

A Survey of Mechanical Ventilator Practices Across Burn Centers in North America

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Burn injury introduces unique clinical challenges that make it difficult to extrapolate mechanical ventilator (MV) practices designed for the management of general critical care patients to the burn population. We hypothesize that no consensus exists among North American burn centers with regard to optimal ventilator practices. The purpose of this study is to examine various MV practice patterns in the burn population and to identify potential opportunities for future research. A researcher designed, 24-item survey was sent electronically to 129 burn centers. The χ^2 , Fisher's exact, and Cochran–Mantel–Haenszel tests were used to determine if there were significant differences in practice patterns. We analyzed 46 questionnaires for a 36% response rate. More than 95% of the burn centers reported greater than 100 annual admissions. Pressure support and volume assist control were the most common initial MV modes used with or without inhalation injury. In the setting of Berlin defined mild acute respiratory distress syndrome (ARDS), ARDSNet protocol and optimal positive end-expiratory pressure were the top ventilator choices, along with fluid restriction/diuresis as a nonventilator adjunct. For severe ARDS, airway pressure release ventilation and neuromuscular blockade were the most popular. The most frequently reported time frame for mechanical ventilation before tracheostomy was 2 weeks (25 of 45, 55%); however, all respondents reported in the affirmative that there are certain clinical situations where early tracheostomy is warranted. Wide variations in clinical practice exist among North American burn centers. No single ventilator mode or adjunct prevails in the management of burn patients regardless of pulmonary insult. Movement toward American Burn Association–supported, multicenter studies to determine best practices and guidelines for ventilator management in burn patients is prudent in light of these findings. (J Burn Care Res 2016;37:e131–e139)

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An estimated 33% of burn patients require mechanical ventilation, a rate that increases considerably in the setting of inhalation injury.¹ Recent data demonstrate that concomitant inhalation injury increases the likelihood of death 16-fold after sustaining a burn injury.² In the general intensive care setting, low tidal volumes (LTV) and limitation of plateau pressure are the cornerstones of currently accepted lung protective ventilation strategy during the mechanical ventilation of critically injured patients both with and without acute respiratory distress syndrome (ARDS).^{3,4} Similarly, in this population, recruitment maneuvers and high positive end-expiratory pressure (PEEP) are recommended modalities in the management of severe ARDS.⁵ However, burn patients and patients with inhalation injury were not included in the studies that led to the widespread adoption of these well-entrenched mechanical ventilation strategies. In addition, clinical characteristics and processes unique to the thermally

injured patient, such as the loss of chest wall compliance from abdominal and thoracic eschar, chest wall edema, the unique pathophysiology of inhalation injury, and the hypermetabolic response to burn injuries, could potentially affect the applicability of these mechanical ventilation approaches to the burn population. It is not known if these mechanical ventilation strategies have been uniformly translated to the burn population, and ultimately, whether or not they are suitable in this population.⁶⁻⁸

We hypothesize that variability in mechanical ventilation practices exists among North American burn centers. The objective of this exploratory survey is to examine mechanical ventilator (MV) practices in burn centers in North America. The secondary aims of this study are to contribute to existing knowledge of MV practices in the burn population and to identify potential commonalities and disparities in practice that can be used to inform future research studies.

METHODS

An institutional review board approved, online survey (Survey Monkey; Palo Alto, CA) was disseminated to the directors and nurse managers of 129 burn centers in the United States and Canada via the American Burn Association. It was available from February 5 to September 19, 2014 (287 days) and consisted of 24 questions relating to ventilator modes and associated practices falling under three main headings: initial ventilator practices, ARDS management, and artificial airway. Eleven questions allowed respondents to select more than one choice, so totals may add up to more than 100%. Initial emails were sent with a link to the survey; four reminder emails were sent intermittently throughout the timeline. From the total responses, we excluded ones that were less than 75% completed or were found to be duplicates from the same facility. The latter was verified by cross-referencing Internet Protocol addresses with identified burn centers. Descriptive and summary statistics were calculated for all variables. The categorical data were exported to STATA (College Station, TX) then analyzed via χ^2 tests to determine if there were any significant differences among the survey answers. Fisher's exact tests were used in categories with low cell counts ($n < 5$). Cochran-Mantel-Haenszel tests were performed to identify any difference in reference to inhalation injury (yes/no) or ARDS (mild vs severe) overall. All determinations of statistical significance were based on two-tailed tests using a P value less than .05.

