RESEARCH ARTICLE

High-flow nasal cannula therapy for patients with blunt thoracic injury: A retrospective study

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OBJECTIVE: High-flow nasal cannula (HFNC) has been shown to reduce the need for mechanical ventilation (MV) and to decrease hospital and ICU days for patients with severe respiratory compromise. HFNC has not been evaluated in trauma patients, thus the goal of this study is to describe the use of HFNC in a chest-injured population.

METHODS: A retrospective study examined trauma patients with moderate to severe thoracic injury admitted to the ICU at a tertiary hospital between March 2012 and August 2015. HFNC was delivered by the Fisher & Paykel Optiflow system. Primary outcomes were the need for intubation after HFNC for respiratory failure, length of hospitalization, and mortality.

RESULTS: During the study period, 105 patients with blunt chest trauma were admitted to the ICU and received HFNC therapy. Eighteen percent received MV prior to HFNC. Overall, 69% of patients who received HFNC never received MV, and 92% of patients were discharged alive. The intubation rate for respiratory failure after HFNC was 18%. For patients who did not receive MV prior to HFNC, delay to first HFNC was correlated with increased hospital days (r_s = 0.41, p = 0.001) and ICU days (r_s = 0.41, p < 0.001).

CONCLUSIONS: Study results suggest that HFNC is comparable with other methods of noninvasive ventilation and may be beneficial for patients with thoracic injury. Additional investigation is warranted to determine if early use of HFNC can deliver effective respiratory support and prevent intubation in this population.

Key Words: *high-flow nasal cannula; respiratory failure; mechanical ventilation; blunt chest trauma; Optiflow*

INTRODUCTION

Humidified, high-flow nasal cannula (HFNC) is a technique of respiratory support that allows for oxygen to be heated to body temperature, saturated with water, and delivered at high flow rates [1–14]. Many benefits have been noted in post-surgical adult populations and patients with severe respiratory compromise, including improved mucociliary clearance, better ventilation–perfusion ratios, increased oxygenation, reduced work of breathing and inspiratory effort, increased end-expiratory lung volume, and lowered respiratory and heart rates [1–3, 5, 9–13, 15–18]. Notably, HFNC has the additional benefit of increased patient comfort and reduced mucosal injury [2, 9, 11–14, 17, 19–20]. Unlike non-invasive ventilation (NIV), it does not impede mobility, oral intake, or speaking [21, 22].

HFNC studies have also found that the therapy can decrease hospital and intensive care unit (ICU) days and prevent the need for invasive mechanical ventilation (MV) [11, 19, 23–25]. The efficacy of HFNC therapy has been established in post-surgical adult populations and patients with severe respiratory compromise [10, 11, 15, 16, 23, 25], but there are no studies that examine the safety and efficacy of HFNC in a population comprised solely of blunt chest-trauma patients. In the only known HFNC study to include trauma patients, delay to first use of HFNC was associated with increased ICU days and post-ICU days in a mixed medical and trauma population, even after controlling for MV and unplanned intubation [23]. It is possible that many of the HFNC benefits demonstrated in other clinical populations may be present in the trauma population, but this has not been evaluated. The purpose of this retrospective study is to describe the use of HFNC in a population of patients with blunt thoracic injury to examine if HFNC was associated with positive patient outcomes such as reduced rates of intubation and decreased hospital days.

METHODS

Study design

A retrospective study was conducted at a tertiary hospital with a mixed medical and surgical adult ICU. The hospital is verified by the American College of Surgeons as a Level I Adult Trauma Center. The trauma registry was used to identify patients with moderate to severe blunt thoracic injury (Abbreviated Injury Scale (AIS) chest score ≥3) admitted to the ICU between March 2012 and August 2015 (n = 358), and 105 patients (29%) received HFNC during their stay. At the time of the study, HFNC was not specified in a respiratory protocol; the decision to initiate HFNC was made at the discretion of the trauma surgeon and respiratory therapist when supplemental oxygen delivery was required. HFNC was delivered by the Optiflow system (Fisher & Paykel Healthcare, Auckland, New Zealand). At the study hospital, initial settings are routinely set at 50 L/min and 50% F_{IO2}, and the device is titrated by respiratory therapists.

Chart review of the electronic medical record was conducted for data not included in the trauma registry, and inter-rater reliability was assessed for 10% of the records to ensure consistency in data abstraction. The study was approved by the institutional review board at the hospital. The requirement of patient consent was waived because chart review occurred retrospectively after patient discharge. No funding or support was received from the manufacturer to conduct this study.

