High-flow nasal cannula versus face mask for preoxygenation in obese patients: A randomised controlled trial

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Abstract

Background: Preoxygenation efficacy with high-flow nasal cannula (HFNC) in obese patients is not clearly established. The primary aim of this study was to compare heated, humidified, high-flow nasal cannula with face mask for preoxygenation in this population.

Methods: We conducted a single-centre, randomised, controlled trial. Forty subjects with BMI ≥ 35 kg m⁻² were randomly assigned to receive 5.0 min of preoxygenation with face mask and 7 cm H₂O of PEEP (PEEP group) or HFNC at 70 L min⁻¹ (HF group). Following induction, bag-mask ventilation continued until laryngoscopy, whereas HFNC was maintained before and during intubation. The primary outcomes were end-tidal fraction of oxygen (EtO₂) at 2.5 and 5.0 min duration of preoxygenation. Secondary outcomes included PaO₂ and PaCO₂ at 2.5 and 5.0 min of preoxygenation and at intubation.

Results: Mean (±SD) EtO₂ was 0.89 (±0.04) versus 0.90 (±0.05) after 2.5 min (95% CI for mean difference −0.02, 0.04) and 0.93 (±0.02) versus 0.91 (±0.02) after 5.0 min of preoxygenation (95% CI for mean difference −0.03, 0.002) in the PEEP (n = 18) and HF group (n = 20), respectively. All subjects reached an EtO₂ ≥ 0.85 at 5.0 min. There were no differences in mean PaO₂ or PaCO₂ during preoxygenation. Subjects in the HF group had a mean (±SD) apnoea time of 199 (±38) s, but no desaturation (SpO₂ < 100%) occurred.

Conclusions: Face mask with PEEP was superior to HFNC for preoxygenation in obese subjects. HFNC provided adequate preoxygenation quality in all subjects and may be considered as an alternative to face mask in selected patients.

Trial registration: #ISRCTN37375068 (www.isrctn.com).

KEYWORDS
apnoeic oxygenation, bariatric anaesthesia, high-flow nasal cannula, morbidly obese, obese, preoxygenation

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1 | INTRODUCTION

Critical desaturation during induction of general anaesthesia may occur rapidly in obese patients.\textsuperscript{1–3} This is mainly due to reduction in the functional residual capacity (FRC), higher oxygen consumption and increased incidence of difficult airway management compared to normal weight subjects.\textsuperscript{4–9} Preoxygenation with face mask and high fractions of inspired oxygen (FiO\textsubscript{2}) creates an alveolar oxygen reservoir that increases apnoea tolerance during airway management.\textsuperscript{10,11} A head up tilt and application of positive end expiratory pressure (PEEP) expand the FRC further prolonging time to desaturation in obese subjects.\textsuperscript{12–15} In some patients, a perfect mask seal is not possible and/or PEEP is not well tolerated, impairing the efficacy of preoxygenation.\textsuperscript{16,17}

A high-flow nasal cannula (HFNC) system that supplies heated, humidified high-flow oxygen through the nose may be an alternative in these patients. HFNC increases airway pressures and end-expiratory lung volume directly related to the flow and inversely related to mouth opening, which may be beneficial in obese patients.\textsuperscript{18–22} Unfortunately, studies of preoxygenation with HFNC are relatively scarce in the obese population and the evidence regarding the efficacy of preoxygenation is conflicting.\textsuperscript{23–27}

The primary aim of this study was to compare HFNC with a tightly fitted, ventilator-connected, standard anaesthesia face mask with PEEP applied for preoxygenation during anaesthesia induction for bariatric surgery.

