

High-Flow Nasal Cannula Versus Standard Oxygen Therapy After Extubation in Liver Transplantation: A Matched Controlled Study

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BACKGROUND: High-flow nasal cannula (HFNC) is a key component of oxygen therapy and has largely been used in patients with acute respiratory failure. We conducted a matched controlled study with the aim to compare the preventive use of oxygen therapy delivered by HFNC versus via air-entrainment mask (standard O₂) after extubation in adult subjects with liver transplantation for reducing postextubation hypoxemia. **METHODS:** Twenty-nine subjects with liver transplantation who received HFNC after extubation (HFNC group) were matched 1:1 with 29 controls (standard O₂ group) chosen from an historical group of 90 subjects admitted to the ICU during the previous 36 months. The primary outcome of the study was the incidence of hypoxemia at 1 h and 24 h after extubation. Secondary outcomes were the rate of weaning failure, ICU length of stay, and 28-d mortality. **RESULTS:** The incidence of hypoxemia was not significantly different between the HFNC and standard O₂ groups at 1 h and 24 h after extubation. In the HFNC group, there was a trend toward a lower rate of weaning failure compared with the standard O₂ group. ICU length of stay and 28-d mortality were similar in both groups. **CONCLUSIONS:** Early application of HFNC in the subjects with liver transplantation did not reduce the incidence of hypoxemia after extubation compared with standard O₂ and did not modify the incidence of weaning failure, ICU length of stay, and 28-d mortality in this high-risk population of subjects. (ClinicalTrials.gov registration NCT03441854.) *Key words:* high-flow nasal cannula; standard oxygen therapy; postoperative pulmonary complications; liver transplantation; noninvasive ventilation; postoperative hypoxemia. [Respir Care 0;0(0):1–•. © 0 Daedalus Enterprises]

Introduction

Postoperative pulmonary complications are frequently observed after major abdominal surgery and increase morbidity, mortality, and length of ICU and hospital stay. Anesthesia, postoperative pain, and surgical procedure, especially liver transplantation, result in a low end-expiratory lung volume and altered physiology (vital capacity, functional residual capacity, tidal volume), atelectasis, re-

strictive syndrome, and diaphragmatic dysfunction. Derangements of respiratory function are observed in up to 90% of patients undergoing major surgery, may last up to 7 d (eg, diaphragmatic dysfunction), and frequently result in significant and prolonged reduction of arterial oxygenation.^{1–6} Furthermore, patients who undergo liver transplantation are commonly affected by several comorbidities and have to cope with stressful surgery due to its duration and risk of bleeding; moreover the latter is associated with massive transfusion and consequent respiratory failure.⁷ In this context, standard O₂ therapy delivered by nasal can-

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The authors have disclosed no conflicts of interest.

DOI: 10.4187/respcare.06866

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nula or an air-entrainment mask is the standard of care to improve postoperative hypoxemia. However, when standard O₂ fails in this intent, noninvasive ventilation is often used to treat arterial de-oxygenation.⁸

Recently, oxygen therapy by high-flow nasal cannula (HFNC) has been largely used in clinical practice due to its capability to deliver heated and humidified air flow (up to 60 L/min) through ease-of-use and noninvasive nasal prongs. HFNC allows better control of F_{IO₂}, generates low levels of PEEP, and decreases physiologic dead space by washout of the pharynx, which thus reduces the work of breathing and dyspnea. Furthermore, gas humidification and heating improve both mucociliary motion and patient comfort. Moreover, HFNC has received increasing interest by the scientific community because of its better performance in minimizing postextubation lung de-recruitment and improving oxygenation compared with standard O₂.^{9,10} There is increasing evidence of the superiority of HFNC compared with standard O₂ in reducing intubation rates and ICU length of stay in patients who are critically ill with acute hypoxemic respiratory failure^{10,11} or at risk for re-intubation.^{12,13}

To date, few studies have been published on HFNC application after extubation in major abdominal surgery.^{14,15} However, to our knowledge, no study has assessed the effect of HFNC oxygen therapy to prevent hypoxemia after extubation in patients who underwent liver transplantation. We performed a prospective observational study in subjects admitted to the ICU after liver transplantation and compared this group with an historical cohort matched for baseline characteristics to test the hypothesis that the prophylactic use of HFNC oxygen therapy is more effective in preventing hypoxemia after extubation than standard O₂ therapy.

