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ORIGINAL ARTICLE

Pressure ulcers in paediatric patients on extracorporeal membrane oxygenation

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It has been shown that pressure ulcer formation in critically ill paediatric patients increases morbidity and mortality. We sought to identify factors associated with pressure ulcer formation in paediatric patients on extracorporeal membrane oxygenation (ECMO). From December 2014 to 2015, we identified patients at our institution who developed a pressure ulcer to create two cohorts: ulcer and no ulcer. Variables of interest included: type of ECMO, ECMO indication, hours on ECMO, location of cannulas, volume of crystalloid and blood products received during the first 7 days or during the length of the ECMO run, albumin and lactate levels on the day of cannulation, and presence of vasopressor support or steroid therapy. Of 43 patients studied, 11 (25.5%) developed a pressure ulcer. Patients that developed ulcers were older ($P = 0.001$) and weighed more ($P = 0.006$). Femoral cannulation was more frequent in the ulcer group (36.4% vs 6.3%, $P = 0.029$), and duration of ECMO was longer ($P = 0.007$). Age, weight, duration of ECMO, and femoral cannulation may contribute to the development of pressure ulcers in children who require ECMO support. Further analysis is imperative to identify specific techniques and protocols that will prevent pressure ulcers in this critically ill population.

KEYWORDS
critical care, extracorporeal membrane oxygenation, outcomes, pressure ulcer

1 | INTRODUCTION

Pressure ulcers develop as a result of localised injury to the epidermis and underlying tissues caused by prolonged pressure to that area.[1] With a reported prevalence ranging as high as 35%,[2] pressure ulcers among the paediatric patient population are a widespread clinical challenge. Pressure ulcers often induce subsequent complications involving pain, infection, increased hospital length of stay, and hospital costs.[3–6] Critically ill paediatric patients have been shown to be at increased risk of pressure ulcers similar to adults.[7] Prevention of pressure ulcers is an important aspect of patient care and incidence, and preventative measures are extensively studied in nursing research.[8,9] However, there are no studies examining some of the most critically ill patients, paediatric patients, on extracorporeal membrane oxygenation (ECMO). Studies have shown that ECMO is a risk factor for pressure ulcer formation in critically ill paediatric patients.[6]

ECMO delivers continuous cardiopulmonary support for the management of severe respiratory and/or cardiac failure with the use of vascular access catheters frequently in the groin and neck. Blood flow to the pump is influenced by cannula position, and even minor changes may negatively impact venous return to the pump.[10] Most of these patients

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are rendered practically immobile given the precarious state of the cannulas and frequent need for deep sedation, which prevents the frequent position changes that are a common nursing practice in the prevention of pressure ulcers.[1,6,8] In addition, fluid shifts and haemodynamic instability are common in these critically ill patients, which contribute to tissue oedema and hypoperfusion, putting them at increased risk of developing pressure ulcers.[11]

The purpose of this study is to investigate factors associated with pressure ulcer formation in paediatric patients on ECMO.

Key Messages

- this is a retrospective study that evaluated pressure ulcer formation in paediatric patients on extracorporeal membrane oxygenation (ECMO)
- age, weight, duration of ECMO, and presence of femoral cannulation may be factors associated with pressure ulcers in a critically ill paediatric patient population

2 | METHODS

A retrospective review was performed at our tertiary care children's hospital. Patients who underwent ECMO at our institution from December 2014 to December 2015 were identified. We separated our patients into two cohorts: patients who developed a pressure ulcer either while on ECMO or within 7 days of decannulation (ulcer) and patients who did not develop a pressure ulcer (no ulcer). Presence of pressure ulcer was based on nursing documentation that requires documentation of a pressure ulcer as soon as it is diagnosed. Exclusion criteria included patients who developed a pressure ulcer greater than 7 days after decannulation and patients who were cannulated at an outside hospital.

Baseline characteristics inherent to ECMO were evaluated to determine potential risk factors for pressure ulcer development including: type of ECMO - venovenous (VV) or venoarterial (VA), ECMO indication, hours on ECMO, and cannula location. We also evaluated the amount of crystalloid and blood products received during the first 7 days of ECMO or during the length of the ECMO run if less than 7 days. Finally, we documented albumin and lactate levels and whether the patient was on vasopressor support or receiving steroid therapy on the day of cannulation.