2 | METHODS

2.1 | Study design, setting and ethics

This was a single-centre, open-labelled, randomised, controlled trial performed in compliance with the Declaration of Helsinki. The study was conducted at a satellite outpatient surgery unit at Uppsala University Hospital, a tertiary referral centre in Sweden between 23 October 2018 and 11 February 2020. The protocol was registered at the ISRCTN registry (#ISRCTN37375068) 19 October 2018 (isrctn.com). Ethical approval for this study (2018-007) was provided by the Regional Ethical Committee of Uppsala, Sweden, on 4 April 2018. Written informed consent was obtained from all subjects.

2.2 | Participants

Patients aged 18–60 years with a BMI ≥ 35 kg m\textsuperscript{-2} presenting for elective laparoscopic bariatric surgery were eligible for inclusion. Exclusion criteria were non-BMI-related ASA class >2, chronic obstructive pulmonary disease or asthma causing restrictions in daily activities, heart failure with New York Heart Association functional classification >2, restrictive lung disease associated with a reduction of total lung capacity >20%, allergy to any of the anaesthetic agents used in the study or being unable to understand oral and/or written study information.

2.3 | Randomisation and masking

Randomisation was performed with an allocation ratio of 1:1 and a block size of two using sealed opaque sequentially numbered envelopes. There was no masking.

2.4 | Interventions during preoxygenation

An arterial cannula was placed under local anaesthesia and ultrasound guidance. Subjects were randomly assigned to receive 5 min of preoxygenation with a FiO\textsubscript{2} of 1.0 using a tightly fitted standard anaesthesia face mask connected to the ventilator (Maquet FLOW-i\textsuperscript{®}, Maquet) with a PEEP of 7 cm H\textsubscript{2}O (PEEP group) and a flow rate of 8 L min\textsuperscript{-1} or HFNC (POINT\textsuperscript{®} high-flow system, Armstrong Medical) with a flow rate of 70 L min\textsuperscript{-1} (HF group) approximately corresponding to a PEEP of 7 cm H\textsubscript{2}O during closed mouth breathing.\textsuperscript{28} A good mask seal in the PEEP group was determined by clinical assessment of leaks, by observing a normal square waveform capnography trace, and by appropriate inspiratory O\textsubscript{2} and expiratory CO\textsubscript{2} values. All subjects were instructed to breathe normally and subjects in the HF group were further instructed to breathe with their mouths closed.

2.5 | Interventions after anaesthesia induction

After induction of general anaesthesia, subjects in the PEEP group were bag-mask ventilated with a FiO\textsubscript{2} of 1.0 until commencement of laryngoscopy during which the face mask was removed. Bag-mask ventilation was performed manually by the attending physician and was not protocolised. In the HF group, a jaw thrust was immediately applied after loss of consciousness.
and HFNC was maintained at 70 L min\(^{-1}\) during apnoea and laryngoscopy until intubation. Laryngoscopy was initiated 90 s following the administration of muscle relaxant. If desaturation, defined as a peripheral capillary oxygen saturation (SpO\(_2\)) ≤95%, occurred during laryngoscopy, rescue bag-mask ventilation was allowed in both groups.

2.6 | Common anaesthesia management

Standard perioperative monitoring including electrocardiogram, pulse oximetry, non-invasive blood pressure (NIBP) and train-of-four monitoring was applied in the operating room. Subjects were placed in the ramped sniffing position using standardised pillows with the operating table at zero degrees angle. The attending anaesthetists were given thorough briefings of the study protocol before the patient arrived in theatre. General anaesthesia was induced according to local guidelines using fentanyl (≈2 µg kg\(^{-1}\) adjusted body weight, ABW) and a target-controlled infusion (TCI) of propofol titrated to clinical effect (initial effect site target concentration 5–7 µg ml\(^{-1}\) ABW). Rocuronium (≈0.6 mg kg\(^{-1}\) lean body weight) was used to facilitate endotracheal intubation. The exact dosing of anaesthetic drugs was determined at the discretion of the attending anesthesiologist.

