

Factors Associated with Endotracheal Tube Related Pressure Injury

Constance C Mussa*, Edita Meksraityte, Jie Li, Barbara Gulczynski, Jing Liu and Ana Kuruc

Department of Cardiopulmonary Sciences, Rush University Medical Center, USA

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*Corresponding author

Constance C Mussa, Department of Cardiopulmonary Sciences, Rush University, USA, Email: Constance_Mussa@rush.edu

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Abstract

Background: Medical devices often facilitate life-saving interventions, but may exert pressure on specific areas of the body leading to pressure injuries. Medical device-related pressure injuries are iatrogenic complications that prolong hospitalization, increase the risk of morbidity and mortality for patients, and ultimately contribute to increased healthcare cost.

Objective: The objectives of this study were to assess the effectiveness of an Endotracheal Tube (ETT) related pressure injury prevention intervention in reducing the prevalence of ETT related mucosal membrane pressure injury, and to identify clinical variables that may be risk factors for this iatrogenic complication.

Methods: We conducted a retrospective, pre-post intervention study involving Institutional Review Board approved review of the electronic medical records of 142 adult intubated patients (61 pre intervention and 81 post intervention implementation) admitted to the Medical Intensive Care Unit (MICU) at an academic medical center.

Results: After implementation of the intervention, the prevalence of ETT related mucosal membrane pressure injury decreased from 16% (10 of 61 subjects) to 10% (8 of 81 subjects), but this decrease was not statistically significant (OR 0.41, 95% CI 0.13 to 1.26). Vasopressor infusion was significantly associated with increased likelihood of developing mucosal injury (odds ratio 6.85, 95% CI 1.71 to 27.56).

Conclusion: Although application of the pressure injury prevention intervention did not achieve a statistically significant decrease in the prevalence of ETT related pressure injury the results have clinical significance as preventing pressure injury in even one patient enhances clinical outcomes. Consequently, the use of interventions that relieve pressure on the lips, tongue and face from the ET tube and securing device in intubated patients should be encouraged. Additionally, patients who receive vasopressor infusion may be at increased risk for developing ETT-related pressure injuries, indicating a need for increased vigilance in performing skin and mucosal membrane assessment in this population.

Introduction

The prevention of pressure injuries in healthcare facilities has long been a concern, but has garnered increased attention over the past few years because of reimbursement penalties imposed by the Centers for Medicare and Medicaid Services for hospital acquired pressure injuries [1]. The relevance and significance of this problem is evident in the fact that pressure injury prevention was one of the hospital-acquired conditions targeted for reduction in The Joint Commission's Partnership for Patients campaign that was in effect from 2012-2014 [2]. With a goal of zero pressure injuries, The Joint Commission (TJC) continues to advise healthcare facilities to implement evidence-based guidelines in an effort to win the fight against pressure injury. Commensurate with this goal, TJC included pressure injury prevention in its 2015 national patient safety goals [3].

Pursuant to the goal of preventing pressure injuries, an abundance of studies have been conducted, [1,4-8], some of which have provided high-quality evidence utilized to inform the development of current pressure injury prevention and management guidelines, protocols, and standards. Although the general problem of pressure injury has been studied extensively, there is an area within this broader problem, namely, Medical Device-Related (MDR) pressure injury that has not received as much attention from healthcare researchers and practitioners [9-16]. Black and Kalowes define MDR pressure injury as "a localized injury to the skin or underlying tissue as a result of sustained pressure from a medical device" [11].

Securing endotracheal tubes in critically ill patients receiving mechanical ventilatory support is of paramount importance to prevent inadvertent extubation, which has a cascade of deleterious consequences such as possible aspiration of oropharyngeal secretions and gastric contents into the lungs, and disruption of mechanical ventilation. Selection of an optimal Endotracheal Tube (ETT) securing device continues to be problematic because of the dual need for stability of the ETT and prevention of trauma to the skin and mucosa. An optimal ETT securing device should provide "maximum stability against inadvertent movement, resistance to oral secretions without becoming loose, [should] hold the ETT securely without slippage, and should be easy to manipulate and easily applied with relatively little time involvement"[17]. Unfortunately, such an ETT securing

device is not currently available, and in many instances, the devices used exert enough pressure on the lips, tongue, and face to cause serious injury [17]. The pressure exerted on the surrounding tissue from the device compresses blood vessels and prevents both the delivery of oxygen and nutrients and the return of metabolic waste in the capillaries. The resulting tissue ischemia is exacerbated by the accumulation of metabolic waste, local vasodilation and edema. The ischemia leads to tissue necrosis and presents clinically as a pressure injury [16].

