High-Flow Nasal Cannula versus Bag Valve Mask for Preoxygenation during Rapid Sequence Intubation in the Emergency Department: A Single-Center, Prospective, Randomized Controlled Trial

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Conflicts of interest/funding/disclaimers: This manuscript was presented as an oral presentation at the 7th Eurasian Congress on Emergency Medicine, at Antalya, Turkey. No funding or grants were received. Authors declare that they have no conflicts of interest.

Keywords: BVM; HFNO; preoxygenation; rapid sequence intubation

Abbreviations:
BVM: bag-valve mask
ED: emergency department
ETI: endotracheal intubation
FiO2: fraction of inspired oxygen
HFNC: high-flow nasal cannula
NIV: non-invasive ventilation
PEEP: positive end-expiratory pressure
RCT: randomized controlled trial
RSI: rapid sequence intubation
SpO2: peripheral oxygen saturation

Received: September 9, 2023
Revised: October 21, 2023
Accepted: November 2, 2023

Abstract

Objective: Hypoxia is a frequently reported complication during the intubation procedure in the emergency department (ED) and may cause bad outcomes. Therefore, oxygenation plays an important role in emergency airway management. The efficacy of oxygenation with high-flow nasal cannula (HFNC) in the ED has been studied, though the evidence is limited. The study aim was to compare two methods of preoxygenation in patients undergoing rapid sequence intubation (RSI) in the ED: (1) HFNC and (2) bag-valve mask (BVM) oxygenation.

Methods: This is a single-center, prospective, randomized controlled trial (RCT) in adult ED patients requiring RSI. Patients were randomized to receive preoxygenation with either HFNC or BVM. While HFNC therapy was continued during the intubation procedure, BVM oxygenation was interrupted for laryngoscopy. The primary outcome was the lowest peripheral oxygen saturation (SpO2) level during intubation. Secondary outcomes were incidence of desaturation (SpO2<90%) and severe hypoxemia (SpO2<80%) throughout the procedure, intubation time, rate of failed intubation, and 30-day survival rates.

Results: A total of 135 patients were randomized into two groups (HFNC n = 68; BVM n = 67). The median lowest SpO2 value measured during intubation was 96% (88.8%-99.0%) in the HFNC group and 92% (86.0%-97.5%) in the BVM group (P = .161). During the intubation procedure, severe hypoxemia occurred in 13.2% (n = 9) of patients in the HFNC group and 8.9% (n = 6) in the BVM group, while mild hypoxemia was observed in 35.8% (n = 24) of the BVM group and 26.5% (n = 18) of the HFNC group. However, there was no statistically significant difference between the groups in terms of hypoxemia development (P = .429 and P = .241, respectively). No significant difference was reported in the rate of failed intubation between the groups. Thirty-day mortality was observed in 73.1% of the BVM group and 57.4% of the HFNC group, with a borderline statistically significant difference (difference 15.7; 95% CI of the difference: −0.4 to 30.7; P = .054).

Conclusion: The use of HFNC for preoxygenation, when compared to standard care with BVM oxygenation, did not improve the lowest SpO2 levels during intubation. Also, the use of HFNC during intubation did not provide benefits in reducing the incidence of severe hypoxemia. However, the 30-day survival rates were slightly better in the HFNC group compared to the BVM group.

Cırıl MF, Akarca M, Unal Akoglu E, Cimilli Ozturk T, Onur Ö. High-flow nasal cannula versus bag valve mask for preoxygenation during rapid sequence intubation in the emergency department: a single-center, prospective, randomized controlled trial. ***Prehosp Disaster Med.*** **2024;39(1):45–51.**

Introduction

Rapid sequence intubation (RSI) is a technique performed in emergency departments (EDs) and intensive care units to facilitate endotracheal intubation (ETI).[1] The risk of adverse events including hypoxia is higher during intubation in the ED due to limited patient history

doi:10.1017/S1049023X23006684

and unstable conditions of the patients. According to the literature, adverse events have been reported in 11% of emergency intubations performed in the ED and peripheral oxygen saturation (SpO2) decreased to critical levels (SpO2<70%) in 83% of cases.[2]

