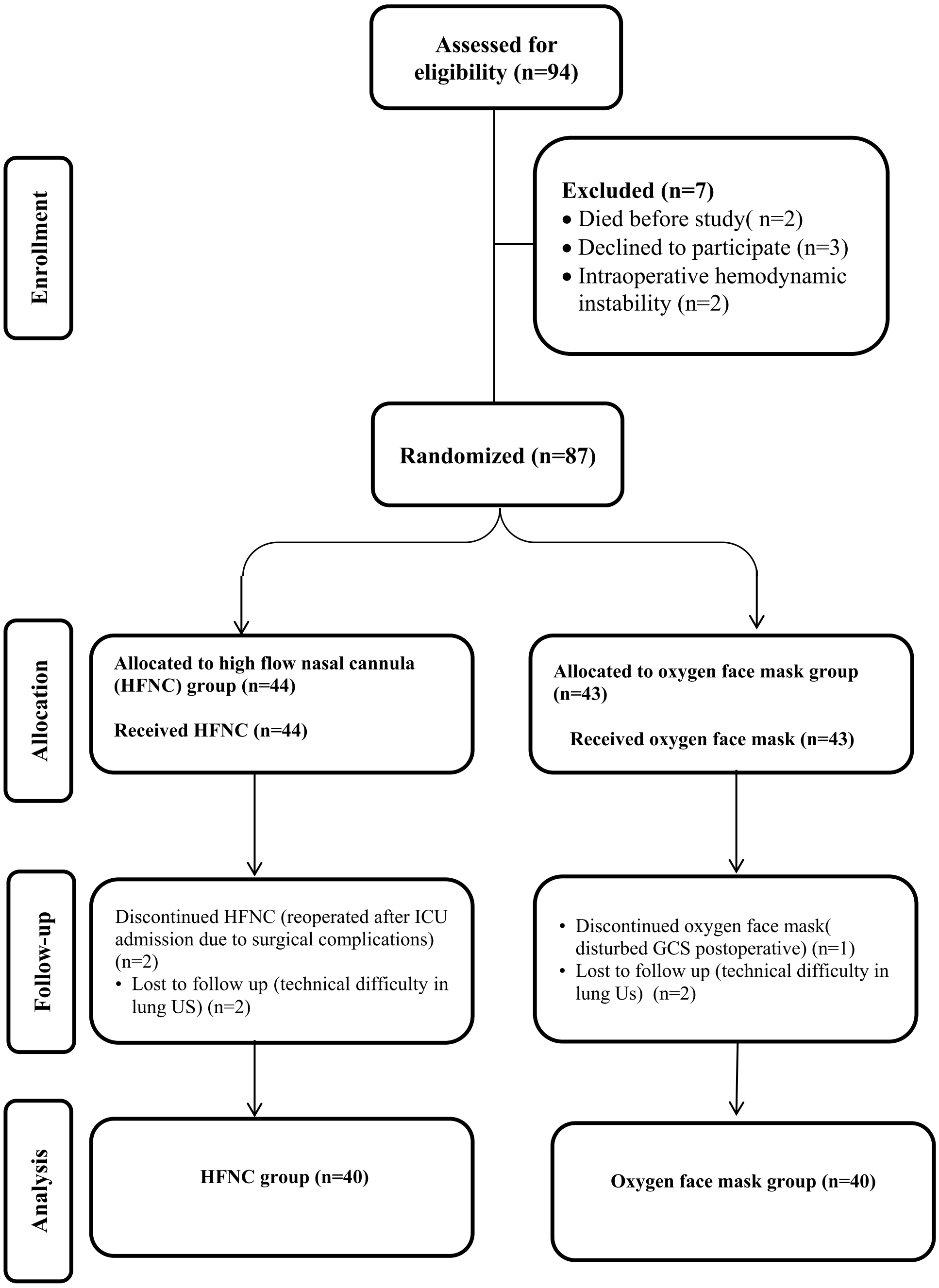

Figure 1. Consort flow diagram (study design).