Manufacturers' recommendations for existing ETT securement devices include warnings that excessive pressure created by the device may cause tissue injury or necrosis. "The package insert for the Hollister Anchor Fast endotracheal tube securement device recommends that the ETT be repositioned every two hours or more frequently if the patient's condition dictates, to minimize the risk of injury to the skin and/or lips from unrelieved pressure" [18]. This recommendation is based on standard pressure injury prevention positioning schedules rather than research done on optimal pressure relief from the device itself. To minimize the risk of pressure injury, the manufacturer also suggests assessment of the patient's lips and skin at least every two hours and to discontinue use of the device if redness or skin irritation occurs.

VanGilder, et al. [19] reported that device related pressure injuries make up approximately 10% of all pressure injuries. In addition to the pain and discomfort of medical device-related pressure injuries, these iatrogenic complications prolong hospitalization, contribute to increased healthcare costs, and increase the risk of patient morbidity and mortality, especially in those who are critically ill. Despite the seriousness of this problem, there is a paucity of studies on its prevention and management.

Our study focused on prevention of pressure injury in intubated patients in the Medical Intensive Care Unit (MICU) at Rush University Medical Center through the use of a pressure injury prevention intervention in conjunction with a commercial ETT securement device.

Methods

Study Design and Participants

This study is a retrospective, pre-post intervention study to determine the prevalence of ETT device-related pressure injury in the MICU of an urban academic medical center following implementation of an ETT device-related pressure injury QI intervention. After approval from the medical center's institutional review board, we reviewed each subject's medical record for clinical data including, age, gender, Body-Mass Index (BMI), vasopressor use, RASS score, Braden score and subscale scores, use of a pressure relief device, and skin assessment results. This data was manually extracted and entered into REDCap, a secure electronic research database.

The target population included intubated subjects age eighteen years or older, whose ETT was secured with the Hollister Anchor Fast ETT securing device (Hollister, Libertyville, USA). Subjects with tracheostomy tubes, those younger than eighteen years, and with pre-existing pressure injury were excluded from the study. The sample size was determined through consecutive sampling over a six-month period (June-December 2015).