Study variables

Demographic and injury variables included patient sex, age, body mass index (BMI), and mechanism of injury. Patients were considered do-not-resuscitate (DNR) if they had a DNR or a do-not-intubate (DNI) order at any time during the hospital stay. Admitting diagnoses were abstracted from ICD-9-CM codes in the trauma registry for the following thoracic injuries: three or more rib fractures (807.0–807.2), flail chest

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(807.4), pneumothorax (860.0–860.1), hemothorax (860.2–860.3), pneumohemothorax (860.4–860.5), and pulmonary contusion (861.2, 861.3). Acuity was represented by the Injury Severity Score (ISS), which is an anatomical coding system ranging from 0 (no injury) to 75 (most severe). ISS is derived from the AIS, with all diagnoses coded to AIS-1998 values. Comorbidities included smoking history (current or former), Chronic Obstructive Pulmonary Disease, and asthma. Delay to HFNC is the length of time between ICU admission and initiation of HFNC, presented in days to assist in interpretation. Duration of initial HFNC therapy is presented in hours.

Patient outcomes included hospital days, ICU days, and post-ICU days. Discharge disposition was reported for patients without mortality and included home (with or without home health services) or facility (skilled nursing or inpatient rehabilitation). Finally, it is consistent with the literature to define HFNC failure as the need for invasive MV (intubation) after HFNC for respiratory failure [6, 19, 24]. If a subject received MV after HFNC, arterial blood gas (ABG) analysis values (pH level, P_{O2}, P_{CO2}, bicarbonate (HCO_3), and arterial oxygen saturation (SaO_2)) were abstracted from the period 24 h prior to intubation to determine the type of respiratory failure. In cases where an ABG was not drawn prior to intubation due to rapid clinical deterioration, we used the physician bedside assessment of reason for intubation. Subjects were categorized as having hypoxemic respiratory failure if $P_{O2} < 60$ mmHg or hypercarbic respiratory failure with or without hypoxemia if $P_{CO2} \geq 50$ mmHg [26]. If a patient was intubated for a change in mental status or an operative procedure and did not have hypoxemic or hypercarbic respiratory failure, the patient was excluded from the HFNC failure rate.

Statistical procedures

Analyses were performed with IBM SPSS Basic Statistics for Windows, version 20.0 (IBM Corp, Armonk, New York, 2011). Categorical data are reported as counts and percentages. Distributions of continuous data were examined using the Komogorov–Smirnov test; because some variables were not normally distributed, all continuous data are reported as medians and interquartile ranges (IQR). Correlations were computed as Spearman rho (r_s) or Biserial (r_b) coefficients. All statistical tests were two-tailed and based on a 0.05 significance level.

TABLE 1

Demographics and injury characteristics of sample

Demographic or characteristic	All trauma patients (*n* = 105)
Male, *n* (%)	71 (68)
Age in years, median (IQR)	63 (53–76)
Body mass index, median (IQR)	30.5 (25.0–35.4)
Do-not-resuscitate order at any time during hospital stay, *n* (%)	17 (16)
Mechanism of injury, *n* (%)	
Motor vehicle collision	54 (51)
Fall	44 (42)
Other	7 (7)
Injuries (not mutually exclusive), *n* (%)	
Rib fractures	92 (88)
Pulmonary contusion	36 (34)
Pneumothorax	29 (28)
Flail chest	10 (10)
Hemothorax	9 (9)
Pneumohemothorax	6 (6)
Injury Severity Score, median (IQR)	21 (14–26)
Comorbidities	
Former smoker, *n* (%)	31 (30)
Current smoker, *n* (%)	26 (25)
Chronic Obstructive Pulmonary Disease, *n* (%)	14 (13)
Asthma, *n* (%)	8 (8)

IQR, interquartile range.

RESULTS

The study sample included 105 patients with blunt thoracic injury, and demographic characteristics of the sample are presented in Table 1. The majority of patients were male (68%), with a median age of 63 years (IQR: 53, 76) and median BMI of 30.5 (IQR: 25.0, 35.4). Patients had a median ISS of 21, indicating a severe level of injury. Eighty-eight percent of patients had three or more rib fractures, 34% had a pulmonary contusion, and 28% sustained a pneumothorax. More than half the patients were current or former smokers.

Timing and duration of HFNC

Figure 1 illustrates the timing of HFNC and MV for all patients in the study. Overall, 69% of patients in the study were never intubated. Nineteen patients (18%) were intubated prior to HFNC; 5 of the 19 patients (26%) who were extubated to HFNC required reintubation for respiratory failure. Conversely, 86 patients (82%) did not receive invasive MV prior to HFNC.