RESULTS

From the 129 centers queried, a total of 74 centers participated. From the 74 surveys that were collected, we excluded 28 surveys because of missing data or found to have identical Internet Protocol addresses, yielding a total of 46 (36%) responses used in the data analysis (Figure 1).

Description of the Sample

The final sample of respondents were predominantly burn center directors and/or burn surgeons 72% ($n = 33$ of 46). The remaining identified themselves as four nurse managers, one associate medical director, one trauma critical care director, one burn clinician, one critical care physician, one administrative director, two respiratory therapists, one pulmonary critical care specialist, and one clinical nurse specialist.

Among the burn centers sampled, more than 95% ($n = 44$ of 46) reported having greater than 100 annual admissions, with 48% ($n = 22$ of 46) reporting more than 300 annual admissions. Of centers surveyed, 72% ($n = 33$ of 46) treat adult and pediatric patients, whereas 9% ($n = 4$ of 46) treat only pediatric patients and 19% ($n = 9$ of 46) treat only adults.

Initial Ventilator Practices

Pressure support ventilation (PSV) and volume assist control (VAC) were the most commonly reported initial ventilator modes used in patients with or without inhalation injury (Figure 2). Overall, initial MV mode selection was statistically significant when comparing patients with and without inhalation injury ($P < .0001$). No statistically significant differences within PSV or VAC modes were noted when comparing presentations with and without inhalation injury.

Open-lung techniques of mechanical ventilation (high-frequency percussive ventilation [HFPV], high-frequency oscillatory ventilation [HFOV], and airway pressure release ventilation [APRV]) were the three most common initial ventilator modes used in the absence of inhalation injury in 24% of responses ($n = 11$ of 46); increasing to 53% with a diagnosis of inhalation injury ($n = 24$ of 46). When queried for modes of initial ventilator management not listed in the survey, pressure-regulated volume control was reported most frequently ($n = 3$).

The majority of respondents (74%; $n = 34$ of 46) also reported routine use of a ventilator management protocol. A total of 71% ($n = 32$ of 45) of respondents reported that both ventilator management protocols and MV management were directed by respiratory therapists.

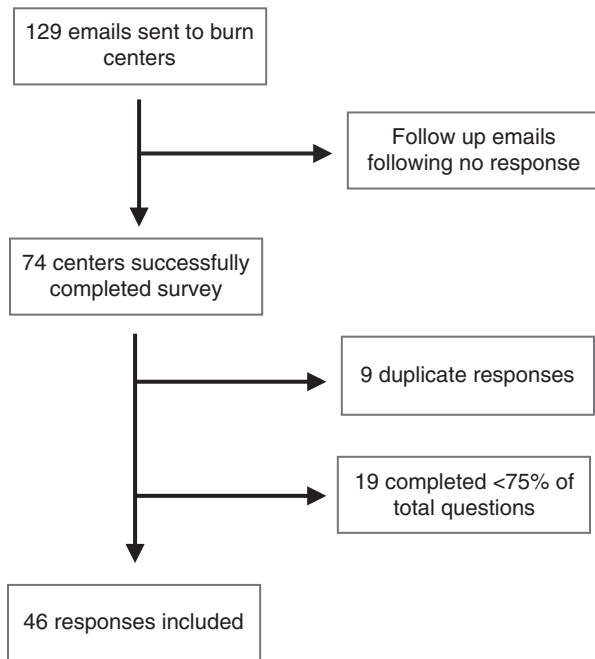


Figure 1. Study profile of survey distributed among North American burn centers.

Practice of routine sedation holidays for all MV patients was reported by 72% (n = 33 of 46) of burn centers.