ETT related pressure injury prevention intervention

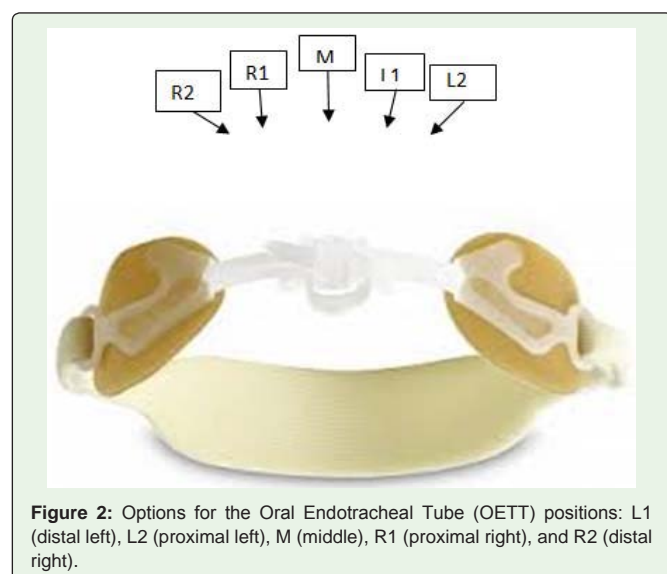
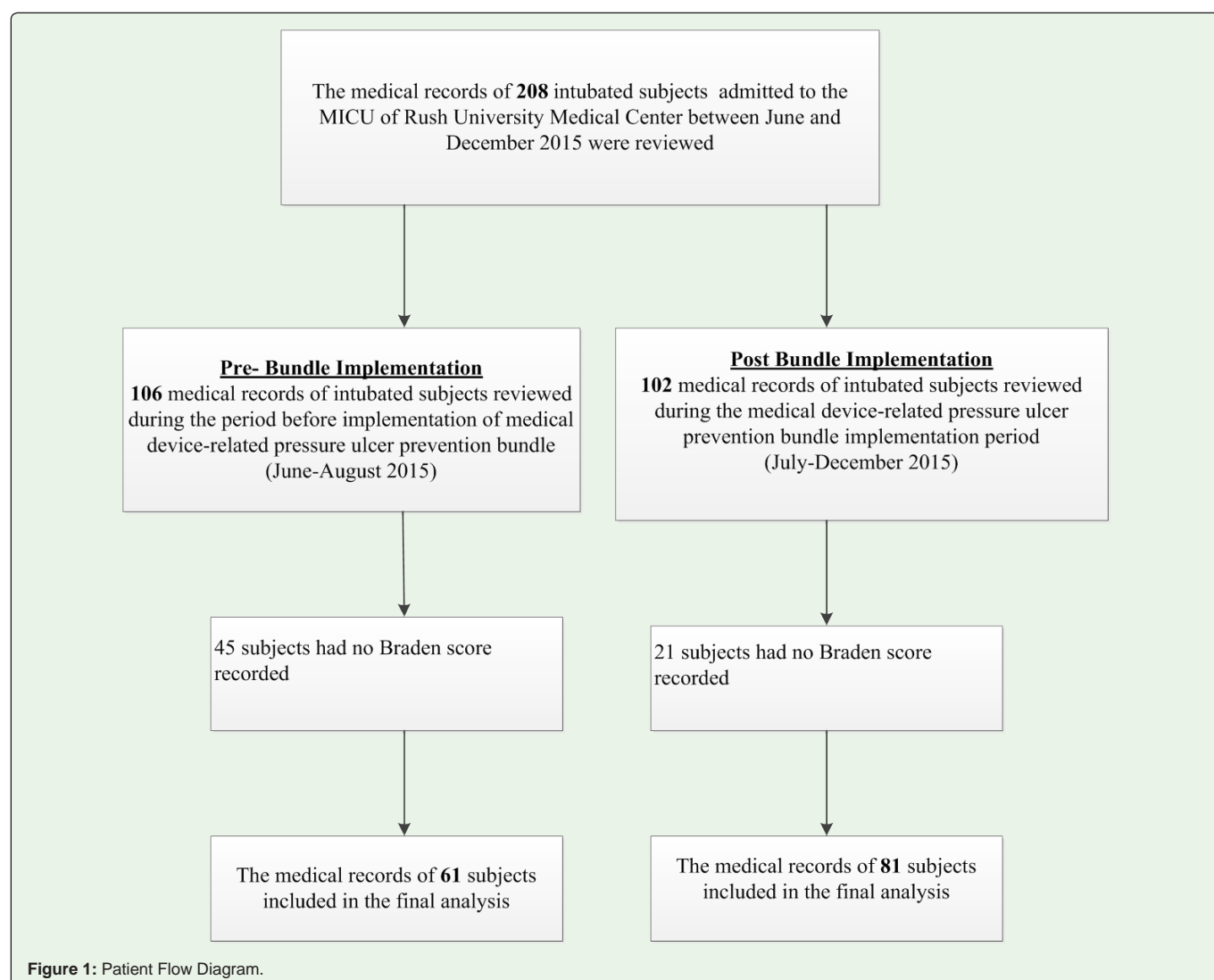
The practice before the ETT related pressure injury prevention intervention was for the respiratory therapist to change the ETT securing device every 7 days (168 hours) and as needed. Responsibility for oral care was shared by the MICU nurse and the respiratory therapist, and was performed every 4 hours and as needed. The OETT (oral endotracheal tube) was repositioned once every 12-hour-shift. Three locations were used for the OETT positioning: L (left), M (middle) and R (right). The weight of the OETT and the ventilator circuit was offset by using the ventilator arm.