On average, HFNC was started 6 h and 40 min after ICU admission (IQR: 0:1:40, 1:00:20), with a median therapy duration of 30 h (IQR: 0:14:15, 2:04:19). However, time to HFNC was related to whether the patient received MV before HFNC. Patients who were not intubated prior to HFNC started the therapy approximately 3 h after admission to the ICU, and the average duration of therapy was 30 h. Delay to first HFNC was associated with increased hospital ($r_s = 0.41$, $p = 0.001$) and ICU days ($r_s = 0.41$, $p < 0.001$). Patients who were extubated to HFNC started therapy 120 h (5 days) after admission to the ICU and average duration of therapy was 26 h. Neither the delay to HFNC initiation nor the duration of therapy was correlated with any demographics or injury characteristics in this population.

HFNC outcomes

The median hospital stay for all patients was 12 days, with a median stay of 5 days in the ICU (see Table 2). There was a strong correlation between receiving MV during the ICU stay and hospital ($r_b = 0.53$, $p < 0.001$) and ICU ($r_b = 0.56$, $p < 0.001$) days. Eight percent of patients died in the hospital; none of the deaths were related to use of HFNC and 75% of these patients were DNR or received comfort care. For patients who were discharged alive, 41% returned home after hospitalization and 59% discharged to a skilled-nursing or inpatient rehabilitation facility.

FIGURE 1

Patient flow chart for timing of high-flow nasal cannula (HFNC)

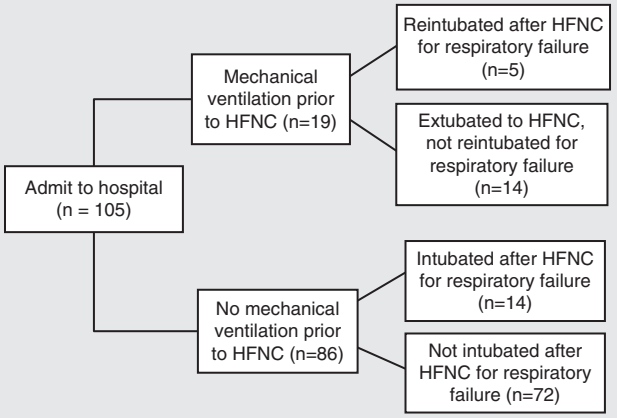

TABLE 2

Outcomes of study sample (*n* = 105)

Outcome	All trauma patients
Hospital days, median (IQR)	12 (8–18)
ICU days, median (IQR)	5 (3–11)
Post-ICU days, median (IQR)	5 (3–8)
Mortality, *n* (%)	8 (8)
High-flow nasal cannula failure, *n* (%)	19 (18)
Discharge home, *n* (%)[a]	40 (41)
Discharged to skilled nursing or rehabilitation facility, *n* (%)[a]	57 (59)

[a]*Excludes deceased patients.*

IQR, interquartile range; ICU, intensive care unit.

HFNC failure was defined as receiving MV (intubation) after HFNC for hypoxemic or hypercarbic respiratory failure, and 19 patients (18%) met that criterion. Failure was not statistically related to any pattern of injuries but was associated with increased hospital days (r_b = 0.40, p = 0.001) and ICU days (r_b = 0.54, p < 0.001). In Table 3, we report the values from ABG analyses for subjects who were intubated after HFNC. Nine of 19 subjects (47%) failed HFNC due to hypoxemic respiratory failure. Conversely, 12 of 19 subjects (63%) failed HFNC due to hypercarbic respiratory failure. In the latter group, there was an associated respiratory acidemia (median pH of 7.27; normal: 7.35–7.45), as well as higher P_{CO2} and lower P_{O2} than the hypoxemic subjects.

DISCUSSION

This is the first known study to describe the use of HFNC therapy in a population comprised solely of blunt thoracic injury patients. In this high acuity sample of trauma patients with moderate to severe thoracic injury, more than two-thirds of patients never received invasive MV and 18% were intubated after HFNC for respiratory failure. Outcomes are similar to rates reported in the trauma literature for MV after NIV, which typically range from 12 to 18% [27–29]. Clinical outcomes are comparable; however, there are also indirect and unmeasured benefits to patients. HFNC does not impede mobility, oral intake, or speaking, which all improve patient outcomes [21, 22]. The findings suggest that use of HFNC may be a suitable respiratory treatment to provide optimal oxygen support to blunt thoracic trauma patients.