Management of ARDS

Statistically significant differences in practice around initial ventilator modes employed for Berlin defined mild and severe ARDS were noted ($P = .0048$).⁹ The most commonly reported initial ventilator management strategies for mild ARDS were ARDSNet protocol based ventilator intervention and optimal

PEEP (Figure 3). In the presence of severe ARDS, respondents most commonly employed APRV (28%; n = 12 of 44) or ARDSNet protocol based ventilator management (26%; n = 11 of 44; Table 1).

Nonventilator interventions showed statistically significant differences between the two severity classes of ARDS ($P < .0001$). For mild ARDS, the most common nonventilator adjuncts used (in descending order) were fluid restriction/diuresis, various adjuncts not explicitly listed in the survey, enteral nutrition formulae designed for ARDS, and neuromuscular blockade (NMB), where severe ARDS was present; NMB was the most common nonventilator management technique followed by fluid restriction/diuresis (Figure 4). Comparing nonventilator adjunct use in mild vs severe ARDS, considerable variability was seen with the use of NMB (20% vs 58%; $P < .0001$), prone positioning (9% vs 33%; $P = .009$), and extracorporeal membrane oxygenation (2% vs 18%; $P = .03$; Table 1).

Artificial Airway Management

The most common endotracheal tube (ETT) care hygiene practiced was regular oral hygiene with chlorhexidine wash (78%; n = 36 of 46; Figure 5).

Greater than half of respondents cited securing the ETT with a linen nonadhesive tape (59%; n = 27 of 46), followed by a manufactured device (48% n = 22 of 46) and orthodontic technique attached to the teeth (24%, n = 11 of 46).

When queried about criteria used for extubation, ETT cuff leak test (84%; n = 39 of 46) and rapid shallow breathing index (80%; n = 37 of 46) were the two most common criteria cited (Figure 6).

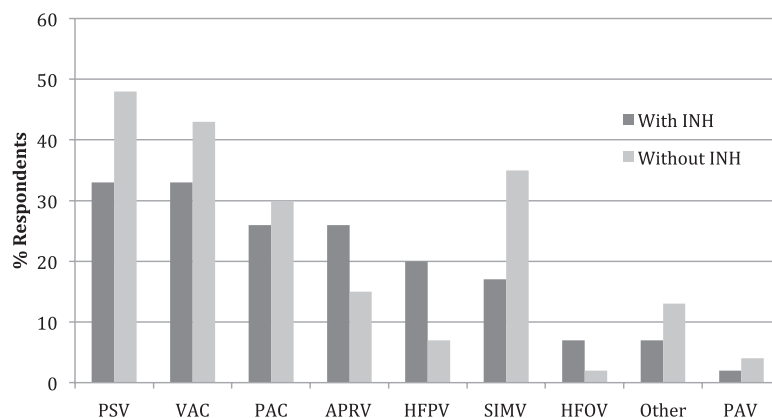


Figure 2. Initial mechanical ventilator modes used in respect to inhalation injury. PSV, pressure support ventilation; VAC, volume assist control; PAC, pressure assist control; APRV, airway pressure release ventilation; HFPV, high-frequency percussive ventilation; SIMV, synchronized intermittent mandatory ventilation; HFOV, high-frequency oscillatory ventilation; PAV, proportional assist ventilation; INH, inhalation injury.