The ETT related pressure injury prevention intervention extended from September 1, 2015 to December 1, 2015 and consisted of the Hollister Anchor Fast ETT securing device recommendations in conjunction with the medical center's practice guidelines. The intervention included a change in application frequency of the ETT securing device (from every 7 days to every 4 days), and a change in the frequency of repositioning the OETT (from every 12 hours to every 4 hours). Additionally, the options for the OETT positions were increased from three: left, middle, and right, to five: L1 (distal left), L2 (proximal left), M (middle), R1 (proximal right), and R2 (distal right). Moreover, the weight from the OETT and the ventilator circuit was offset by using either a rolled towel or an air blown medical glove placed on the patient's chest in addition to the ventilator arm (Figures 1 and 2).

Before initiation of the QI intervention, education was provided to all respiratory therapists and MICU nurses by a clinical specialist from Hollister. Education included the demonstration of correct application and removal of the ETT securing device using a manikin, discussion of the indications for selecting the Hollister Anchor Fast ETT securing device, and correct repositioning of the OETT. Respiratory Care supervisors provided additional education regarding appropriate documentation in the Electronic Health Record (EHR) to all respiratory therapists. Respiratory therapists were also trained to perform skin and mucous membrane assessment by a registered nurse who is a certified wound and ostomy specialist. Pamphlets containing information about the ETT related pressure injury prevention intervention were laminated and posted in MICU work areas and the respiratory therapy department to serve as a "quick reference" for respiratory therapists. Reminders about implementation of the intervention were announced in daily huddles. Information about the presence and location of mucosal pressure injuries was obtained from RN and RT documentation in the airway assessment section of the medical center's EHR.

Statistical analysis

The sample was summarized across the two groups of subjects (i.e., those admitted to the MICU in the six-month period before the intervention was introduced and those admitted to the MICU in the six-month period after the intervention was introduced) by using the frequency with the percentage for categorical variables, the median for ordinal variables, and the mean for continuous variables. The data was analyzed to determine if there were significant differences between the before and after intervention groups with regard to age, gender, Braden score, RASS score, and BMI, using Chi-squared or Fisher's Exact Test for categorical variables, the Mann-Whitney U Test for ordinal variables, and the independent-samples t-test for



continuous variables. Additionally, logistic regression analysis was performed to determine the influence of the intervention and other clinical variables on the development of mucosal membrane pressure injury. Each model adjusted for gender (female vs. male), age, race (black vs white), BMI, RASS score, and Braden score. These statistical analyses were conducted using SPSS (version 22; IBM, Chicago, IL). Two-sided p-values less than 0.05 were considered as statistically significant.

Results

A total of 208 medical records were reviewed (106 before pressure injury prevention intervention implementation and 102 after implementation of the intervention). of the 208 records that were reviewed, 142 were included in the final analysis (Patient Flow Diagram, Figure 3) as Braden scores were unavailable for 66 subjects (45 from the non-intervention group and 21 from the intervention group). There were no significant differences between the pre and post intervention groups in terms of age, gender, race, BMI, RASS scores, Braden scores and whether or not vasopressor was received.



Figure 3: Depiction of how the weight from the Oral Endotracheal Tube (OET) T and the ventilator circuit was offset by either a rolled towel or an air blown medical glove.

of a Fisher's Exact Test (Table 2) showed that vasopressor infusion was significantly associated with mucosal membrane pressure injury ($P = .004$). The logistic regression model predicting likelihood of ETT related mucosal membrane pressure injury was statistically significant ($\chi^2(9) = 17.32, p = .04$). The pressure injury prevention intervention was not associated with a reduction in the likelihood of having ETT related mucosal injury (OR 0.41, 95% CI 0.13 to 1.26). However, vasopressor infusion was associated with a 6-fold increase in the odds of developing ETT related mucosal injury (OR 6.85, 95% CI 1.71 to 27.56). A logistic regression model predicting the influence of norepinephrine vs vasopressin on likelihood of ETT related mucosal injury was also statistically significant ($\chi^2(11) = 21.17, p = .03$). Both vasopressin and norepinephrine were independent

Table 1: Characteristics of study participants before and after implementation of the ETT-related pressure ulcer prevention intervention.