Methods

Subject Characteristics

We included all consecutive patients admitted to the 13-bed ICU of a tertiary teaching hospital in Rome who underwent liver transplantation for end-stage liver disease and/or hepatocellular carcinoma and for whom extubation was considered safe by the treating physician. The ethics institutional review committee at Fondazione Policlinico Universitario A Gemelli Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) approved the study (approval 14923/18). Subjects who were included in the study or the next of kin gave consent to participate before inclusion. The study was registered on ClinicalTrials.gov (reference NCT03441854). We excluded patients ages < 18 y, with acute liver failure, previous cardiopulmonary resuscitation, hemodynamic instability (defined as one mean arterial pressure ≤ 65 mm Hg, vasopressors, cardiac

QUICK LOOK

Current knowledge

Patients undergoing liver transplantation usually have several concomitant morbidities that increase the risk of postextubation hypoxemia and postoperative pulmonary complications. Oxygen therapy via high-flow nasal cannula (HFNC) has been widely used in patients who are critically ill with acute respiratory failure.

What this paper contributes to our knowledge

In subjects with liver transplantation, compared with subjects who were critically ill with acute hypoxemic respiratory failure, the routine use of HFNC oxygen therapy did not significantly impact the rate of hypoxemia over the first 24 h after elective extubation. In this specific population, the risk of postoperative pulmonary complications and of consequent gas exchange impairment was not affected by the system used to deliver oxygen therapy in the postoperative period.

ischemia, or arrhythmias), tracheotomy, hemorrhagic diathesis, sepsis or septic shock, or primary graft dysfunction, or those who were extubated in the operating room.

Study Protocol

All the subjects were admitted to the ICU deeply sedated, intubated, and on mechanical ventilation. According to hospital protocol, extubation was deemed safe when all the following criteria were verified: hemodynamic and metabolic stability, Glasgow Coma score ≥ 13, P_{aO₂}/F_{IO₂} ≥ 300 mm Hg, breathing frequency ≤ 25 breaths/min, no clinical signs of respiratory distress (dyspnea, significant use of accessory muscles, or paradoxical abdominal motion), excessive orotracheal secretions, low pressure support, and PEEP requirement. Subjects who fulfilled these criteria underwent a spontaneous breathing trial with either a T-piece or pressure support of 7 cm H₂O and PEEP of 0 cm H₂O for 30 to 120 min.

Only subjects who showed no signs of respiratory fatigue or hypoxemia and/or hypercapnia with pH derangement were extubated and started on prophylactic oxygen therapy by using either HFNC (HFNC group) or air-entrainment mask (standard O₂ group) with F_{IO₂} titrated to maintain an S_{pO₂} of at least 93%, for 24 h. The HFNC group received high-flow oxygen via the mechanical ventilator (Servo U, Maquet, Wayne, New Jersey) at a mean ±SD gas flow of 50 ± 10 L/min through an MR850 heated humidifier and a RT202 breathing circuit (Opti-flow; Fisher & Paykel Healthcare, Auckland, New Zealand).

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The gas mixture was heated and humidified at 37°C and delivered to the patient through large-bore binasal prongs. The standard O₂ group was chosen from a group of 90 subjects with liver transplantation from the hospital database, admitted to the same ICU between January 1, 2015, and December 31, 2017. All the subjects received the same postoperative analgesia protocol based on remifentanyl infusion.