6. Discussion

The development of PPCs is substantially associated with higher postoperative mortality, morbidity, and hospitalisation after upper abdominal surgery. PPCs rise linearly with the surgical incision's proximity to the diaphragm, which is responsible for ventilation of the lower lung fields, where atelectasis and infection are prevalent. [12]

HFNC is a procedure that uses nasal prongs to provide humidified and heated gas to the airways. Because it increases functional residual capacity, HFNC enhances respiratory mechanics and gas exchange. These physiological findings imply that HFNC may be useful for postoperative oxygen supplementation. [13]

When comparing the two groups according to the respiratory rate, the mean for the HFNC group was statistically significantly lower than for the face mask group; the cause may be the washout effect of anatomical dead space and increased expiratory resistance caused by HFNC jet flow against the exhaled expiratory air and the cannula. [14]

The results coincide with Motoyasu et al. [15] where the respiratory rate was significantly decreased 3 minutes after starting HFNC therapy, and these results suggested that the use of HFNC can reduce the respiratory rate up to 6 hours after oxygen therapy. This study was done on patients with hypoxemic respiratory failure who were treated using HFNC in the ICU.

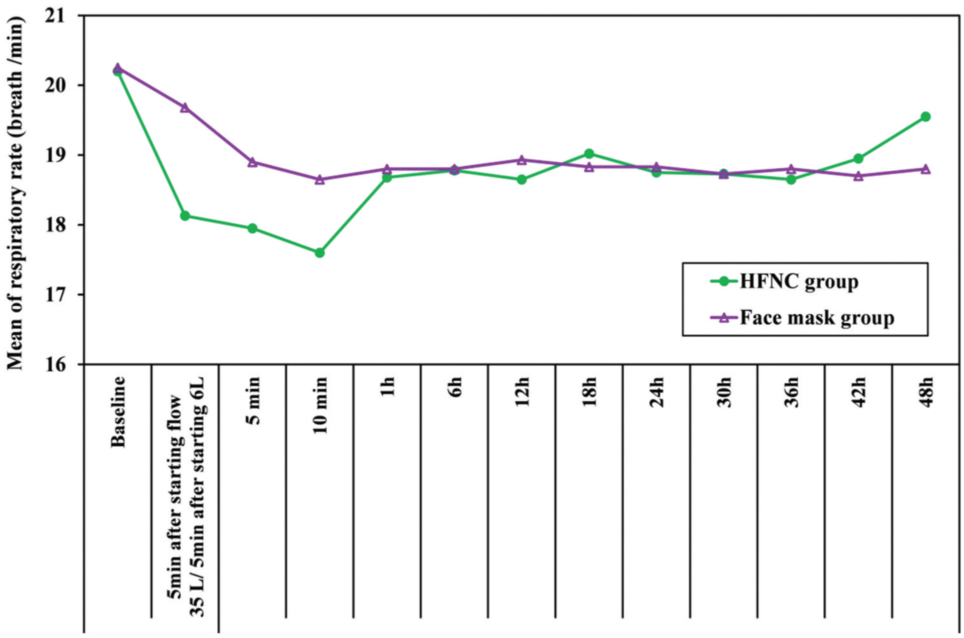

Figure 2. Comparison between the two studied groups according to respiratory rate (breath/min).