Preoxygenation is the delivery of 100% oxygen for a specific duration to minimize the risk of hypoxemia during intubation.[3] However, in some conditions, acute physiological changes may render preoxygenation less effective. The level of SpO2 during laryngoscopy can vary depending on the patient's oxygen reserves and the method of preoxygenation.[4] The best approach remains uncertain. The most commonly used method is oxygen delivery with a bag-valve mask (BVM) of at least 15L/min. High-flow nasal cannula (HFNC) is used to deliver humidified and heated oxygen at high flow rates. In recent years, HFNC has been studied for apneic oxygenation in the operating room and intensive care units.[5] Although HFNC has become popular, especially in critically ill patients, the effectiveness of this method is still debated. The advantages of HFNC oxygenation therapy include providing low positive airway pressure to reduce anatomical dead space and increase functional residual capacity.[6,7] Nevertheless, HFNC therapy can be maintained during the intubation procedure, which is defined as apneic oxygenation. Apneic oxygenation has benefits in prolonging safe apnea time and reducing the incidence of severe hypoxia.[8]

The authors hypothesized that preoxygenation with HFNC would be more effective at preventing hypoxemia and would be associated with higher SpO2 levels during tracheal intubation compared to BVM. The aim of this study was to evaluate the effects of two different preoxygenation methods, HFNC and BVM, on SpO2 levels during intubation in patients who required RSI in the ED.

Method

Study Design

This study was conducted at the ED of Fatih Sultan Mehmet Training and Research Hospital, Health Sciences University (Istanbul, Turkey) from June 2020 through November 2020. This study was approved by the institutional review board of Fatih Sultan Mehmet Training and Research Hospital, Health Sciences University (Number: FSMEAH-KAEK 2019/87). Consent was obtained from patients or their relatives. This study was a single-center, prospective, randomized controlled trial (RCT) conducted in an open-label non-inferiority design.

Study Participants

Patients aged 18 and older, who required RSI in the ED, were recruited.

The patients who met the following conditions were excluded: contraindications for orotracheal intubation (do not resuscitate), trauma patients that required intubation, suspicion or confirmed diagnosis of severe facial trauma, cardiac arrest, no need for RSI (crash intubation) or delayed-sequence intubation, difficulty in applying HFNC or BVM due to previous facial or nasal surgery, initiation of HFNC or non-invasive ventilation (NIV) treatment upon ED admission, need for surgical airway management, and pregnant women. Additionally, eligible patients were excluded from the trial if their 30-day mortality information could not be accessed and they refused to sign delayed consent.

All consecutive patients were included in the study. Only the initial ED admission of patients was included in the study and repeat visits were excluded.

Randomization

Randomization was performed with an allocation ratio of 1:1 and used fixed blocks of four patients for two groups. Patients were enrolled in one of the two preoxygenation methods (HFNC or BVM). A computerized algorithm was used. Since the study was open-label, blinding criteria were not required.

Study Interventions

The patients were randomized immediately after inclusion. Preoxygenation was applied using either HFNC or BVM. The RSI procedure was performed after randomization. In the HFNC group (O2FLO High Flow Respiratory Humidifier; Inspired Medical; Hong Kong), preoxygenation was performed for three minutes with a flow rate of 60L/min humidified oxygen (100% fraction of inspired oxygen [FiO2]) at a 34°C temperature. After induction, HFNC oxygenation was continued throughout the ETI until successful intubation and connection to the mechanical ventilator. In the BVM group, preoxygenation was performed with a flow rate of 15L/min for three minutes. Passive ventilation with dry and unheated oxygen was administered. The BVM was removed from the patient's face immediately before intubation. No extra ventilation was performed.

In all patients, the indications for intubation were determined according to the international guidelines. Anesthesia was induced with boluses of intravenous Ketamine (1-2mg/kg), and neuromuscular blockade was achieved by the administration of intravenous Rocuronium (1-1.2mg/kg). After the loss of consciousness, an intubation attempt was performed. If the practitioner failed after two attempts, a more experienced physician took over. The placement of the endotracheal tube was confirmed by using end-tidal carbon dioxide ($ETCO_2$) monitoring. All patients included in the study were intubated using the Infinium ClearVue VL3R (Florida USA) video laryngoscope. The Covidien Nellcor Pulse Oximeter Monitor Console Type Bedside (Dublin, Ireland) was used to monitor patients' oxygen saturation levels.

Data Collection

Demographic variables were obtained from hospital records. The clinical data collected in the ED included SpO2, heart rate, blood pressure, respiratory rate, Glasgow Coma Scale, and comorbidities. To minimize observer bias, an independent researcher not involved in the performance of the procedure recorded data using a standardized patient follow-up form. The 30-day mortality information of patients was obtained from the Ministry of Health (Ankara, Turkey) Death Reporting System (DRS).