Preventive oxygen therapy was discontinued if the patient developed moderate acute hypoxemic respiratory failure (at least 2 of the following criteria: (1) respiratory frequency >25 and < 35 breaths/min persistent for at least 1 h, (2) clinical signs of respiratory distress, (3) respiratory acidosis (pH < 7.35 units and P_{aCO₂} > 45 mm Hg), (4) moderate hypoxemia defined as P_{aO₂}/F_{IO₂} > 150 and < 300. In such situations, noninvasive ventilation was delivered by full-face or oronasal mask. If the subjects developed one of the following conditions: (1) hemodynamic instability, (2) agitation that required deep pharmacologic sedation, (3) surgical complication that required an urgent operative procedure, and (4) severe acute hypoxemic respiratory failure (at least 2 of the following criteria: clinical signs of respiratory distress, frequency >40 breaths/min, respiratory acidosis with arterial pH ≤ 7.30, and P_{aCO₂} > 45 mm Hg, and severe hypoxemia defined as P_{aO₂}/F_{IO₂} ≤ 100), endotracheal intubation was performed.

End Points

The primary end point of the study was the incidence of hypoxemia at 1 h and at 24 h after extubation. Hypoxemia was defined as P_{aO₂}/F_{IO₂} of <300.¹³ Secondary end points were the following: pH, P_{aO₂}, and P_{aCO₂} at 1 h and at 24 h after extubation, weaning failure (defined as the need for endotracheal intubation or noninvasive ventilation, infectious pulmonary complication during the first 48 h after extubation¹⁶), ICU length of stay, and 28-d mortality. Pulmonary infection was defined as a new infiltrate on chest radiograph, and two of the following clinical signs: body temperature > 38°C or < 35°C, leukocyte count > 10 × 10³/mm³ or < 4 × 10³/mm³, or purulent tracheal secretions.¹⁷

Measurements

Baseline assessment included age, sex, body mass index, the presence of diabetes mellitus, etiology of chronic liver disease, Model for End-Stage Liver Disease score, degree of hepatic encephalopathy, cardiac function assessed by bedside echocardiography (left ventricular ejection fraction and systolic pulmonary arterial pressure), the ARISCAT (Assess Respiratory Risk in Surgical Patients in Catalonia) risk index¹⁸ for developing postoperative pulmonary complications (low risk if < 26 points, intermediate if > 26 points and < 45 points, high if > 45 points),

and preoperative pulmonary function tests. The pulmonary function tests included the value of FEV₁, FVC, and the total lung capacity. On the basis of pulmonary function tests,¹⁹ the subjects were divided into 3 classes: restrictive (total lung capacity < 80% of the predicted), obstructive (FEV₁/FVC < 70% of the predicted), and normal pattern. In addition, arterial pH, P_{aO₂}, and P_{aCO₂} before surgical procedure were also recorded.

Intraoperative parameters included the duration of surgery and blood product requirement (erythrocytes, fresh frozen plasma, and platelets). Ascites was defined as mild (<5 L) or moderate-severe (≥5 L) according to the volume drained during surgery. Postoperative variables included the following: Simplified Acute Physiology Score II, length of invasive mechanical ventilation before extubation, gas exchange values (arterial pH, P_{aO₂}, P_{aCO₂}), breathing frequency, and S_{PO₂} before extubation, at 1 h and at 24 h after extubation, chest radiograph evaluation (atelectasis, pleural effusion, interstitial and/or alveolar edema, and suspected pneumonia) before and after extubation.

Statistical Analysis

A review of data from our database over a 6-y period (2012–2017) revealed that ~ 50% of patients with liver transplantation developed hypoxemia at 1 h after extubation when treated with standard O₂ via an air-entrainment mask. A sample size of 25 for each group provided 80% power to detect a reduction of hypoxemia from 50% to 15% (alpha = 0.05). We did a 1:1 matching between the HFNC group and standard O₂ group according to age, liver dysfunction assessed by Model for End-Stage Liver Disease, severity of illness at ICU admission assessed by Simplified Acute Physiology Score II, and body mass index. Continuous data were expressed as mean ± SD. Categorical data were presented as number and percentage. Comparisons were made by using the Student *t* test and Fisher exact test, as appropriate. A *P* value of <.05 was considered statistically significant. Statistical analysis was performed by using MEDcalc version 18.6 (MedCalc Software, Mariakerke, Belgium).