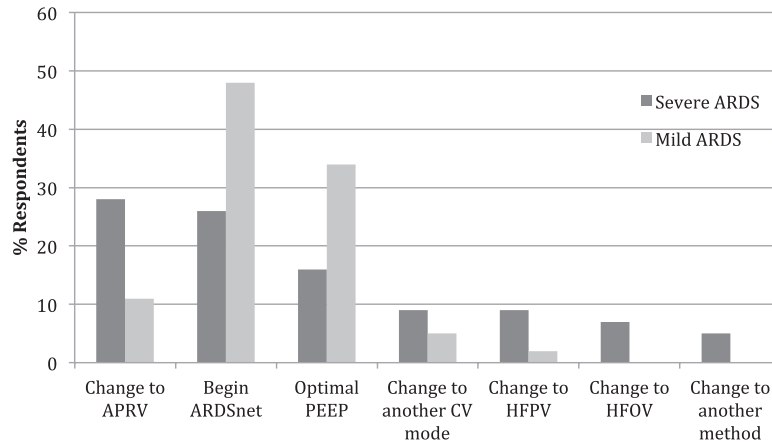


Figure 3. Mechanical ventilator methods used in ARDS. ARDS, acute respiratory distress syndrome; APRV, airway pressure release ventilation; PEEP, positive end expiratory pressure; CV, conventional ventilation; HFPV, high-frequency percussive ventilation; HFOV, high-frequency oscillatory ventilation.

The most common time frame considered for a tracheostomy was after 2 weeks of mechanical ventilation (67%; $n = 30$ of 45; Figure 7). Other factors listed as possible indicators for tracheostomy exclusive of time of MV included %TBSA, involvement of face and neck, number of previous extubation attempts, and fluid resuscitation status. However, there was a consensus of early tracheostomies in specific clinical situations, such as severe traumatic brain injury and predicted prolonged MV requirements ($n = 46$ of 46). Approximately 90% ($n = 41$ of 46)

of sites stated that burn surgeons were consulted for tracheostomy placement, with 78% ($n = 36$ of 46) performing the procedure in the operating room rather than at the bedside.

DISCUSSION

This exploratory cross-sectional survey evaluating the various MV interventions in North American burn centers shows a wide variation in clinical practice but illuminates common themes with respect to

Table 1. Interventions for Berlin Defined ARDS

Question	For Berlin Defined Mild ARDS n (%)	For Berlin Defined Severe ARDS n (%)	P
Initial MV management	N = 44	N = 44	
Change to APRV	5 (11)	12 (28)	0.10
Begin protocol based on ARDSNet	21 (48)	11 (26)	0.027
Use optimal PEEP	15 (34)	7 (16)	0.049
Change to another mode of CV	2 (5)	4 (10)	0.68
Change to HFPV	1 (2)	4 (9)	0.36
Change to HFOV	0 (0)	3 (7)	0.24
Change to another mode not listed	0 (0)	2 (5)	0.50
Nonventilator adjuncts	N = 45	N = 45	
Neuromuscular blockade	9 (20)	26 (58)	<0.0001
Fluid restriction/diuresis	21 (47)	21 (47)	1.0
Prone positioning	4 (9)	15 (33)	0.0090
Enteral nutrition formula	11 (24)	13 (29)	0.63
Inhaled NO	3 (7)	10 (22)	0.069
ECMO	1 (2)	8 (18)	0.030
None listed	17 (38)	7 (16)	0.017
Inhaled prostacyclin	1 (2)	5 (11)	0.20
IV corticosteroids	4 (9)	5 (11)	1.0

ARDS, acute respiratory distress syndrome; MV, mechanical ventilation; PEEP, positive end-expiratory pressure; APRV, airway pressure release ventilation; HFPV, high-frequency percussive ventilation; HFOV, high-frequency oscillatory ventilation; NO, nitric oxide; ECMO, extracorporeal membrane oxygenation; IV, intravenous.