2.7 | Outcomes

The primary outcomes of this study were EtO\(_2\) after 2.5 and 5.0 min of preoxygenation. Secondary outcomes were the proportion of subjects with an EtO\(_2\) ≥0.85 and ≥0.90, partial pressure of arterial oxygen (PaO\(_2\)), partial pressure of arterial carbon dioxide (PaCO\(_2\)), SpO\(_2\), end tidal carbon dioxide (EtCO\(_2\)), NIBP and heart rate at 2.5 and 5.0 min of preoxygenation and the level of discomfort during preoxygenation.

Apnoea time following induction of general anaesthesia was registered and defined as time from discontinuation of bag-mask ventilation or time from last spontaneous breath as assessed visually to endotracheal intubation confirmed by waveform capnography in the PEEP group and HF group respectively. EtO\(_2\), EtCO\(_2\), PaO\(_2\), PaCO\(_2\), NIBP and heart rate were measured immediately following intubation. End-tidal gas fractions were recorded during the first breath delivered manually by the anaesthetist following intubation and arterial blood gas sampling was performed at the inflation of the endotracheal tube cuff. The lowest SpO\(_2\) during apnoea was noted.

2.8 | Measurements

EtO\(_2\) and EtCO\(_2\) were measured with the subject continuously breathing through the face mask in the PEEP group or by two intermittent exhalations at 2.5 and 5.0 min, respectively, in the y-piece in the HF group and analysed by the ventilator (Maquet FLOW-i®, Maquet). To ensure reliable measurements, subjects in the HF group practised exhalation through the y-piece on room air at least 5 min before preoxygenation started. We considered the technique satisfactory when normal capnograms could be observed and similar EtO\(_2\) values obtained during two consecutive exhalations. Arterial blood gas results were analysed using a point-of-care blood gas analyser (Abbott i-STAT® 1, Abbott Laboratories). SpO\(_2\), NIBP and heart rate were analysed using a standard multi-parameter monitor display (Dräger Infinity Delta® monitor, Dräger Medical System Inc.).

Following adequate recovery from anaesthesia and at least 1 h in the post anaesthesia care unit, the level of discomfort during preoxygenation was assessed using a four-step ordinal scale defining increasing levels of discomfort as none, mild, moderate or severe. Aborting the procedure was considered equivalent to severe discomfort.

2.9 | Sample size calculation

We assumed that mean EtO\(_2\) would be 0.90 in the face mask group after 2.5 min preoxygenation with standard deviation of 3% partly based on previous studies of preoxygenation in non-obese subjects. With a type I error of 5% and a power of 80%, a sample size of 16 subjects in each group was calculated to detect a mean EtO\(_2\) difference of 3%. To compensate for dropouts, we planned for inclusion of a total of 40 subjects.

2.10 | Statistical analysis

All data were analysed using Microsoft Excel and R (version 4.0.2) with the R package “Rcmdr” (R Commander. R package version 2.7–0). Assumption of normality was tested using quantile-quantile plots and/or Shapiro–Wilks test. Continuous data were presented as mean and standard deviations (±SD) or median and ranges (min-max). Categorical data were presented as number and percentages. The two primary outcomes were analysed with unpaired t-test. We did not correct for multiple statistical analysis of the primary outcome. Secondary outcomes were analysed with unpaired t-test or Mann–Whitney’s test for normally and non-normally distributed variables as appropriate. Chi-square test or Fisher exact test was used to compare categorical variables. Ordinal regression was used to calculate odds ratio for discomfort during preoxygenation. Effect size was estimated with 95% confidence intervals (95% CI) for mean differences. Correlation was analysed using the Pearson correlation coefficient. We did not correct secondary or post-hoc analysis for multiple statistical analysis and these results should therefore be considered exploratory. Imputation was not done for missing data. All tests were two-sided and p-values less than 0.05 were considered statistically significant.
3 | RESULTS

Forty subjects were included in the study. Subjects in the HF group were a mean of 5.7 years older. More patients were ongoing or previous smokers in the HF group. Baseline characteristics (Table 1) and baseline measurements (Table 2) were otherwise similar between groups. In the PEEP group, two subjects withdrew consent and arterial access could not be achieved in two additional subjects. Eighteen subjects in the PEEP group were thus available for analysis of end-tidal gas fractions and hemodynamic variables during preoxygenation and 16 subjects were available for analysis of arterial blood gas results. In the HF group, all 20 patients were included in the final analysis (Figure 1). There was one unexpected difficult intubation in the PEEP group and two in the HF group, all three requiring three intubation attempts (Table 1).