Characteristic	Total (N=142)	Pre-bundle implementation (N=61)	Post-bundle implementation (N=81)	P value for pre-bundle implementation versus after implementation
AGE, YEARS: Mean (SD)		57.44 (15.99)	57.83 (15.63)	0.89
BMI: Mean (SD)		29.39 (8.85)	28.94 (7.85)	0.75
Braden Score: Mean (SD)		12.95 (2.97)	12.58 (2.14)	0.4
RASS Score: Median (IQR)		0 (-2, 0)	-1 (-2, 0)	0.092
GENDER: Freq (%)				
Female	72 (51)	31 (51)	41 (51)	0.98
Male	70 (49)	30 (49)	40 (49)	
RACE: Freq (%)				
Black	60 (42)	28 (46)	32 (39.5)	0.74
White	54 (38)	22 (36)	32 (39.5)	
Other	28 (20)	11(18)	17 (21)	
VASOPRESSOR USE: Freq (%)				
No	71 (50)	32 (53)	39 (48)	0.61
Yes	71 (50)	29 (47)	42 (52)	
VASOPRESSOR TYPE: Freq (%)				
Norepinephrine	28 (41)	7 (26)	21 (51)	.038*
Vasopressin	40 (59)	20 (74)	20 (49)	
PRESSURE INJURY: Freq (%)				
No	124 (87)	51 (84)	73 (90)	0.25
Yes	18 (13)	10 (16)	8 (10)	

*Significant difference pre-bundle implementation versus after implementation ($P < .05$).

However, there was a significant difference between groups in terms of the types of vasopressor received. Table 1 summarizes the demographics of the sample included in the final analysis. Clinician documentation revealed 100% compliance with all pressure injury prevention intervention elements for the 142 subjects included in the analysis.

During the period before implementation of the pressure injury prevention intervention, ten subjects (16%, $n = 61$) were found to have mucosal membrane pressure injury, which decreased to eight (10%, $n = 81$) after implementation of the intervention. However, this reduction in prevalence of mucosal injury pre and post intervention implementation was not statistically significant. Results

Table 2: Association between mucosal membrane pressure injury and vasopressor use.

	Total	Pressure Injury	No Pressure Injury	P value for association between pressure injury and vasopressor use
	(N=142)	(N=18)	(N=124)	
VASOPRESSOR USE: Freq (%)				
No	71 (50)	3 (17)	68 (55)	0.004
Yes	71 (50)	15 (83)	56 (45)	

Table 3: Results of logistic regression predicting likelihood of ETT related mucosal membrane pressure injury based on age, race, gender, BMI, Braden score, vasopressor use, RASS score, and use of ETT related pressure ulcer prevention bundle.

Variables	P Value	Odds Ratio	95% C.I. for Odds Ratio	
			Lower	Upper
BMI	0.95	1	0.94	1.07
Braden Score	0.49	1.11	0.82	1.51
Vasopressor Use	.007*	6.85	1.71	27.56
Norepinephrine	.020*	7.35	1.37	39.3
Vasopressin	.004*	10.78	2.13	54.44
RASS Score	0.86	0.96	0.62	1.51
Intervention	0.12	0.41	0.13	1.26

*Significant difference in prevalence of mucosal membrane pressure injury for patients who received vasopressor versus patients who did not receive vasopressor ($P < .05$).

ETT -Endotracheal Tube

Note:

- Vasopressor use - vasopressor use compared to no vasopressor use
- Vasopressor type -vasopressin Vs norepinephrine
- Mucosal injury compared to no mucosal injury
- Intervention - ETT related pressure ulcer prevention bundle compared to no bundle

predictors of mucosal membrane pressure injury, but vasopressin was a stronger predictor (OR 10.78, 95% CI 2.13 to 54.44) compared to norepinephrine (OR 7.35, 95% CI 1.37 to 39.30). A summary of these findings is presented in table 3.