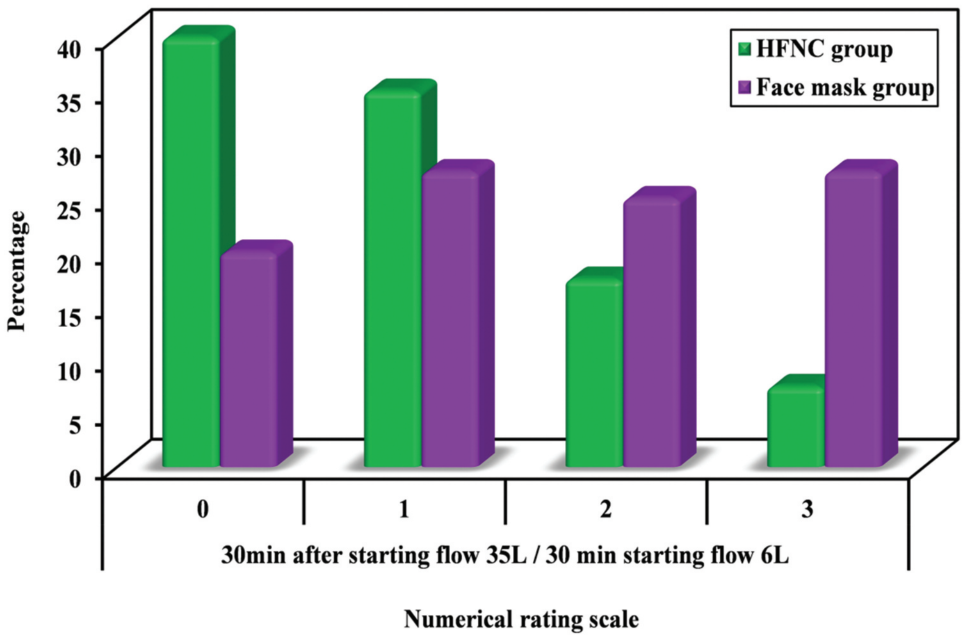

Figure 3. Comparison between the two studied groups according to numerical rating scale.

These results were also supported by Perbet et al. [16] who conducted a study on patients undergoing major abdominal surgery where PPCs were evaluated by ARISCAT (Assessed Respiratory Risk in Surgical patients in Catalonia) score. A significant respiratory rate reduction was observed. [17]

In concern to the Numerical Rating Scale for patient respiratory comfort, the HFNC group had a statistically significantly lower scale than the face mask group which means better comfort for HFNC therapy. This evidenced by HFNC may assist the patients because it increases humidity in inspired gases to reduce the feeling of dryness and improve comfort sensation. [17] Even more important, the temperature of the HFNC appears to have a substantial influence on the comfort of individuals. Mauri et al. reported that, for constant flow, a lower temperature was related to greater comfort. [5] The study was done on 40 patients with acute hypoxemic respiratory failure supported by HFNC and patients were more comfortable at the temperature of 31°C in comparison to 37°C. In the present study, the temperature was preset on 31°C.

On the contrary, in the OPERA trial, Futier et al. [18] observed no significant difference between the two groups in patient respiratory comfort, 1 h after enrollment and after oxygen discontinuation; this may be attributed to a high constant flow of HFNC (50–60 L/