3.1 | Primary outcome

$\text{EtO}_2$ increased rapidly in both groups from baseline during preoxygenation (Figure 2). Mean $\text{EtO}_2$ was similar at 2.5 min of preoxygenation. At 5.0 min, mean $\text{EtO}_2$ was higher in the PEEP group compared with the HF group (Table 2).

| TABLE 1 | Subject characteristics, experience of the laryngoscopist and number of intubation attempts |
|-----------------------------|---------------------------------|-----------------------------|-----------------------------|
|                             | PEEP group (n = 18)             | HF group (n = 20)           |
| Age (year)                  | 38.7 ± 10.0                     | 44.0 ± 8.8                  |
| Sex (female)                | 17 (94)                         | 17 (85)                     |
| Height (cm)                 | 166 ± 6                         | 166 ± 9                     |
| Weight (kg)                 | 111 ± 9                         | 109 ± 10                    |
| BMI (kg m$^{-2}$)           | 40.0 ± 2.7                      | 39.8 ± 4.2                  |
| BMI 35–40                   | 8 (44)                          | 10 (50)                     |
| BMI ≥ 40                    | 10 (56)                         | 10 (50)                     |
| ASA 1/2                     | 6/12                            | 3/17                        |
| OSAS                        | 2 (11)                          | 3 (15)                      |
| Smoker                      |                                 |                             |
| Ongoing                     | 0 (0)                           | 1 (5)                       |
| Previous                    | 2 (11)                          | 4 (20)                      |
| Experience of laryngoscopist|                                 |                             |
| Nurse anaesthetist          | 1 (6)                           | 2 (10)                      |
| Registrar                   | 15 (83)                         | 14 (70)                     |
| Specialist                  | 2 (11)                          | 2 (10)                      |
| Consultant                  | 0 (0)                           | 2 (10)                      |
| Laryngoscopy attempts       | 16/1/1                          | 17/1/2                      |

Data are presented as mean ± standard deviation for continuous variables and n (%) for categorical variables.

Abbreviations: BMI, Body mass index; OSAS, Obstructive sleep apnoea syndrome.

3.2 | Secondary outcomes

There were no differences in the proportions of subjects with $\text{EtO}_2 > 0.85$ at 2.5 or 5.0 min. A higher proportion of patients in the PEEP group reached $\text{EtO}_2 > 0.90$ at 5.0 min, but the difference was not statistically significant. All subjects in both groups reached an $\text{EtO}_2 > 0.85$ at 5 min of preoxygenation (Table 2). There were no differences between groups in mean $\text{PaO}_2$ when comparing values at 2.5 and 5.0 min of preoxygenation, respectively. There were no differences in $\text{EtCO}_2$, $\text{PaCO}_2$, $\text{SpO}_2$, NIBP or heart rate respectively, at any of the predefined time points (Table 2).

By study design, apnoea time differed between the PEEP group and the HF group. $\text{PaO}_2$ was higher at intubation in the PEEP group compared with the HF group, but the difference was not statistically significant.

A majority of subjects in both groups reported no or mild discomfort (Figure 3). Only one subject reported severe discomfort (PEEP group). None of the interventions were aborted.