Measurements

Patients were continuously monitored throughout the procedure. Sudden drops in oxygen saturation during the intubation procedure were also recorded by continuous pulse oximetry. The parameters that are continuously monitored, including arterial blood pressure, pulse rate, and oxygen saturation, were measured at specified points throughout the RSI procedure (Figure 1). The initial diagnosis on admission was noted according to hospital records. Duration of RSI procedure steps, the incidence of hypoxemia and severe hypoxemia, the incidence of unsuccessful intubation attempts, the need for an alternative airway device, and the development of cardiac arrest or exitus during or immediately after the procedure were recorded. Severe hypoxemia was defined as an oxygen saturation level of <80% and desaturation was defined as a peripheral SpO2 level of <90% during the RSI procedure steps. All practitioners were Emergency Medicine residents who had

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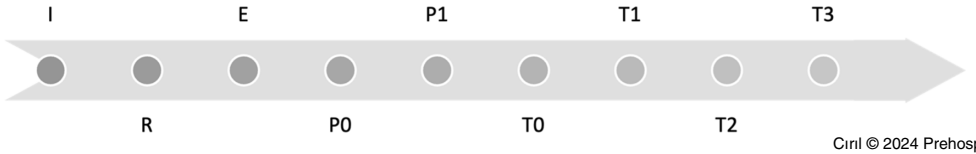

Figure 1. Time Diagram of the Study Procedure.
Note: I = Decision for RSI procedure (inclusion); R = Randomization; E = Exclusion criteria; P0 = Initiation of preoxygenation; P1 = After Preoxygenation (3 minutes 100% FiO2); T0 = Initiation of induction; T1 = Initiation of neuromuscular blockade; T2 = Initiation of intubation; T3 = End of successful intubation.
Abbreviations: FiO2, fraction of inspired oxygen; RSI, rapid sequence intubation.

received advanced airway management training. Only two intubation attempts were allowed for the exchange of the laryngoscope. Each entry of the laryngoscope into the patient's oral cavity was considered an intubation attempt.

Study Outcomes

The primary outcome was the lowest SpO2 measured during ETI, from the end of the induction until the patient was connected to mechanical ventilation.

The secondary outcomes were the lowest SpO2 level during the entire RSI procedure at the specified points (Figure 1), the incidence of desaturation (SpO2<90%) and severe hypoxemia (SpO2<80%) during the entire procedure and during ETI, time duration of intubation, and 30-day mortality.

Sample Size Calculation

Based on the study by Raineri, et al,[9] a sample size of 63 patients per group was calculated to detect a two percent difference in the lowest SpO2 value between the two groups, assuming a power of 80%, a Type 1 error of five percent, and a two percent dropout rate.

Statistical Methods

Since there was no patient loss after randomization in this study, all data were analyzed. Descriptive statistical measures for the lowest SpO2 were calculated for each group. Two-sample t-tests or non-parametric tests were used to compare the mean or median lowest SpO2 values between the groups, depending on the normal distribution of the data. Fisher's exact test was used for the analysis of categorical variables. An ANOVA test for repeated measurements was used for the analysis of consecutive measurements, and post-hoc analysis was applied if a significant difference was found. A Type 1 error of five percent was accepted in this study. The Jamovi software (The Jamovi Project; Sydney, Australia) was used for all statistical analyses.

Results

A total of 149 patients who presented to the ED and required airway intervention were included for randomization. Fourteen of them were excluded. Finally, 135 patients were included in the statistical analysis (68 in the HFNC group and 67 in the BVM group).

The main characteristics were similar between the two groups (Table 1). The main causes of intubation among patients were shortness of breath in 85.2% (n = 115) and altered mental status in 14.8% (n = 20). Pneumonia was the most common diagnosis in both groups.

All patients who presented to the ED with respiratory complaints and had oxygen saturation levels below 90% on admission were started on oxygen therapy. Among the patients, 21 (30.9%) in the HFNC group and 32 (47.8%) in the BVM group received oxygen support through a mask prior to the procedure. The difference between the two groups is marginally significant (P = .045).

There was no statistical difference regarding the median lowest SpO2 during the ETI procedure comparing the HFNC group (96% [89%-99%]) and the BVM group (92% [86%-98%]); P = .161 (Table 2; Figure 2).