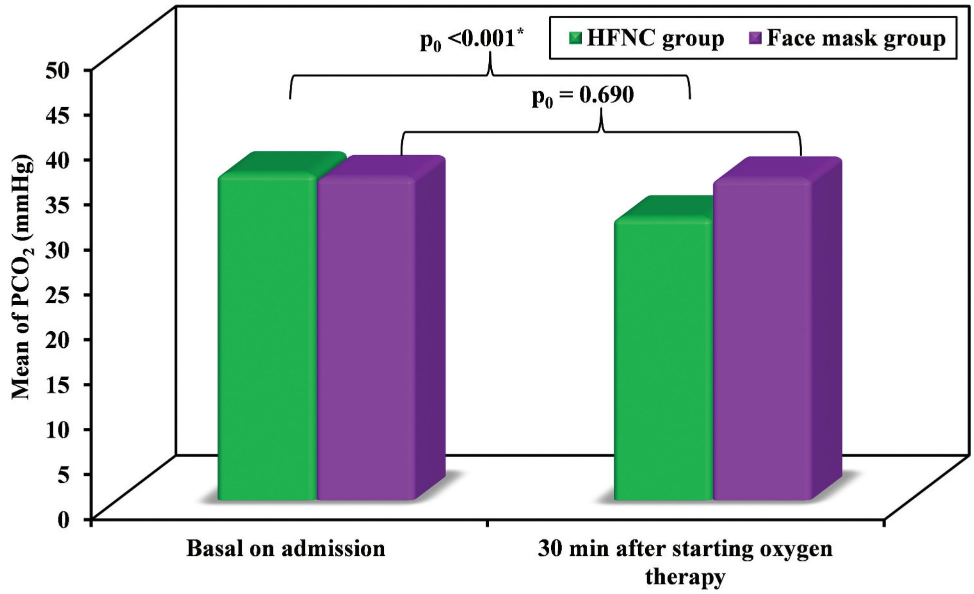

Figure 4. Comparison between the two studied groups according to partial pressure of carbon dioxide ($PaCO_2$) (mmHg). p_0: p value for comparing between the two studied periods *: Statistically significant at $p \le 0.05$

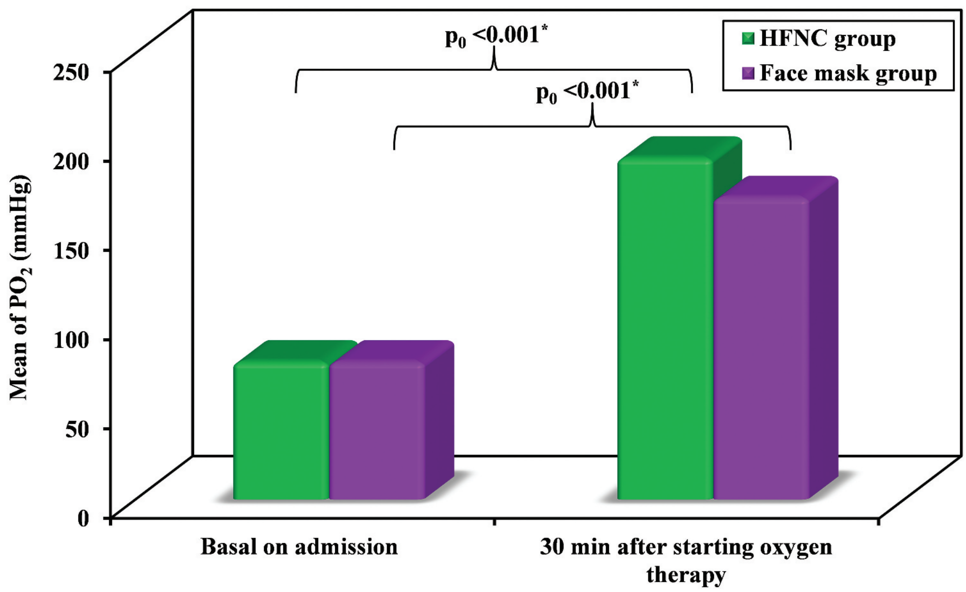

Figure 5. Comparison between the two studied groups according to arterial oxygen partial pressure (PaO_2) (mmHg). p_0: p value for comparing between the two studied periods *: Statistically significant at $p \le 0.05$

min), and the study did not report the preset temperature of the HFNC device #.

The mean of partial pressure of carbon dioxide ($PaCO_2$) after starting oxygen for the HFNC group was statistically significantly lower than for the face mask group. This may be evidenced by the fact that HFNC can reduce the total dead space and increase alveolar ventilation by decreasing the dead space inside the nasopharynx through fresh gas insufflation. [19]

Similarly, Motoyasu et al. [15] found that $PaCO_2$ was significantly decreased 3 minutes after the application of the HFNC.

Moving on to arterial oxygen partial pressure (PaO_2), the mean of PaO_2 was increased for both groups after the application of oxygen therapy, but the increase in the mean of PaO_2 for the HFNC group was statistically significantly higher than for the face mask group; this may be because HFNC delivers the gas at greater flow rate than the patient's peak inspiratory flow rate, and supplies a constant FiO_2. Furthermore, the increased gas flow may cause washout of the upper airway dead space and the creation of an oxygen reservoir inside the upper airways. [20]

Perbet et al. reported the same results supporting the results of the present study concerning arterial oxygen partial pressure improvement on using HFNC after abdominal surgeries. [16]

Table 3. Comparison between two groups regarding arterial blood gases.