3.3 | Post-hoc analysis

A subgroup analysis comparing the PEEP and the HF groups in subjects with BMI 35–40 kg m$^{-2}$ and ≥40 kg m$^{-2}$ separately showed no differences for any of the predefined outcomes during preoxygenation (Supplement A). Within the HF group, $\text{PaO}_2$ tended to be lower at intubation in subjects with BMI ≥ 40 kg m$^{-2}$ (mean ± SD: 33.80 ± 14.83 kPa) compared with subjects with BMI 35–40 kg m$^{-2}$ (mean ± SD: 44.07 ± 13.38 kPa); however, the difference was not statistically significant (95% CI −23.55, 3.01. $p = .122$). Further analysis of subjects in the HF group revealed a negative correlation of $\text{PaO}_2$ measured at intubation and apnoea time in subjects with a BMI ≥ 40 kg m$^{-2}$ but no such correlation in subjects with a BMI < 40 kg m$^{-2}$ (Figure 4).

3.4 | Adverse events

There were no adverse events related to the use of face mask or HFNC. There were two cases of difficult intubation in the HF group, both requiring 3 laryngoscopy attempts. One subject had a BMI of 35.9 kg m$^{-2}$ and an apnoea time of 264 s. The other subject had a BMI of 35.7 kg m$^{-2}$ and an apnoea time of 284 s. Both subjects maintained a $\text{SpO}_2$ of 100% on HFNC without rescue bag-mask ventilation. There was one difficult intubation in the PEEP group also requiring 3 laryngoscopies. This subject had a BMI of 37.5 kg m$^{-2}$. During the first attempt, lasting 42 s, desaturation did not occur. Preparing for the second attempt, the patient was bag-mask ventilated for 34 s. A video laryngoscope was used for the second attempt, yet, intubation was unsuccessful and the $\text{SpO}_2$ fell to 78% after 60 s. Bag-mask ventilation was recommenced and continued for 82 s until an $\text{SpO}_2$ of 100% was reached after which a third laryngoscopy attempt was made by a consultant anaesthetist who successfully could intubate...
TABLE 2 Results. PEEP group, n = 18. HF group n = 20. End-tidal gas fractions, arterial blood gas results, pulse oximetry and hemodynamic variables at baseline, during preoxygenation and immediately after intubation

Primary outcome

|                | Baseline | Preoxygenation 2.5 min | Mean difference (95% CI) | p-value |
|----------------|----------|------------------------|--------------------------|---------|
|                | PEEP     | HF                     | PEEP                     | HF      |         |
| EtO₂           |          |                        |                          |         |
|                | 0.18 ± 0.008 | 0.18 ± 0.009 | 0.89 ± 0.05 | 0.90 ± 0.04 | 0.01 (-0.02, 0.04) | .616 |

Secondary outcomes

|                | Baseline | Preoxygenation 2.5 min | Mean difference (95% CI) | p-value |
|----------------|----------|------------------------|--------------------------|---------|
|                | PEEP     | HF                     | PEEP                     | HF      |         |
| EtO₂ ≥ 0.85 n (%) |          |                        |                          |         |
| EtO₂ ≥ 0.90 n (%) |          |                        |                          |         |
| EtCO₂ (kPa)     |          |                        |                          |         |
| PaO₂ (kPa)      |          |                        |                          |         |
| PaCO₂ (kPa)     |          |                        |                          |         |
| SpO₂ (%) median [range] |          |                        |                          |         |
| Heart rate (min⁻¹) |          |                        |                          |         |
| SBP (mm Hg)     |          |                        |                          |         |
| DBP (mm Hg)     |          |                        |                          |         |

Preoxygenation 5.0 min

|                | Baseline | Preoxygenation 5.0 min | Mean difference (95% CI) | p-value |
|----------------|----------|------------------------|--------------------------|---------|
|                | PEEP     | HF                     | PEEP                     | HF      |         |
| EtO₂           |          |                        |                          |         |
|                | 0.93 ± 0.02 | 0.91 ± 0.02 | -0.02 (-0.03, -0.002) | .028 |

Intubation

|                | Baseline | Preoxygenation 5.0 min | Mean difference (95% CI) | p-value |
|----------------|----------|------------------------|--------------------------|---------|
|                | PEEP     | HF                     | PEEP                     | HF      |         |
| EtO₂           |          |                        |                          |         |
|                | 0.91 ± 0.02 | 0.87 ± 0.10 | -0.04 (-0.09, 0.006) | .084 |

Data are presented as mean ± standard deviation if not stated otherwise. Duration of apnoea is presented in the intubation column.