HFNC failure has been defined in the literature as the need for MV (intubation) after HFNC therapy [3, 6, 25]. However, we question if HFNC should be considered ineffective if patients require intubation for hypercarbia. The primary indication for HFNC is hypoxemic respiratory failure [13, 19], with a secondary purpose to improve alveolar ventilation by decreasing the work of breathing and flushing the anatomical dead-space, thereby improving hypercarbia [2, 7, 14]. Early HFNC studies did not support the modality for improving carbon dioxide (CO_2) retention [16], but some work supports use of the modality for this purpose [7, 30, 31]. Our results suggest that HFNC may be efficacious in supporting patients with hypoxemic respiratory failure but less effective for patients with hypercarbic respiratory failure.

TABLE 3

Arterial blood gas values after high-flow nasal cannula and prior to mechanical ventilation (*n* = 19)

	Hypoxemic respiratory failure	Hypercarbic respiratory failure
pH level (median IQR)	7.40 (7.34, 7.43)	7.27 (7.24, 7.31)
P_{CO2}, (median IQR)	37 (36, 48)	57 (53, 65)
P_{O2}, (median IQR)	62 (53, 79)	84 (75, 100)
Bicarbonate (median IQR)	23.6 (20.5, 26.0)	26.4 (22.0, 31.7)
Arterial oxygen saturation (median IQR)	91.9 (86.14, 94.7)	93.9 (91.0, 97.3)

IQR, interquartile range

The mortality rate of the sample was 8% and there were no cases where HFNC caused harm or delayed definitive care. The literature notes that blunt chest trauma patients have a mortality rate between 3 and 9% when receiving conventional NIV [26, 27], thus results from the study are within this range. It is noteworthy that 16% of patients were DNR/DNI at some point during the hospital stay, and three-quarters of patients who died were DNR/DNI or received comfort care. HFNC is a potential method of oxygenation for palliative patients because it is more comfortable and better tolerated than other NIV methods and does not inhibit speaking or oral intake [21, 22]. HFNC may provide a method of oxygen support for patients who wish to avoid invasive measures, and further examination is warranted to determine the utility of HFNC in these phases of care.

Study findings indicate a moderate relationship between delay to first HFNC and total length of the hospital stay (r_s = 0.36, p = 0.001) for patients who did not receive MV prior to HFNC. It may benefit patients with thoracic injury to start HFNC immediately after ICU admission, and efforts are in place to make that the standard of care at the study hospital.

An additional reason to start HFNC as early as possible is because patient improvement has been found to progress rapidly after HFNC initiation. Sztrymf et al. [25] found that patients with acute respiratory failure noted improvement within 1 h of therapy initiation, and Vargas et al. [32] noted that short-term HFNC use had positive effects on respiratory effort and oxygenation. Although patients in these two studies were not trauma patients, the physiologic effect of HFNC was evident soon after starting the therapy and may work similarly in a trauma population.

Limitations

This is a retrospective study to describe the efficacy of HFNC in a trauma population, thus the study has several limitations. First, this study was performed at a single trauma center and results may not be generalizable to other settings. In addition, the study is retrospective and does not include a comparator group of patients that did not receive HFNC. Because use of HFNC was not part of standard protocol at our hospital, it was difficult to retrospectively identify a comparable patient population with equivalent acuity. Future work should be conducted prospectively and in collaboration with other hospitals to further evaluate the utility of HFNC in the chest trauma population. Second, 18 patients in this study received Bilevel Positive Airway Pressure (BiPAP) immediately before or after HFNC, and 6 of these patients oscillated between the two therapies (daytime or nighttime). We have not included data on NIV in this manuscript because it was not part of the original study design or data abstraction; however, in the future it would be important to identify the temporal order of NIV and HFNC therapies to determine how HFNC can best be utilized.

Third, at the time of the study there was no respiratory protocol for the initiation or titration of HFNC therapy; there may be physician and therapist biases in which patients were selected to receive HFNC and the settings that were used during therapy. Because there is historically no work on HFNC in a trauma population, this retrospective study is a first step in directing future research and building protocols suitable for trauma patients with chest injury.

Finally, HFNC was only available in the ICU at the study hospital and not on general inpatient floors. Some patients may have avoided an ICU admission if HFNC was available outside the ICU. Researchers at the study hospital are currently evaluating the feasibility of implementing HFNC on general inpatient floors at the institution, which would allow more patients to benefit from HFNC therapy without admission to the ICU.

In conclusion, this retrospective examination is the first to suggest that HFNC may be considered as an initial respiratory therapy for trauma patients with blunt chest injury. HFNC was well-tolerated and provided adequate oxygen support for patients with moderate to severe blunt chest injury.

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