		HFNC group (n = 40)	Face mask group (n = 40)	p
$PaCO_2$(mmHg)	**Basal on admission**			
	Mean ± SD	36.32 ± 3.74	35.91 ± 3.22	0.596
	30 min after starting oxygen therapy			
	Mean ± SD	31.43 ± 3.72	35.75 ± 3.10	<0.001*
	$t_0(p_0)$	10.660* (<0.001*)	0.401 (0.690)	
PaO_2(mmHg)	**Basal on admission**			
	Mean ± SD	77.03 ± 6.31	77.0 ± 6.36	0.986
	30 min after starting oxygen therapy			
	Mean ± SD	191.3 ± 14.26	156.1 ± 31.0	<0.001*
	$t_0(p_0)$	80.408* (<0.001*)	18.701* (<0.001*)	
(PaO_2/FiO_2 ratio)	**Basal on admission**			
	Mean ± SD	366.7 ± 30.07	366.5 ± 30.21	0.979
	30 min after starting oxygen therapy			
	Mean ± SD	383.2 ± 28.51	354.95 ± 70.50	0.023*
	Median (Min.–Max.)	384.0(326.0–452.0)	379.5(223.0–439.0)	
	$t_0(p_0)$	7.267* (<0.001*)	1.378 (0.176)	

SD: Standard deviation; t_0: Paired t-test; Z: Wilcoxon signed ranks test; t: Student's t-test
U: Mann–Whitney test; p: p value for comparing between the two studied groups
p_0: p value for comparing between the two studied periods
*: Statistically significant at $p \leq 0.05$
$PaCO_2$: Partial pressure of carbon dioxide
PaO_2: Arterial oxygen partial pressure
FIO_2: Inspiratory oxygen fraction

Table 4. Comparison between the two studied groups according to incidence of PPCs.

	HFNC(n = 40)		Face mask(n = 40)			
	No.	%	No.	%	χ^2	^{FE}p
Pneumonia	1	2.5	5	12.5	2.883	0.201
Pleural effusion	2	5.0	5	12.5	1.409	0.432
Atelectasis	1	2.5	8	20.0	6.135*	0.029*
Pneumothorax	0	0.0	0	0.0	–	–

χ^2: Chi-square test; FE: Fisher's exact test
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$

Table 5. Comparison between the two studied groups according to the need to escalate respiratory support.

	HFNC(n = 40)		Face mask(n = 40)			
The need to escalate respiratory support	No.	%	No.	%	χ^2	^{FE}p
Noninvasive ventilation	1	2.5	3	7.5	1.053	0.615
Endotracheal intubation	0	0.0	2	5.0	2.051	0.494

χ^2: Chi-square test; FE: Fisher's exact test
p: p value for comparing between the two studied groups

Table 6. Comparison between the two studied groups according to ICU stay and hospital stay days.

	HFNC(n = 40)	Face mask(n = 40)	Test of Sig.	p
ICU stay days				
Mean ± SD	2.18 ± 0.59	2.73 ± 1.41	U = 652.0*	0.036*
Median (Min.–Max.)	2.0 (2.0–5.0)	2.0 (2.0–8.0)		
Hospital stay days				
Mean ± SD	7.73 ± 1.55	10.28 ± 2.90	t = 4.903*	<0.001*
Median (Min.–Max.)	7.0 (6.0–14.0)	10.0 (7.0–20.0)		

SD: Standard deviation; t: Student's t-test; U: Mann–Whitney test
p: p value for comparing between the two studied groups
*: Statistically significant at $p \leq 0.05$

When comparing hypoxic index (PaO_2/FiO_2), it was statistically significantly higher for HFNC group than for the face mask group.

Several studies have suggested that HFNC had better oxygenation compared to low oxygen flow systems in cardiothoracic patients postoperatively and critically ill patients in ICU. [19–21] and this was explained by # by more fitting of the nasal catheter than the oxygen mask and the inhalation of oxygen at high flow.