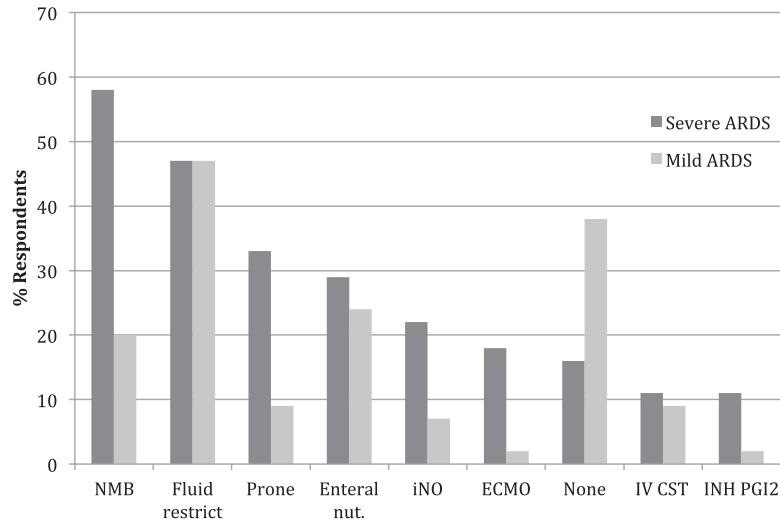


Figure 4. Nonventilatory adjuncts for ARDS. ARDS, acute respiratory distress syndrome; NMB, neuromuscular blockade; Nut, nutrition; iNO, inhaled nitric oxide; ECMO, extracorporeal membrane oxygenation; IV, intravenous; CST, corticosteroid; INH, inhaled; PGI2, prostacyclin.

management techniques in the presence of inhalation injury and ARDS. A similar survey conducted in pediatric burn centers mirrored comparable results with variability in MV practices.¹⁰ We found balanced responses over the standard modes of mechanical ventilation (ie, VAC, pressure assist control, synchronized intermittent mandatory ventilation, and PSV) with no particular mode being favored. A significant change overall was detected when inhalation injury was factored with relatively more considering APRV and HFPV, but again no one modality dominated the list. Although recommendations have been

made around the respiratory management of burn patients, there is a lack of standardization in practice that is further compounded by a lack of supporting scientific evidence.¹¹

Staunch fidelity to LTV protocols has been found to be ineffective in the burn population with one trial finding a third of the subjects failing to meet adequate oxygenation and ventilation goals, with two thirds failing when inhalation injury was present.⁶ It is no surprise that less than half of the respondents stated they follow the ARDSNet protocol when dealing with severe ARDS. Although

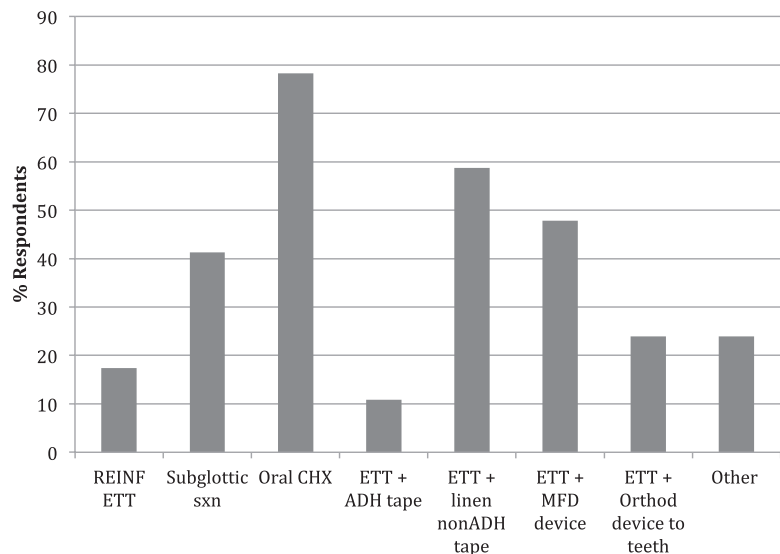


Figure 5. ETT care methods employed. ETT, endotracheal tube; REINF, reinforced; CHX, chlorhexidine; ADH, adhesive; Sxn, suctioning; MFD, manufactured; Orthod, orthodontic.