Abbreviations: CI 95%, 95% confidence interval; DBP, diastolic blood pressure; EtCO₂, end-tidal fraction of carbon dioxide; EtO₂, end-tidal fraction of oxygen; n.a., not applicable; n.s., not significant; PaCO₂, partial pressure of arterial carbon dioxide; PaO₂, partial pressure of arterial oxygen; SBP, systolic blood pressure; SpO₂, peripheral capillary oxygen saturation.

The main finding of this study was that preoxygenation using a standard anaesthesia face mask with PEEP provided higher EtO₂

4 | DISCUSSION

the trachea in 45 s during which the SpO₂ fell once more to 92%. All difficult intubations were unexpected, and all three patients had been thoroughly assessed pre-operatively including mouth opening, Mallampati score, cervical spine mobility and thyromental distance.
values compared with HFNC after 5 min of preoxygenation. This difference may be due to a lower alveolar ventilation in the HF group secondary to dead space CO\textsubscript{2} washout.\textsuperscript{29} However, this explanation is in part contradicted by the fact that subjects in the HF group tended to have higher PaO\textsubscript{2} at 2.5 min. A more plausible explanation may be that inspiratory flows in the HF group could have exceeded the flow of HFNC due to deep-breathing leading to entrainment of room air. We did not record respiratory data and cannot draw definitive conclusions.

Preoxygenation efficacy depends on two key factors. First, denitrogenation of the FRC is important, because it increases the fraction of oxygen within the available lung volume. This can be measured by EtO\textsubscript{2}.\textsuperscript{30} Second, the size of the FRC dictates the maximal amount of oxygen that can be stored. The size of the FRC is more difficult to measure,\textsuperscript{31} but may be indirectly assessed the PaO\textsubscript{2}.\textsuperscript{32}

Although standard face mask preoxygenation with PEEP was superior to HFNC, all subjects reached an EtO\textsubscript{2} ≥ 0.85 after 5 min of preoxygenation irrespective of method. Efficient preoxygenation was further supported by PaO\textsubscript{2} values that reached high, and similar levels in both groups. These findings suggest that HFNC may be used in patients in whom face-mask preoxygenation quality is compromised, warranting further research.

Our findings differ from previous studies of preoxygenation with HFNC in non-obese subjects. In one study of pregnant subjects, a
investigators found that preoxygenation with HFNC resulted in inadequate preoxygenation, and a significant variability in EtO$_2$ after 3 min of preoxygenation. However, they conducted the study with a flow of 50 L min$^{-1}$ and the subjects were instructed to take deep breaths, which may have led to high inspiratory flows and entrainment of room air explaining the observed difference. In another study of normal weight subjects, a flow rate of 70 L min$^{-1}$ and tidal volume breathing were used. They found a greater variability in EtO$_2$ values after 2.5 min and fewer subjects reaching an EtO$_2$ of 0.90 compared with our results, which is more difficult to explain. The difference could perhaps be due to different breathing patterns, but this was not recorded in either study. Similar to a third study, we report high PaO$_2$ levels in both groups during preoxygenation.