Results

Baseline Characteristics

Between January 1 and September 1, 2018, 32 adult patients were admitted to the ICU after liver transplantation. Three patients were not included in the analysis because of acute liver failure (*n* = 1) and hemorrhagic diatheses (*n* = 2). The remaining 29 subjects had preventive HFNC oxygen therapy after extubation and were matched with 29 controls who were selected from an historical

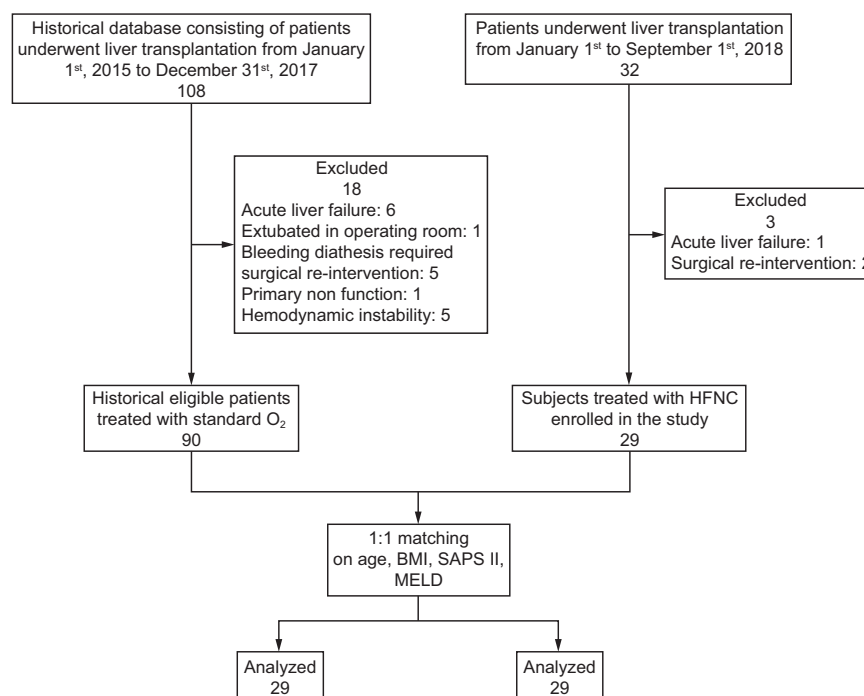
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Fig. 1. Flow chart. HFNC = high-flow nasal cannula; BMI = body mass index; SAPS II = Simplified Acute Physiology Score II; MELD = Model for End-Stage Liver Disease.

group of 90 patients treated with preventive standard O₂ via air-entrainment mask (Fig. 1).

Baseline characteristics of standard O₂ and HFNC groups are shown in Table 1. Both groups had comparable demographic characteristics; however the mean \pm SD P_aCO₂ was lower in the standard O₂ group compared with the HFNC group (32.36 ± 3.28 mm Hg and 36.00 ± 4.77 mm Hg, respectively, $P < .01$). The mean \pm SD volume of ascites drained during surgery was larger in standard O₂ group than in the HFNC group (4.64 ± 3.85 L vs 2.31 ± 3.19 L, $P < .01$, respectively). The duration of invasive mechanical ventilation before extubation as well as chest radiograph that documented pleural effusion were similar between both groups (Table 1). One subject in each group started continuous renal replacement therapy before liver transplantation for acute kidney injury.

Primary Outcome

No significant difference was observed between the standard O₂ group versus HFNC group for the incidence of hypoxemia at 1 h (48% vs 41%, $P = .59$) and 24 h (34% vs 45%, $P = .41$) after extubation. Furthermore, the mean \pm SD P_aO₂/F_{IO₂} during hypoxemic episodes was similar between both groups at 1 h (242.75 ± 39.69 mm Hg vs 263.20 ± 49.23 mm Hg), and at 24 h after extubation (243.23 ± 41.77 mm Hg vs 262.42 ± 39.47 mm Hg).