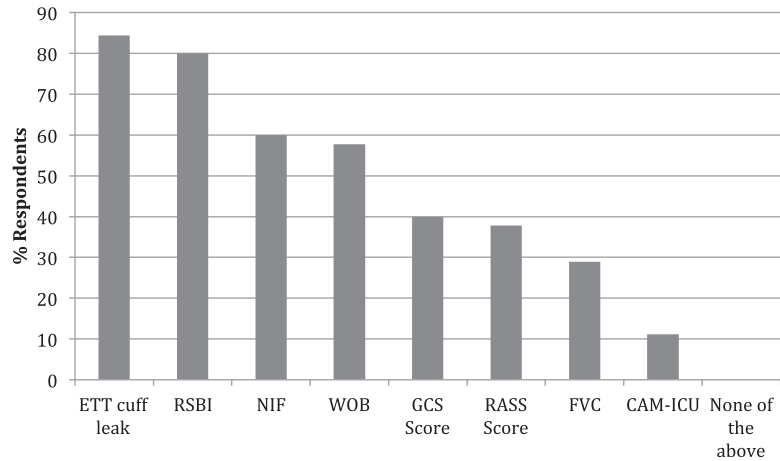


Figure 6. Evaluation criteria considered for extubation. ETT, endotracheal tube; RSBI, rapid shallow breathing index; NIF, negative inspiratory force; WOB, work of breathing; GCS, Glasgow coma scale; RASS, Richmond agitation sedation scale; FVC, forced vital capacity; CAM-ICU, confusion assessment method for the intensive care unit.

abundant preclinical and clinical data support broad usage of a LTV strategy, it is unclear if this approach can successfully be applied universally to the burn population.¹²⁻¹⁴ A recent study in pediatric burn patients by Sousse et al⁷ highlights the inferiority of LTV strategies, showing that in inhalation injuries, higher tidal volumes lead to significantly less ventilator days and reduced incidence of ARDS and atelectasis compared with LTV strategies. Chest wall edema and eschar formation increases pulmonary resistance while fibrin clots, common in inhalation injury, lead to airway obstruction leading to unique clinical considerations that can result in practice differences across general intensive care units. This inference is substantiated by the consistent omission of significant thermal insults from previous benchmark trials.^{3,15,16}

The effect of altered chest wall and abdominal mechanics is a particularly important concept, because major trials, such as the ARDSNet³ study of LTV, and the open-lung trials,^{15,17} did not take into account chest wall and lung mechanics. Rather, PEEP and FiO₂ were adjusted according to arterial oxygenation. Talmor et al¹⁸ have demonstrated that lung and chest wall mechanics may have a significant effect on transpulmonary pressure—the opening or distending pressure of the lung, and in turn, the appropriate adjustment of PEEP. It is entirely possible that burn patients, with edematous and eschar-thickened chest walls and abdomens, would not generate sufficient transpulmonary pressures and lung openings based on currently recommended tidal volumes, plateau pressure, and PEEP limits for example.

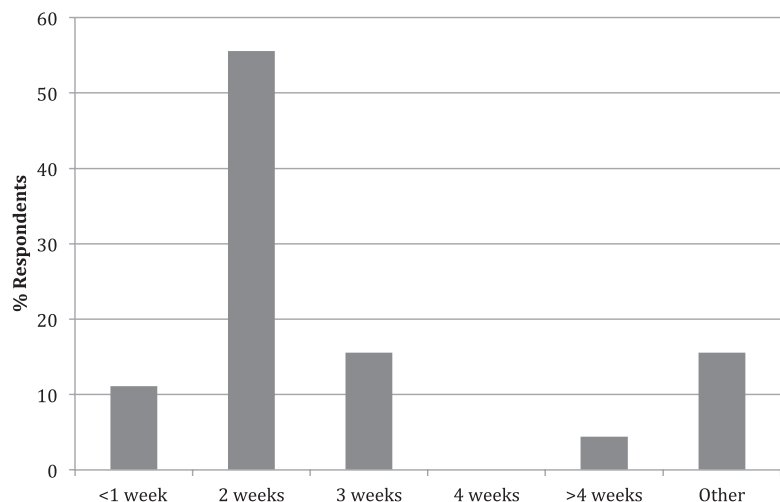


Figure 7. Probable time frame requirement used to consider tracheostomy intervention.