On the other hand, Corley and colleagues [22] found no significant difference between the standard oxygen group and the HFNC group regarding the hypoxic index in the first 24 h post-extubation.

Amanda study was done on postoperative cardiac patients with BMI greater than or equal to 30 kg/m^2.

Likewise, Zochios et al. failed to show any difference. [23] Zochios et al. conducted a study on patients undergoing cardiac operations with a high risk for respiratory complications.

For Amanda et al. and Zochios et al. [23] studies, the confounding factors involved in patients play an important role as BMI, smoking status, blood transfusion, COPD patients, etc., which were not rolled out in such different studies and this may explain why there was no significant difference in the hypoxic index.

For the incidence of PPCs, 2.5% of the patients in the group of HFNC developed pneumonia versus 12.5% in the face mask group; pleural effusion developed in 5% of the patients in the HFNC group versus 12.5% in the face mask group; the most patient who developed pleural effusion had been operated for hepatectomy in both group; reactive pleural effusion following hepatectomy results from injury of diaphragm during surgery or obstruction of venous and lymphatic drainage. [24]

There was statistically significantly lower lung atelectasis in the HFNC group than in the face mask group; 2.5% of the patients in the HFNC group developed atelectasis versus 20% of the patients in the face mask group. This may be attributed to HFNC increasing airway moisture and may improve the retention of mucosal secretions. ##increasing the expiratory positive airway pressure (EPAP) level may be another cause where expiratory resistance is caused by the jet flow of HFNC against the exhaled expiratory air, as well as the size of the cannula that is fitted to the nostrils that finally leads to raising the end-expiratory lung volume (EELV). [25] None of the patients in both groups developed pneumothorax.

Nevertheless, in the OPERA trial, Futier et al. [18] found that there was no significant difference in pulmonary complications 7-day postoperative follow-up.

The results of the OPERA study may be different from the present study due to several variables. In OPERA, the enrollment of a heterogeneous population of surgical patients, for example, patients operated for upper and lower gastrointestinal laparoscopic operations, had a lower risk for PPCs compared with open surgeries. [26]

Also, there was enrollment for patients operated for esophageal and colorectal resection and it is known that oesophagectomy and upper abdominal procedures carry higher risk for PPCs than colectomy. [22] Lastly, the site of surgical incision was variable from the midline, transverse, and other patterns that was not described in the Opera trial. But in the present study, the surgical incision for all patients was a midline incision that carries a greater risk for PPCs due to affection of the # respiratory movement of the diaphragm . [2]

Also, there was an enrollment of asthmatic and COPD patients in the Opera trial, and the use of recruitment manoeuvre was not applied to all the patients during surgery only 61% of the study population.

The high gas flow produces a positive airway pressure ranging from 2 to 5 cm H_2O, which is proportional to gas flow and may recruit the lung. [22] Many studies found that lung atelectasis occurs following extubation [27] and may persist for up to 2 days. Because of the aforementioned causes, the HFNC can prevent atelectasis postoperatively which means fewer postoperative complications.

The comparison of the two groups showed that there was no significant difference between them as regards the need to escalate the respiratory support.

Similar results were obtained in the Opera trial [18] where the need for NIV or intubation for the HFNC was 19% versus 13% for conventional oxygen therapy (COT), which was nonsignificant.

Zayed Y et al. found that patients treated with HFNC post-cardiothoracic surgery had a significantly lower rate of intubation than the conventional oxygen therapy group. [28]

This could be explained by the fact that in thoracic surgery, HFNC could decrease lung atelectasis by providing high continuous positive airway pressure. [29]

The length of hospital and ICU stay days for the HFNC group was statistically significantly lower than for the face mask group. This may be due to the lower incidence of respiratory complications associated with the HFNC group.

Conclusion

HFNC is more effective than a simple oxygen face mask in reducing lung atelectasis after major upper abdominal surgeries, improving oxygenation with decreasing respiratory rate, and reducing ICU and hospital days of stay.

Disclosure statement

The authors report that there are no competing interests to declare.

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