Secondary Outcomes

The mean \pm SD P_aCO₂ at 1 h after extubation was lower in the HFNC group compared with the standard O₂ group (36.6 ± 4.3 vs 39.0 ± 6.7 , $P = .04$), whereas no difference was observed at 24 h. We did not observe differences in the rate of weaning failure or ICU length of stay or 28-d mortality (Table 2).

Adverse Events

No subjects required HFNC therapy interruption due to intolerance, although 10% of the subjects requested air-flow reduction immediately after the beginning of HFNC due to dryness of nasal mucosa.

Discussion

In this observational matched controlled study, the preventive application of oxygen therapy with HFNC after extubation in the subjects with liver transplantation did not reduce the incidence of hypoxemia compared with standard O₂ via air-entrainment mask. Also, the preventive use of HFNC oxygen therapy did not decrease the rate of weaning failure, ICU length of stay, and 28-d mortality. Accordingly, these results implied that the use of preventive oxygen therapy by HFNC did not have a superior impact on arterial oxygenation or related respiratory out-

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Table 1. Baseline Characteristics of the Subjects

Parameter	Standard O ₂ Therapy (n = 29)	HFNC (n = 29)	P
Age, mean ± SD y*	59.03 ± 8.25	56.69 ± 7.67	.29
Males/females, n	26/3	24/5	.42
Body mass index, mean ± SD kg/m ² *	25.66 ± 3.28	26.50 ± 4.74	.43
MELD score at transplantation, mean ± SD	16.07 ± 6.19	16.59 ± 7.83	.80
SAPS II, mean ± SD*	39.93 ± 12.83	40.14 ± 12.48	.93
LVEF, mean ± SD %	63.63 ± 4.7	62.46 ± 3.34	.18
SPAP, mean ± SD mm Hg	30.90 ± 8.15	28.45 ± 4.62	.24
ARISCAT mild, n (%)	18 (62)	16 (55)	.83
ARISCAT high, n (%)	11 (38)	13 (45)	.81
Etiology liver failure, n (%)			
Viral hepatitis	14 (48)	11 (37)	.64
Alcoholic abuse	10 (34)	9 (31)	>.99
Cryptogenic	2 (7)	4 (24)	.67
HCC co-indication	3 (10)	5 (17)	.70
PFTs			
Obstructive pattern, n (%)	6 (21)	2 (7)	.26
Restricted pattern, n (%)	3 (10)	2 (7)	>.99
Normal pattern, n (%)	20 (69)	24 (82)	.69
pH, mean ± SD	7.43 ± 0.03	7.44 ± 0.03	.66
P _a O ₂ , mean ± SD mm Hg	88.89 ± 11.98	87.41 ± 14.22	.39
P _a CO ₂ , mean ± SD mm Hg	32.36 ± 3.28	36.00 ± 4.77	<.01
Ascites, mean ± SD L	4.64 ± 3.85	2.31 ± 3.19	<.01
Pre-extubation			
F _I O ₂ , mean ± SD %	39 ± 5	39 ± 5	.96
S _p O ₂ , mean ± SD %	98.00 ± 0.84	98.20 ± 0.77	.50
Duration of mechanical ventilation, h	24 (18–48)	30 (18–44)	.70

* Matching criteria.
 HFNC = high-flow nasal cannula
 MELD = Model for End-Stage Liver Disease
 SAPS II = Simplified Acute Physiology Score II
 LVEF = left-ventricular ejection fraction
 SPAP = systolic pulmonary arterial pressure
 ARISCAT = Assess Respiratory Risk in Surgical Patients in Catalonia
 HCC = hepatocellular carcinoma
 PFT = pulmonary function test (parameter assessed during surgery)

comes compared with standard O₂. However, HFNC did not increase the risk of postoperative pulmonary complications and was associated with a trend toward reduced weaning failure.