The change in mean SpO2 levels throughout the RSI procedure at specified points was analyzed within and between groups. From the beginning of preoxygenation until the initiation of induction, an increase of 8.6% in the HFNC group and 6.3% in the BVM group was observed and the difference within the groups was statistically significant (rmANOVA within, P <.001); Figure 3. However, no statistically significant difference in the repeated measures of mean SpO2 levels was found between the groups (rmANOVA between, P = .662).

In short-term mortality, within the first 24 hours, it was determined that eight patients (11.8%) in the HFNC group and eight patients (11.9%) in the BVM group died, and the difference was not statistically significant (difference 0.1; 95% CI of the difference: −11.3 to 11.5; P = .975). In the 30-day survival rate, 57.4% of patients in the HFNC group (n = 39) and 73.1% of patients in the BVM group (n = 49) died. The difference was slightly statistically better for HFNC (difference 15.7; 95% CI of the difference: −0.4 to 30.7; P = .054); Table 3.

Discussion

In this randomized controlled study comparing the effectiveness of HFNC and BVM in preoxygenation, no significant difference was found between the groups in terms of median lowest SpO2 values measured during the intubation procedure. Although the SpO2 values in the HFNC group were consistently higher than the BVM group throughout the procedure, there was no statistically significant difference observed in the consecutive measurements of mean SpO2 values between the groups (P = .174). After preoxygenation with either method, a statistically significant increase was observed within groups (rmANOVA, P <.001). However, no difference between groups was found (rmANOVA, P = .662).

It is well-known that intubation procedures performed in emergency conditions are associated with a high rate of unwanted complications. Hypoxemia, especially in critically ill patients, is associated with poor outcomes. Proper preoxygenation techniques can help reduce the risk of hypoxemia and intubation-related complications.[10] In this study, SpO2 levels below 90% were detected in 31.1% of cases and below 80% in 11.1% of cases, which is partly consistent with the literature. Unlike other studies, patients presented to the ED usually are clinically unstable and prone to desaturation and hypoxemia.

https://doi.org/10.1017/S1049023X23006684 Published online by Cambridge University Press

	HFNC (n = 68)	BVM (n = 67)	P Value
Age, years, mean (SD)	76 (13)	80 (11)	.06[2]
Male, n (%)	31 (46)	23 (34)	.182[3]
Vital Parameters			
SBP, mmHg, mean (SD)	125.4 (39.9)	135.5 (43)	.161[2]
DBP, mmHg, mean (SD)	76.5 (32.5)	71.3 (24.6)	.302[2]
MAP, mmHg, mean (SD)	92.8 (31.9)	92.7 (28.8)	.988[2]
Heart Rate, beats/min, mean (SD)	106.3 (24.5)	104.1 (26.9)	.608[2]
SpO2, %, mean (SD)	84.4 (9.7)	82.7 (9.8)	.310[2]
Comorbid Diseases			
Diabetes Mellitus, n (%)	25 (37)	18 (27)	.217[3]
Hypertension, n (%)	46 (67)	37 (55)	.138[3]
Coronary Artery Disease, n (%)	33 (48)	31 (46)	.793[3]
COPD, n (%)	20 (29)	16 (24)	.467[3]
Initial Diagnoses			
Respiratory Diseases, n (%)	47 (69.1)	52 (77.6)	
Metabolic Diseases, n (%)	7 (10.3)	5 (7.4)	.183[3]
Cerebrovascular Diseases, n (%)	11 (16.1)	4 (6)	
Cardiovascular Diseases, n (%)	3 (4.4)	6 (9)	
Other Variables			
Failed Intubation, n (%)	4 (5.8)	6 (8.9)	.527[3]
Pre-Procedural Oxygen Therapy, n (%)	21 (31)	32(47)	**.045[3]**

Table 1. Demographics and Clinical Characteristics of the Patients
Note: P values are obtained from [1]Mann Whitney U test; [2]Student t test; and [3]Chi-Squared test.
Abbreviations: HFNC, high-flow nasal cannula; BVM, bag-valve mask; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; COPD, chronic obstructive pulmonary disease; SpO2, oxygen saturation.