Discussion

The finding that our ETT related pressure injury prevention intervention was not associated with a statistically significant decrease in the prevalence of mucosal membrane pressure injury differs from the results of a study by Coyer, et, al.¹⁰ that demonstrated a significant decrease in incidence (from 30% to 18%, $p = .04$) of skin and mucous membrane injuries with use of an intervention that included securing ETT and nasogastric tubes to minimize pressure, and repositioning them at least every 12 hours. Failure of our pressure injury prevention intervention to demonstrate a statistically significant reduction in pressure injury prevalence rate may indicate that relieving the pressure exerted by the ETT and securing device on the oral mucosa may be necessary but not sufficient to prevent this type of injury [21]. In a review of the etiology of pressure injuries, Thomas [21] presented convincing evidence from extant research regarding the multifactorial etiology of this problem. The author concluded that physiologic variables specific to each individual may negatively affect skin blood flow response time and cause derangements in tissue perfusion leading to pressure injury.

Although use of the ETT related pressure injury prevention intervention was not associated with a statistically significant decrease in the prevalence of mucosal membrane pressure injury, the results have important clinical implications. Specifically, the 6% reduction in the prevalence of mucosal pressure injury suggests

that an intervention which distributes the pressure of the ETT more evenly should be included in an ETT related pressure injury prevention strategy. Additionally, more frequent repositioning of the ETT provides respite from the pressure it exerts on the mouth, lips, and tongue, and also allows more frequent inspections.

Our finding that vasopressor use is associated with more than a 6-fold increase in the odds of a subject showing evidence of an ETT related mucosal membrane pressure injury is consistent with the findings of a retrospective study by Alderden and colleagues [22] who found that vasopressor infusion was associated with a 5-fold increase in the odds that a patient's pressure ulcer was not healed at discharge or death. The researchers pointed out that vasopressor infusion is usually given to patients who are hypotensive. Consequently, they speculated that hypotension in patients receiving vasopressor infusion may be the underlying reason for increased risk of pressure injury as it causes blood to be shunted away from the skin to priority organs. A systematic review by Cox [23] revealed emerging empirical evidence that vasopressor infusion is a significant predictor of pressure injury. Specifically, Cox reported that of the ten studies included in the review, four studies identified vasopressor infusion as a significant predictor of pressure injury in critically ill patients, and three studies demonstrated a significant association between vasopressors and pressure injury. Acknowledging that "the current level of evidence regarding the role of vasopressors in the development of pressure injuries in critically ill patients is in its infancy," [23] Cox and Roche [24] conducted a study, which demonstrated that more than 50% of patients who received vasopressin and norepinephrine as combination therapy developed pressure injuries. Moreover, they found that although vasopressin and norepinephrine were significantly associated with pressure injuries, only vasopressin was a significant predictor of pressure injury development. In our study, vasopressin and norepinephrine were both independent predictors of mucosal membrane pressure injury, but vasopressin was a stronger predictor. Cox and Roche suggested that poor perfusion resulting from the vasoconstrictive effect of vasopressin as well as the hypotensive state of patients receiving vasopressors may be the underlying reason for pressure injury development. The authors indicated that heightened vigilance at the point where a patient needs a second vasopressor to treat hypotension may be warranted to prevent pressure injury.

The retrospective nature of our study has inherent limitations including the limited control we had over the selection of the sample and quality of the data. Another major limitation is that we obtained data regarding the presence or absence of mucosal injury from the documentation of the nurses and respiratory therapists caring for each patient rather than from a wound and ostomy specialist. However, these clinicians were trained to identify mucosal membrane injury by a certified wound and ostomy specialist. Moreover, the nurses and respiratory therapists were required to refer any stageable pressure injury (e.g., injury to the cheek area under the ETT securing device) they might find to a wound care specialist.

Conclusion

Although application of the pressure injury prevention intervention did not achieve a statistically significant decrease in the prevalence of ETT related pressure injury the results have clinical significance as preventing pressure injury in even one patient enhances clinical outcomes. Consequently, the use of interventions

that reduce torque on the ET tube in intubated patients should be encouraged. Additionally, patients who receive vasopressor infusion may be at increased risk for developing ETT-related pressure injuries, indicating a need for increased vigilance in performing skin assessment in this population.

Our findings can be used to improve clinical practice by contributing to the development of evidence-based guidelines for the prevention and management of endotracheal tube related mucosal membrane pressure injury in particular and device related pressure injuries in general.

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