Patients who are admitted to the ICU after liver transplantation are at increased risk of hypoxemia and postoperative pulmonary complications for several reasons.²⁰ The transplantation procedure itself causes bilateral transection of the abdominal muscles and chest-wall damage due to retractor use, which amplifies diaphragmatic impairment.^{20–25} Furthermore, these patients present with many concomitant morbidities, such as poor muscle mass, sarcopenia, hypoalbuminemia, and restrictive lung volumes due to ascites and pleural effusion. They also have to endure the effects of an extremely invasive surgery that may prolong the duration of mechanical ventilation, which increases the incidence of hypoxemia and the re-intubation rate after extubation. Although not supported by our find-

ings, the application of increased flows by HFNC has been shown to progressively reduce inspiratory effort and improve lung aeration, dynamic compliance, and oxygenation in patients who are critically ill with acute hypoxemic respiratory failure.²⁶ HFNC oxygen therapy has been widely used for patients of all age groups with respiratory failure of several etiologies, including preterm infants and adult medical and surgical patients who are critically ill. Unique features of HFNC lie in its simplicity of use and its remarkable tolerance and comfort.

To date, few studies have evaluated preventive HFNC application after extubation in abdominal surgery in heterogeneous populations.^{14,15} Overall, abdominal surgery can lead to postoperative pulmonary complications by altering diaphragmatic function and contractility, which causes reduced lung volumes and flows, which predisposes to lower-lobe atelectasis.^{1–4,27} Among the surgical population, the role of HFNC in preventing deterioration

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Table 2. Respiratory Variables and Secondary Outcomes

Parameter	Standard O ₂ Therapy (n = 29)	HFNC (n = 29)	P
1 h after extubation			
Incidence of hypoxemia, n (%)	14 (48)	12 (41)	.59
pH, mean ± SD	7.49 ± 0.04	7.50 ± 0.04	.37
P _{aO₂} /F _{IO₂} , mean ± SD	307.96 ± 77.26	327.13 ± 81.77	.37
P _{aCO₂} , mean ± SD mm Hg	39.01 ± 6.67	36.66 ± 4.26	.04
Frequency, mean ± SD breaths/min	22.20 ± 5.8	18.40 ± 3.84	.25
24 h after extubation			
Incidence of hypoxemia, n (%)	10 (34)	13 (45)	.41
pH, mean ± SD	7.50 ± 0.03	7.49 ± 0.05	.26
P _{aO₂} /F _{IO₂} , mean ± SD	355.50 ± 114.40	327.81 ± 85.95	.40
P _{aCO₂} , mean ± SD mm Hg	38.50 ± 4.82	38.85 ± 5.33	.97
Frequency, mean ± SD breaths/min	20.20 ± 4.56	18.54 ± 4.35	.26
Secondary outcomes in the ICU			
Weaning failure, n (%)	10 (34)	3 (10)	.06
ICU length of stay, median (IQR), d	6 (5–8)	6 (5–11)	.36
28-d mortality, n (%)	3 (10)	2 (7)	>.99

NIV = noninvasive ventilation

in pulmonary function after surgery is poorly defined. In cardiac surgery, results of studies demonstrated that prophylactic HFNC postextubation did not lead to improvements in pulmonary function or postoperative oxygenation in subjects with a body mass index ≥ 30 kg/m².^{28,29} Conversely, in patients who underwent thoracoscopic lobectomy, oxygen therapy by HFNC improved oxygenation and reduced the risk of re-intubation, although it did not decrease the incidence of postoperative pulmonary complications.³⁰

Our results concurred with a multicenter randomized control trial in which Futier et al¹⁴ found nonsuperiority of HFNC compared with standard O₂ to prevent respiratory deterioration (incidence of hypoxemia, postoperative pulmonary complications, and length of hospital stay) after extubation in major elective abdominal surgery. However, Dhillon et al¹⁵ showed that HFNC was associated with a lower risk of re-intubation compared with conventional oxygen therapy, although interpretation of these results is limited by the retrospective nature of the study.