	HFNC (n = 68)	BVM (n = 67)	P Value
Primary Outcomes			
Lowest SpO2 during Intubation, %, median (IQR)	96 (89-99)	92 (86-98)	.161[1]
Secondary Outcomes			
Lowest SpO2 during Entire Procedure, %, median (IQR)	94 (88-100)	91 (84-100)	.133[1]
SpO2 Values during the Entire RSI Procedure			
P0, %, mean (SD)	87.8 (9.9)	88.5 (8)	
P1, %, mean (SD)	96.1 (4.8)	94.9 (5.5)	
T0, %, mean (SD)	96.3 (4.9)	94.7 (6.2)	
T1, %, mean (SD)	96 (6.0)	93.3 (8.4)	.174[3]
T2, %, mean (SD)	95 (7.5)	93.5 (6.8)	
T3, %, mean (SD)	93.7 (8.3)	92.4 (8.5)	
Severe Hypoxemia and Desaturation during the Entire Procedure			
SpO2 <80, %, n (%)	9 (13.2)	9 (13.4)	.973[2]
SpO2 <90, %, n (%)	20 (29.4)	28 (41.7)	.133[2]
Severe Hypoxemia and Desaturation during Intubation			
SpO2 <80, %, n (%)	9 (13.2)	6 (9.0)	.429[2]
SpO2 <90, %, n (%)	18 (26.5)	24 (35.8)	.241[2]
Successful Intubation Time, sec, median (IQR)	41 (28-61.5)	40 (28-60.5)	.817[1]

Table 2. Primary and Secondary Outcomes
Note: P values are obtained from [1]Mann Whitney U test; [2] Chi-squared test; and [3] Repeated measures ANOVA. P0, initiation of RSI procedure; P1, after preoxygenation (3 minutes 100% oxygenation); T0, induction agent; T1, paralysis agent; T2, intubation start; T3, end of successful intubation. The whole procedure means the time period between P0 and T3. The intubation period is the time between T2 and T3.
Abbreviations: HFNC, high-flow nasal cannula; BVM, bag-valve mask; SpO2, oxygen saturation; RSI, rapid sequence intubation.

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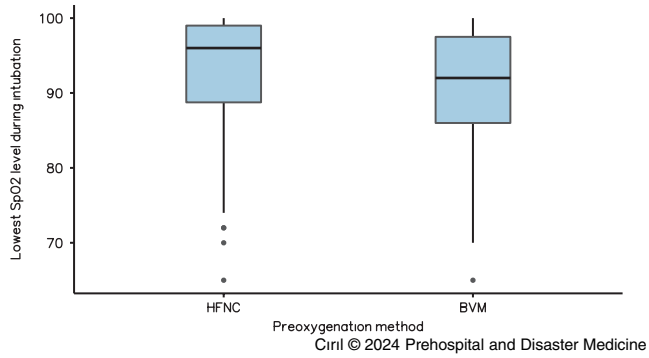

Figure 2. Lowest SpO2 Level during the Intubation Procedure.
Abbreviations: HFNC, high-flow nasal cannula; BVM, bag-valve mask; SpO2, oxygen saturation.

There are very few studies evaluating RSI procedures in the ED. Preoxygenation in healthy individuals before anesthesia can maintain oxygen saturation above 90% for approximately nine minutes of apnea,[11] but the effectiveness of preoxygenation is lower in patients with unstable cardiovascular or respiratory conditions.[12]

Mort, et al have reported that the use of BVM for preoxygenation to prevent desaturation during intubation is not effective,[13] while Robinson, et al have demonstrated that the use of BVM and non-rebreather masks during preoxygenation has the same efficacy.[14] The evidence regarding the use of the HFNC for preoxygenation is controversial, despite its benefits in acute hypoxemic respiratory failure and post-extubation settings.

Studies have shown that HFNC and NIV methods are more effective than standard oxygen therapy.[12,15,16] The results of three RCTs conducted so far have shown that preoxygenation with HFNC is not superior to standard oxygen therapy.[15,17,18]

In this study, both the HFNC and BVM groups achieved a safe SpO2 level with preoxygenation (98% versus 96%). The median lowest SpO2 values measured during the intubation procedure were 96% in the HFNC group and 92% in the BVM group (P = .161). The incidence of severe hypoxemia (SpO2<80%) was observed in 13.2% (n = 9) of the HFNC group and 8.9% (n = 6) of the BVM group (P = .429), while the incidence of desaturation (SpO2<90%) was observed in 18 patients (26.5%) in the HFNC group and 24 patients (35.8%) in the BVM group (P = .241).