For the variables described above, we compared the ulcer group with the non-ulcer group using Pearson's chi-square, Fisher's exact test, and student's *t* test, with significance set at $P < 0.05$. All statistical analyses were performed with SPSS software (SPSS 20, IBM, Armonk, New York). Institutional review board approval was obtained prior to initiating data collection. As this is a minimal-risk retrospective chart review, no patient consent was required.

3 | RESULTS

A total of 43 patients underwent ECMO from December 2014 to December 2015. Of these patients, 11 (25.5%) developed a pressure ulcer during their ECMO run or within 7 days of decannulation. Baseline demographics are shown in Table 1. Patients who developed a pressure ulcer were older (4061 vs 966 months, $P = 0.001$) and had a greater body surface area (BSA) (1.3 vs 0.38, $P = 0.01$) and body mass index (BMI) (19.5 vs 14.8, $P = 0.006$). ECMO characteristics are shown in Table 2. Those who developed pressure ulcers remained on ECMO longer (487.5 vs 113.5 hours, $P = 0.007$). There was no significant difference in the indication for ECMO or type of ECMO between the groups; however, patients who developed pressure ulcers

TABLE 1 Baseline demographics

Variable	Ulcer[a] (11, 25.5%)	No ulcer (32, 74.5%)	*P* value
Age (d)	4061 ± 2353	966 ± 1712	0.001
Gender			0.337
Male	7 (63.6)	15 (46.9)	
Female	4 (36.4)	17 (53.1)	
Weight (kg)	44 ± 30.3	9.9 ± 12.5	0.004
Height (cm)	139.1 ± 41.4	70.5 ± 31.9	0.001
BSA (m^2)	1.3 ± 0.6	0.38 ± 0.36	0.01
BMI (kg/m^2)	19.5 ± 6.2	14.8 ± 3.7	0.006

Abbreviations: BMI, body mass index; BSA, body surface area.
Data presented as mean ± SD or n (%).
Significance set at $P < 0.05$.
[a] Within the first 7 days of cannulation.

TABLE 2 Characteristics of ECMO

Variable	Ulcer[a] (11, 25.5%)	No ulcer (32, 74.5%)	*P* value
Hours on ECMO	487.5 ± 366.2	113.5 ± 98.7	0.007
ECMO indication			
Respiratory	4 (36.4)	9 (28.1)	0.709
Cardiac	3 (27.3)	10 (31.3)	1.000
ECPR	4 (36.4)	13 (40.6)	1.000
Cannula location			
Neck	2 (18.3)	15 (46.9)	0.154
Femoral	4 (36.4)	2 (6.3)	0.029
Central	4 (36.4)	15 (46.9)	0.728
Neck/femoral	1 (9.1)	0 (0.0)	0.256
ECMO type			
VA	8 (72.7)	26 (81.3)	0.672
VV	2 (18.2)	5 (15.6)	1.000
VAV	0 (0.0)	1 (3.1)	1.000
VVA	1 (9.1)	0 (0.0)	0.256

Abbreviations: ECMO, extracorporeal membrance oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation; VA, venoarterial; VAV, venoarterial venous; VV, venovenous; VVA, venovenous arterial.
[a] Within the first 7 days of cannulation.

were more likely to have femoral cannulas (36.4% vs 6.3%, $P = 0.029$). A majority of the patients were on VA ECMO (79.0%). There was no significant difference in the amount of crystalloid or blood products received, the albumin and lactate levels, or the use of steroids or pressors on the day of cannulation (Table 3).

4 | DISCUSSION

This is the first retrospective study to date evaluating pressure ulcer formation in paediatric patients receiving ECMO. We found that age, BSA, BMI, hours on ECMO, and femoral cannulation significantly correlated with the formation of a pressure ulcer while on ECMO.