According to Futier et al,¹⁴ HFNC application did not reduce the risk of pneumonia compared with standard O₂. This finding is contrary to physiologic evidence that demonstrates the role of high-flow humidified oxygen to improve mucociliary function, secretion mobilization, and lung recruitment by PEEP.³¹ However, lung de-recruitment and atelectasis after extubation following general anesthesia may persist more than 24 h and is worsened by the negative effect of muscular paralysis on respiratory mechanics, patient inspiratory effort, and gas exchange.^{23,32,33}

More recently, Azoulay et al³⁴ randomized 776 immunocompromised and critically ill subjects with hypoxemic acute respiratory failure, to receive standard oxygen therapy or HFNC. The primary outcome of the study was 28-d mortality, and secondary outcomes were intubation and mechanical ventilation by day 28, P_{aO₂}/F_{IO₂} over 3 d after intubation, breathing frequency, ICU, and hospital length of stay, ICU-acquired infections, patient comfort, and dyspnea.³⁴ The investigators found no significant reduction in 28-d mortality by using HFNC compared with standard oxygen therapy.³⁴ In accordance with the clinical trial by Azoulay³⁴ (with 19 subjects with liver transplantation), we also found no significant difference for the 28-d mortality or ICU length of stay when comparing these modalities.

In a recent prospective randomized crossover study, Mauri et al²⁶ assessed the effect of HFNC delivered at increasing flow on inspiratory effort and the work of breathing in subjects with acute hypoxemic respiratory failure. In this cohort, the investigators demonstrated that increasing HFNC flows progressively decreased inspiratory effort and improved lung aeration and dynamic compliance.²⁶ Furthermore, the results of this study showed that the effect on inspiratory work load and CO₂ clearance was already obtained at the lowest flow.²⁶ In our trial, we observed a significantly lower P_{aCO₂} 1 h after extubation in the HFNC group. In fact, the literature reports reduced anatomic dead space due to increased nasopharyngeal washout, with a consequently larger fraction of minute ventilation participating in gas exchange.³⁵ Frequently, candidates for liver transplantation display a restricted respiratory pattern related to the size of the ascites and/or pleural effusion.³⁶ In

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fact, in our population, we detected a significantly low preoperative P_aCO₂, especially those in the standard O₂ group who had more ascites. This condition was solved by the liver transplantation.³⁷

To the best of our knowledge, this was the first clinical study that explored the usefulness of the preventive application of HFNC after elective extubation in subjects who were undergoing liver transplantation. Another strength of our study was the selection of a specific patient population at increased risk for postoperative pulmonary complications demonstrated by the moderately high ARISCAT index. These issues led to the wide spread application of HFNC in these patients at high risk. Furthermore, the use of a high-flow system was economical because it was integrated into the ICU ventilator, therefore, no new equipment charge was applied. This finding was contrary to the results of Mayordomo-Colunga and Medina,³⁸ who evaluated clinical and cost-effectiveness of HFNC compared with noninvasive ventilation. The investigators concluded that the cost of acquiring HFNC equipment is not currently justified, because HFNC is not superior to noninvasive ventilation in many clinical scenarios, and most pediatric and adult ICUs already have noninvasive ventilation devices.

Study Limitations

We acknowledge that this study had some limitations. First, this was not a randomized control trial. Second, this study was conducted in a single center with a relatively small sample size. Third, the aim of study was to evaluate HFNC efficacy compared with standard O₂, without analyzing modifications in respiratory mechanics during the utilization of different oxygenation techniques. Fourth, we did not measure actual delivered F_{IO₂} with either the HFNC or air-entrainment mask because this would have required invasive maneuvers, such as the insertion of a nasopharyngeal catheter.³⁹ These maneuvers could decrease patient comfort, which thus affected our results.

Conclusions

Preventive application of HFNC after extubation in subjects with liver transplantation did not reduce the incidence of hypoxemia in comparison with standard O₂ via an air-entrainment mask. Moreover, among this high-risk population of subjects who were immunocompromised, HFNC did not reduce weaning failure, ICU length of stay, or 28-d mortality compared with standard O₂. Further studies are needed to identify the subset of patients with liver transplantation who are the best candidates to benefit from HFNC.

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