In a multi-center study by Guitton, et al, the effect of the HFNC and BVM for preoxygenation was compared. No significant difference was found between the two methods regarding the lowest SpO2 levels measured during intubation (P = .30). In the same study, the incidence of desaturation (SpO2<90%) was observed in six percent of patients in the HFNC group and 14% of patients in the BVM group (P = .10).[16]

In a meta-analysis, including 14 RCTs and 1,012 participants, the effectiveness of HFNC versus standard face mask ventilation for preoxygenation and apneic oxygenation was compared. According to the results, HFNC can improve oxygenation during preoxygenation and prolong the safe apnea time during the induction of anesthesia. There was no difference regarding the lowest SpO2 level and the incidence of desaturation between groups (P = .17 and P = .60, respectively). High source heterogeneity, due to different patient populations, preoxygenation time, and HFNC application ways in the included articles, is an important limitation.[19]

Mitsuyama, et al compared the use of BVM and HFNC methods for preoxygenation. But the study has been prematurely terminated due to the COVID-19 pandemic. In contrast to this study, the median lowest SpO2 level in the HFNC group (94%) was found to be higher than the BVM group (85%), and the difference between the groups was statistically significant (P = .006). The patients in the BVM group had more critical conditions and the vital parameters were poorer. Also, the number of participants included in the HFNC group was fewer than intended, which are important limitations for generalizing the results.[2]

In the Pre-AeRATE Trial comparing preoxygenation and apneic oxygenation with HFNC and non-rebreather mask + nasal cannula in patients requiring RSI in the ED, no significant difference was found between the two groups, but a prolonged safe apnea duration was observed in the HFNC group.[20]

Especially in obese patients, rapid desaturation during the apneic phase of RSI has been observed. In a study by Bright, et al including 351 obese elective surgery patients, the efficacy of preoxygenation with HFNC and face mask was compared during anesthesia. Although an extension of safe apnea duration was observed in the HFNC group, no significant difference was found between the two groups regarding the lowest SpO2 level.[21]

In the study by Rosen, et al, the use of a face mask with positive end-expiratory pressure (PEEP) and HFNC was compared in obese patients during the preoxygenation, and it was concluded that PEEP application was superior to HFNC. The end-tidal oxygen level was found to be lower in the HFNC group during intubation, but the difference was not statistically significant. In the HFNC group, there were two cases, and in the face mask group, there was one case of difficult intubation requiring three attempts at laryngoscopy. Although rescue ventilation was not required in the HFNC group, rescue ventilation and a need for operator change were required in the PEEP group.[22] In the study by Guitton, et al, 28% of patients in the HFNC group and 16% of patients in the BVM group required operator change during intubation.[16] In this study, there were four cases (5.8%) of failed intubation in the HFNC group and six cases (8.9%) in the BVM group (P = .527). Only one patient in the HFNC group required a need for operator change. Patients with failed intubation did not require rescue ventilation.

In the literature, the preoxygenation studies have shown no significant difference in terms of 28-day mortality or in-hospital mortality.[15,23,24] When comparing the 30-day mortality rates of patients, the current results showed that 49 patients in the BVM group and 39 patients in the HFNC group died. The difference between the groups was slightly statistically significant (P = .054). However, it is a multifactorial parameter, and further investigation is needed to determine whether the causes of death are related to intubation or the conditions leading to intubation.

Limitations

This study has limitations. It was conducted in a single center, which may limit the generalizability. In the ED setting, serial arterial blood gas monitoring or arterial catheterization is not a practical method, thus oxygen saturation levels of patients were continuously monitored with a non-invasive method, peripherally. However, this approach may have led to some measurement mistakes, albeit minimal, particularly in critically ill patients.

In this study, the use of video laryngoscopy as the standard method for intubation may have shortened the airway management

https://doi.org/10.1017/S1049023X23006684 Published online by Cambridge University Press

	HFNC (n = 68)	BVM (n = 67)	Difference (95% CI)	P Value
Mortality in 24 Hours, n (%)	8 (11.8)	8 (11.9)	0.1 (–11.3 to 11.5)	.975
Mortality in 30 Days, n (%)	39 (57.4)	49 (73.1)	15.7 (–0.4 to 30.7)	**.054**

Table 3. Short- and Long-Term Mortality Outcomes
Abbreviations: HFNC, high-flow nasal cannula; BVM, bag-valve mask.