Pressure ulcers are defined as any lesion caused by unrelieved pressure resulting in damage to underlying tissue. The main factors in the development of pressure ulcers include: increased duration of pressure, increased intensity of pressure, and reduced tissue tolerance. The latter can be divided into extrinsic and intrinsic factors. Extrinsic factors include increased moisture, friction, and shearing forces resulting in trauma. Intrinsic factors include numerous items, including nutritional status and tissue oxygen consumption.[11,12]

We found that patients who had a greater BSA and BMI were more likely to develop pressure ulcers while on ECMO. This is unsurprising given that increased pressure intensity and friction forces have been described as main factors in the development of pressure ulcers.[12] Interestingly, however, we did not find a statistically significant correlation between volume of fluids administered and the development of a pressure ulcer in our study. It is generally thought that increased fluid administration leads to total body oedema, and one would expect that this could contribute to extrinsic factors of pressure ulcer development.

This study also demonstrated that increased time on ECMO and femoral cannulation are significant factors in the development of pressure ulcers in the paediatric ECMO patient. Evidence-based practices have been published regarding the prevention of pressure-based injury,[4,8] and one of the mainstays of the treatment of pressure ulcers includes frequent repositioning and pressure off-loading.[13,14] However, this is not easily feasible in the ECMO patient with a femoral cannula as great care is taken to prevent cannula dislodgement. There are many instances where ECMO is an emergent situation and part of cardiopulmonary resuscitation; however, when possible, avoidance of femoral cannulation may be important in the prevention of pressure ulcers in paediatric patients on ECMO.

Efforts to decrease sedation and mobilise ECMO patients early have been validated in adult patients. Studies show that survival and ICU length of stay are improved when patients are awake and mobilised while on mechanical circulatory support.[15–17] Multiple adult studies have advocated for early physiotherapy and mobilisation during ECMO and, in fact, have shown improved outcomes following this technique during bridge to lung transplantation.[18] Obviously, there is an increased risk of dislodging or kinking the cannulas while patients are mobile, and practitioners caring for paediatric patients may be more cautious in waking their ECMO patients for fear of anxiety and difficulty in communication. There are no data regarding early mobilisation in paediatric ECMO patients. However, it appears that such an approach may have beneficial outcomes, such as decreased ulcer development.

This study has a number of limitations. Because of the small number of patients, we could not control for confounding variables. The main limiting factor in acquiring patients for study was the accuracy of ulcer documentation. Only at the end of 2014 was ulcer documentation consistently performed, which was a result of a number of important nursing initiatives. In addition, only recently have we begun to implement a standard ulcer prevention technique, and it cannot be assumed that nursing practices were equal among all patients. In being retrospective, associations can be proposed, but causation cannot be proven.

Pressure ulcers in the critically ill paediatric patient increase length of stay and hospital costs and can result in a decreased quality of life and permanent disfigurement.[19] Paediatric patients on ECMO are among the most critically ill, and their mobility is often limited by fear of dislodging external devices or causing further clinical decompensation. The results of this study promote increased effort for mobilisation and lightening of sedation in the paediatric ECMO patient. Special preventive efforts should be taken for larger patients who are intrinsically at higher risk of ulcer development. At our institution, an ulcer prevention protocol has been instituted. We hope that this will reduce the incidence of ulcer formation in our most critically ill patients.

TABLE 3 Variables of interest while on ECMO

Variable	Ulcer[a] (11, 25.5%)	No ulcer (32, 74.5%)	*P* value
Crystalloid[a] (cc/kg)	131.4 ± 76.8	727.1 ± 2510.6	0.212
Blood products[a] (cc/kg)	169.5 ± 192.2	291.3 ± 483.2	0.245
Albumin[b] (g/dL)	3.4 ± 0.8	3 ± 0.7	0.384
Lactate[b] (mmol/L)	6.8 ± 5.5	8.5 ± 5.4	0.404
Pressors[b] (Y/N)	9 (81.8)	22 (68.8)	0.698
Steroids[b] (Y/N)	7 (63.6)	10 (31.3)	1.000

Abbreviation: ECMO, extracorporeal membrance oxygenation.
Data presented as mean ± SD or n (%).
[a] Within 7 days of ECMO cannulation.
[b] On the day of ECMO cannulation.

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