Long apnoea times were observed in the HF group and although two unexpected difficult laryngoscopies with apnoea times that exceeded 4 min were encountered, no patient desaturated. In one case of difficult intubation in the PEEP group, desaturation occurred quickly during laryngoscopy despite intermittent face mask ventilation. Furthermore, mean PaO$_2$ was 38.9 kPa at intubation in the HF group after a mean apnoea time of 199 s. This may be compared with the results by Jense et al. who reported a mean PaO$_2$ of 7.9 kPa following a mean apnoea time of 163 s in subjects with similar BMI who received preoxygenation with face mask but no apnoeic oxygenation. Although these observations should be interpreted with caution, they suggest that maintenance of HFNC during difficult laryngoscopy prolongs safe apnoea time in the obese, in line with previous reports. The post-hoc analysis, however, indicates that the effect of apnoeic oxygenation may be limited in morbidly obese patients with BMI $\geq$ 40 kg m$^{-2}$. The possibility of reduced efficacy of apnoeic oxygenation in this subset of morbidly obese patients may be correlated to the degree of FRC reduction after induction of general anaesthesia and must be carefully considered when using HFNC for difficult airway management in patients with extreme BMIs. This is similar to patients undergoing rapid sequence induction in the intensive care unit, where HFNC seems to prevent critical desaturation if the cause of intubation is non-hypoxemic in contrast to hypoxemic causes of intubation. Both patients intubated for hypoxemic respiratory failure and patients with morbid obesity may thus need more PEEP than HFNC can provide, which is further supported by a study comparing non-invasive ventilation (NIV) to HFNC in a more diverse obese population than ours. Although not studied in the obese, a combination of preoxygenation with NIV followed by apnoeic oxygenation with HFNC during laryngoscopy may be the most efficient method.

Our study has several limitations. First, due to the nature of the intervention, subjects and anaesthetists were not blinded to the allocated intervention, increasing the risk of bias. Second, the small sample size reduces statistical power and the single-centre design and the homogenous study population limit generalisability. However, most anaesthetists were registrars conversely increasing generalisability. Third, measurement of EtO$_2$ may be prone to errors, especially in the HF group. We tried to minimise technical errors by practising the technique before starting preoxygenation in the HF group and included PaO$_2$ as a supportive secondary outcome less likely to be biased. Fourth, controls in this study received preoxygenation with PEEP, which may not be generalisable to centres.
where preoxygenation with PEEP and pressure support is standard care. Fifth, comparison of oxygenation between groups at intubation could have been more relevant if HFNC was compared with an RSI-technique. Subjects in the PEEP group were ventilated during apnoea as part of standard care at our institution and we did not think it was ethical to forego this routine. However, our study provides important information for bedside clinicians and future research regarding apnoeic oxygenation in obese patients.

5 | CONCLUSIONS
In obese patients with no or mild systemic disease presenting for elective bariatric surgery, preoxygenation using a standard anesthetic face mask with PEEP was superior to preoxygenation with HFNC. However, HFNC provided adequate preoxygenation quality in all patients and although further research is warranted, HFNC may be considered in selected patients in whom face mask preoxygenation is not feasible.

CONFLICTS OF INTEREST
JR and PF declare that they have no conflict of interest. DF has received travel funding to participate in a scientific symposium on HFNC sponsored by Armstrong Medical Ltd.

AUTHORS’ CONTRIBUTIONS
JR: Patient recruitment, data collection, data analysis, data interpretation, writing the first draft of the manuscript and critical revision of the manuscript. DF and PF: Study design, patient recruitment, data collection, data analysis and interpretation and critical revision the manuscript.

ETHICS APPROVAL, TRIAL REGISTRATION AND CONSENT TO PARTICIPATE
The protocol was approved by the Regional Ethical Committee of Uppsala (dnr 2018-007, chairperson M. Tunudd), 4 April 2018 and registered at the ISRCTN registry (#ISRCTN37375068), 19 October 2018 (isrctn.com). Written informed consent was obtained from all subjects.

CONSENT FOR PUBLICATION
Not applicable.

PRESENTATION
Preliminary data from this study were in part presented as an abstract at the World Airway Management Meeting in Amsterdam, November 2019.

DATA AVAILABILITY STATEMENT
The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.