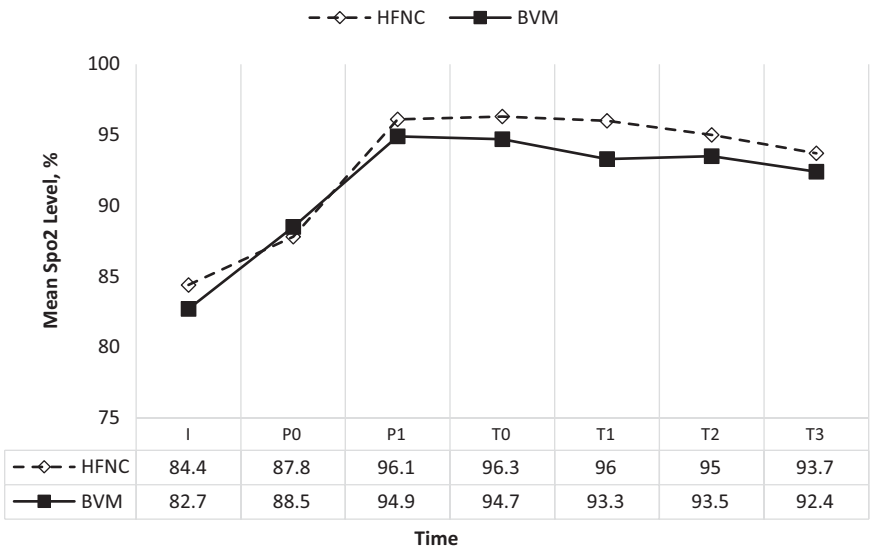

Figure 3. Change of SpO2 Levels Over Time.
Note: I = Decision for RSI procedure (inclusion); P0 = Initiation of preoxygenation; P1 = After Preoxygenation (3 minutes 100% FiO2); T0 = Initiation of induction; T1 = Initiation of neuromuscular blockade; T2 = Initiation of intubation; T3 = End of successful intubation.
Abbreviations: HFNC, high-flow nasal cannula; BVM, bag-valve mask; SpO2, oxygen saturation; FiO2, fraction of inspired oxygen; RSI, rapid sequence intubation.

duration, reduced the level of desaturation, and presented results better than expected. Comparing these results with studies using direct laryngoscopy can be considered an important limitation.

If active oxygenation had been performed instead of passive oxygenation in the BVM group, it could have led to differences in oxygen saturation measurements and outcomes. The amount of leakage around the mask during BVM preoxygenation was not measured, this is another limitation. Lastly, in the HFNC group, oxygenation was continued during the intubation procedure, while in the BVM group, no apneic oxygenation was performed.

Conclusion

Despite the advantages, the use of HFNC for preoxygenation was not more effective than the BVM during intubation in the ED. However, an important increase in oxygen saturation was observed with both methods during preoxygenation. Although no impact on short-term mortality was found, 30-day mortality was slightly statistically better for HFNC.

Author Contributions

Initials of the contributing authors are listed in brackets after the relevant parts of the research: literature search (MFC, EUA, TCO, OO); study design (MFC, EUA, TCO, OO); legislative applications (MFC, EUA, TCO, OO); data collection (MFC, EUA, MA); supervision and quality control (MFC, EUA, TCO, OO); statistical advice (MFC, EUA, TCO); statistical data analysis (EUA, TCO); data interpretation (MFC, EUA, TCO, MA); and drafting the manuscript (MFC, EUA, TCO). All authors were involved in the writing and critical revision of the manuscript and approved the final version. MFC, EUA, and TCO take responsibility for the paper as a whole.

Acknowledgments

The authors thank Haldun Akoglu, MD, Professor of Emergency Medicine, for assistance with statistical analysis and for the comments that greatly improved the manuscript.

References

1. Jishnu M, Bhoi S, Sahu AK, Suresh S, Aggarwal P. Airway management practices among emergency physicians: an observational study. *Turk J Emerg Med.* 2022; 22(4):186–191.
2. Mitsuyama Y, Nakao S, Shimazaki J, Ogura H, Shimazu T. Effectiveness of high-flow nasal cannula for tracheal intubation in the emergency department. *BMC Emerg Med.* 2022;22(1):1–7.
3. Caputo N, Azan B, Domingues R, et al. Emergency department use of apneic oxygenation versus usual care during rapid sequence intubation: a randomized controlled trial (the ENDAO trial). *Acad Emerg Med.* 2017; 24(11):1387–1394.
4. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med.* 2012;59(3):165–175.

https://doi.org/10.1017/S1049023X23006684 Published online by Cambridge University Press