Enthusiasm for HFOV use has been tempered by conflicting evidence in the literature and is evidenced by its limited use across centers.^{19–22} Although HFOV appears to be effective in improving oxygenation in burn patients with ARDS if there has been an inhalation injury,¹⁹ the role for HFOV in a burn patient with moderate or severe ARDS, in the absence of inhalation injury, is much less clear. Recent trials in nonburn critically injured populations, such as OSCILLATE²⁰ and OSCAR,²² found no benefits, and even potential harm with the use of HFOV. Given the lack of burn-specific data, we caution against the extrapolation of such findings to critically injured burn patients. In OSCILLATE, for example, pneumonia was the single largest cause of ARDS (56%), potentially affecting the “recruitability” of the lung in those cases. The cause of ARDS in critically injured burn patients widely varies with the likelihood of some ARDS lungs being more recruitable than others due to a number of different pulmonary and extra-pulmonary factors.^{23,24} Thus, ARDS in the burn patient might respond very differently to HFOV. These nuances require further study, and it is anticipated that the results of this survey will be used to inform the design of subsequent clinical trials to investigate these questions and potential discrepancies.

Although HFPV has not been proven to affect overall mortality in randomized controlled trials, it has been shown to have added benefits in other clinical endpoints and thus a justifiable option when pulmonary dysfunction progresses. The largest randomized trial to date demonstrated that HFPV was at least as “lung protective” as LTV with significantly less patients requiring rescue because of inadequate gas exchange.⁹ Other studies have consistently shown favorable outcomes when compared with conventional modalities across various injury etiologies and most importantly in burns.^{6,25,26} Specifically, these studies describe lower peak inspiratory pressures during ventilation leading to fewer incidences of barotrauma, superior oxygenation and ventilation, and significant decrease in pneumonia compared with conventional modalities.^{6,26–29} Unlike HFOV, heavy sedation and paralytics are not a requisite for HFPV, as it allows for passive exhalation and better patient comfort with less detrimental hemodynamic effects.²⁵

The findings of limited use among specific adjuncts may be attributed to additional costs and training required to support such products and limited evidence supporting these technologies.^{19,30–34}

According to epidemiological findings listed in the National Burn Repository published in 2014, pneumonia remains the most frequent complication

in burn injury patients—especially in patients receiving four or more days of mechanical ventilation.² The following evidence-based interventions for pneumonia prevention were queried in this survey: continuous subglottic suctioning of secretions, use of oral care with chlorhexidine, sedation interruption for daily assessment for appropriateness of extubation, and protocol driven ventilator practices.²⁶ Of these, continuous subglottic suctioning of secretions was the only practice not employed by a majority of respondents. Tracheostomies have been described as a complementary tool to prevent infection and improve pulmonary hygiene, but confounding factors convolute the benefits.³⁵ Variability in the definitions of “early” and “late” tracheostomy exists in the literature, making it difficult to interpret results.^{36–42} The decision to perform a tracheostomy is multifactorial and takes into consideration clinical stability, preexisting and concurrent comorbidities, and individual patient characteristics, ultimately filtering into the possibility of prolonged mechanical ventilation—the subjective hinge on if intervention is warranted. However, despite the inherent situation-specific nature of procedural tracheostomy, results of this study reveal that majority of burn centers agree on tracheostomies being indicated when expected MV days exceeds 2 weeks.

Limitations of this study followed intrinsic characteristics of the cross-sectional design of our survey. Although responses were received from every region partitioned by the American Burn Association, a 36% response rate from 129 sites creates a possibility of our data representing a nonresponder bias. Despite seeing variability in practice around commonly used specific MV modes in the setting of inhalation injury, statistical significance could not be verified. The absence of statistical validity could be attributed to type 2 error. Validity and reliability of this researcher-designed questionnaire were not determined via a pilot study pretest.

CONCLUSION

Clinical burn practice related to mechanical ventilation tends to deviate from traditional protocols commonly observed in the general critical care community. A focused approach toward the standardization of MV practices needs to be established to inform and optimize best practice guidelines and interventions associated with pulmonary dysfunction in the setting of a primary burn etiology. The results of this survey illustrate that no single mechanical ventilation mode or adjunct prevails in the clinical management of burn patients regardless of the presence

of pulmonary insult. Variation in clinical practice and management across individual sites suggest the need for future ABA supported multisite burn center studies to further inform the development of evidence-based clinical guidelines for mechanical ventilation management in acutely injured burn patients.

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