5. Gulen M, Satar S, Yesiloglu O, Avci A, Acehan S. High-flow nasal cannula oxygen therapy in the management of acute respiratory distress syndrome secondary to opioid overdose. *Turk J Emerg Med.* 2021;21(1):30–33
6. Spoletini G, Alotaibi M, Blasi F, Hill NS. Heated humidified high-flow nasal oxygen in adults. *Chest.* 2015;148(1):253–261.
7. Ejiofor BD, Carroll RW, Bortcosh W, Kacmarek RM. PEEP generated by high-flow nasal cannula in a pediatric model. *Resp Care.* 2019;64(10):1240–1249.
8. Ang KS, Green A, Ramaswamy KK, Frerk C. Preoxygenation using the Optiflow system. *Br J Anesth.* 2017;118(3):463–464.
9. Raineri SM, Cortegiani A, Accurso G, et al. Efficacy and safety of using high-flow nasal oxygenation in patients undergoing rapid sequence intubation. *Turk J Anesthesiol Reanim.* 2017;45(6):335.
10. Fong KM, Au SY, Ng GWY. Preoxygenation before intubation in adult patients with acute hypoxemic respiratory failure: a network meta-analysis of randomized trials. *Crit Care.* 2019;23(1):1–12.
11. Russotto V, Cortegiani A, Raineri SM, Gregoretti C, Giarratano A. Respiratory support techniques to avoid desaturation in critically ill patients requiring endotracheal intubation: a systematic review and meta-analysis. *J Crit Care.* 2017;41:98–106.
12. Baillard C, Fosse JP, Sebbane M, et al. Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients. *Am J Resp Crit Care Med.* 2006;174(2): 171–177.
13. Mort TC. Preoxygenation in critically ill patients requiring emergency tracheal intubation. *Crit Care Med.* 2005;33(11):2672–2675.
14. Robinson A, Ercole A. Evaluation of the self-inflating bag-valve-mask and non-rebreather mask as preoxygenation devices in volunteers. *BMJ Open.* 2012;2(5): e001785.
15. Vourc'h M, Asfar P, Volteau C, et al. High-flow nasal cannula oxygen during endotracheal intubation in hypoxemic patients: a randomized controlled clinical trial. *Intensive Care Med.* 2015;41:1538–1548.
16. Guitton C, Ehrmann S, Volteau C, et al. Nasal high-flow preoxygenation for endotracheal intubation in the critically ill patient: a randomized clinical trial. *Intensive Care Med.* 2019;45:447–458.
17. Semler MW, Janz DR, Lentz RJ, et al. Randomized trial of apneic oxygenation during endotracheal intubation of the critically ill. *Am J Resp Crit Care Med.* 2016; 193(3):273–280.
18. Simon M, Wachs C, Braune S, de Heer G, Frings D, Kluge S. High-flow nasal cannula versus bag-valve-mask for preoxygenation before intubation in subjects with hypoxemic respiratory failure. *Respir Care.* 2016;61(9):1160–1167.
19. Song J li, Sun Y, Shi Y bo, Liu X ying, Su Z bo. Comparison of the effectiveness of high-flow nasal oxygen vs. standard facemask oxygenation for pre- and apneic oxygenation during anesthesia induction: a systematic review and meta-analysis. *BMC Anesth.* 2022;22(1):100.
20. Chua MT, Khan FA, Ng WM, et al. Pre-and apneic high flow oxygenation for rapid sequence intubation in the emergency department (Pre-AeRATE): study protocol for a multicenter, randomized controlled trial. *Trials.* 2019;20:1–9.
21. Bright MR, Harley WA, Velli G, Zahir SF, Eley V. High-flow nasal cannula for apneic oxygenation in obese patients for elective surgery: a systematic review and meta-analysis. *Anesth Analg.* 2023;136(3):483–493.
22. Rosén J, Frykholm P, Fors D. High-flow nasal cannula versus face mask for preoxygenation in obese patients: a randomized controlled trial. *Acta Anaesth Scand.* 2021;65(10):1381–1389.
23. Semler MW, Janz DR, Russell DW, et al. A multicenter, randomized trial of ramped position vs sniffing position during endotracheal intubation of critically ill adults. *Chest.* 2017;152(4):712–722.
24. Jaber S, Monnin M, Girard M, et al. Apneic oxygenation via high-flow nasal cannula oxygen combined with non-invasive ventilation preoxygenation for intubation in hypoxemic patients in the intensive care unit: the single-center, blinded, randomized controlled OPTINIV trial. *Intensive Care Med.* 2016;42:1877–1887.

https://doi.org/10.1017/S1049023X23006684 Published online by Cambridge University Press