

ORIGINAL ARTICLE

Risk factors for heel pressure injury in cardiovascular intensive care unit patients

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Abstract

This study analyzed the risk factors for heel pressure injury in cardiovascular intensive care unit patients with the aim of laying the groundwork for preventive nursing interventions. We conducted a retrospective case-control study of 92 patients who were admitted to the cardiovascular surgical or medical intensive care unit of a university hospital in South Korea between January and December 2017. Of these patients, 31 and 61 were included to the heel pressure injury group and the non-heel pressure injury group, respectively. Data on their demographic, disease-related, and intensive care unit treatment characteristics, as well as the degree of pressure injury, were collected from the hospital's electronic medical records using a standardized form. Cardiac surgery ($P < .001$), operation time ($P = .001$), use of a mechanical ventilator ($P < .001$), use of vasoconstrictors ($P < .001$), use of sedative drugs ($P < .001$), and extracorporeal membrane oxygenation treatment ($P < .001$) were identified as significant risk factors for heel pressure injury. A total of 22 patients (71%) from the heel pressure injury group developed deep tissue injury, and 16 patients (51.6%) who received extracorporeal membrane oxygenation treatment developed heel pressure injury.

KEYWORDS

heel pressure injury, risk factors

Key Messages

- the objective of this study was to identify risk factors for heel pressure injury (HPI) in patients with cardiovascular disease
- a retrospective case-control study design was used to sample 92 patients who were admitted to the cardiovascular surgical or medical intensive care unit (ICU) of a university hospital. Patients who developed HPI were assigned to the HPI group; non-HPI group was selected through a random generation program among hospitalised patients without HPI during the same period

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- this study found significant risk factors for heel pressure injury (HPI); cardiac surgery, operation time, use of a mechanical ventilator, use of vasoconstrictors, use of sedative drugs, body temperature at ICU admission, and extracorporeal membrane oxygenation treatment
- the results of this study lay the groundwork for the development of HPI-preventive nursing interventions for patients with cardiovascular disease

1 | INTRODUCTION

The heel is a body part with limited subcutaneous tissue and an area where pressure is directly applied to the bone. It constitutes the extremity of the arterial plexus, which leads to the posterior tibial artery and peroneal artery. Moreover, it has a layer of fat with no blood vessels, making it vulnerable to ischaemia. The panniculus carnosus muscles in its subcutaneous layer are metabolically active tissues involved in the early course of pressure injury (PI).¹ Because of the heel's anatomical and physiological characteristics, it is underprotected by damage from pressure and shear forces.²

According to a global systematic review and meta-analysis, PI has a prevalence rate of 12.8%(95% CI 11.8-13.9%) in all groups and 8.4%(95% CI 7.6-9.3%) in hospitalised patients, most affected body sites were sacrum 37.3%(95% CI 36.1-38.6%), heels 29.5%(95% CI 22.2-37.3%), and hip 7.8%(CI 3.0-14.4%).³ A study found that 9% of all PIs were classified as deep tissue pressure injury (DTPI), with one-third of them involving the heel.⁴ The National Pressure Ulcer Advisory Panel (NPUAP) defined PI and classified it as follows: Stage 1 to 4, unstageable full-thickness pressure injury, deep tissue pressure injury, medical device-related pressure injury, mucosal membrane pressure injury.⁵ DTPI is persistent non-blanchable deep red, maroon, or purple discoloration. DTPIs present intact surface of skin similar to stage 1, but it often evolves to ulceration.² Heel pressure injury (HPI) can be determined that it occur to worsen.

Numerous variables are regarded as risk factors for PI. A systematic literature review classified the risk factors into five conceptual frameworks, with the specific domains being mechanical boundary conditions, immobility, susceptibility and tolerance of the individual, poor perfusion, and skin injury/PI status.⁶ Another systematic review categorised the risk factors under the following domains: mobility/activity, skin/pressure ulcer status, and perfusion.⁷ Coleman et al. identified the risk factors according to the following sub-domains: haematological measures, moisture, body temperature, nutrition, age, sensory perception, mental health status, race, sex, general health status, and medication.⁷ Although a plethora of studies about the risk factors for PI exist, they present

varying opinions on the significance of PI development. Especially a recent study refined HPI risk factors: Diabetes mellitus, vascular disease, perfusion issues, impaired nutrition, age, mechanical ventilation, and surgery.⁸

Patients with cardiovascular disease are suspected to be more vulnerable to PI owing to their risk of exposure to low perfusion and hypoxia. Hypotension can be an indicator of poor blood flow to tissues and has been demonstrated to be a significant risk factor for PI.^{9,10} Moreover, heart disease and heart failure could cause low perfusion and have also been identified as risk factors for PI.¹¹⁻¹³

Treatment with extracorporeal membrane oxygenation (ECMO), which is currently being applied in patients with heart disease or other medical/surgical problems, is also closely related to PI. ECMO treatment in adults requires placement of a large-bore catheter (21-23 Fr) on the surface of the body. Peripheral cannulation is the most common approach to initiating ECMO support in cardiogenic shock, cardiopulmonary arrest, and acute myocardial infarction. The femoral artery and vein are the preferred sites for cannulation as the large size of adult femoral vessels allows for technical ease of the procedure.¹⁴ The primary disadvantage of peripheral cannulation via the femoral artery is the interference of distal flow to the cannulated limb. Moreover, positioning-related bleeding commonly occurs in ECMO treatment or removal.¹⁵ In particular, if a patient's movement does not reach the target ECMO flow and bleeding occurs as a result of the catheter's vascular stimulation, then the patient's body position becomes further restricted and the likelihood of floating PI increases. In addition, maintaining ECMO can efficiently supply blood to organs such as the head and heart but can restrict blood flow to organs that are less sensitive to the vasculature, such as the skin and skeletal muscle.¹⁶ Thus, patients on ECMO maintenance may have an increased risk of developing PI, particularly on the heel. Some patients with acute coronary syndrome undergoing intra-aortic balloon pump (IABP) treatment also need to maintain an immovable posture using a thick catheter in the femoral area. Few studies related to PI in patients on IABP maintenance have been reported, with one study reporting that 9 of 36 patients (25%) who had undergone IABP treatment developed PI, of whom 2 developed it on the heel.¹⁷

European Pressure Ulcer Advisory Panel (EPUAP), National Pressure Injury Advisory Panel (NPIAP), and Pan Pacific Pressure Injury Alliance (PPPIA) updated Prevention and Treatment of Pressure Ulcers/Injuries Clinical Practice Guideline.¹⁸ The guideline includes heel pressure injuries prevention strategies. They mainly recommended heel assessment, offloading the heel. It was suggested using heel suspension device or pillow/foam cushion, prophylactic dressing as an adjunct to heel offloading.¹⁸ A recent systematic review and meta-analysis by Lovegrove et al investigated nine interventions: continence management, heel protection devices, medication, nutrition, positioning, prophylactic dressings, support surfaces, topical preparations, and bundled interventions. Only support surface, heel protection device demonstrated a significant effect.¹⁹

In this study, we aimed to identify the risk factors for HPI among cardiovascular intensive care unit (ICU) patients. Many studies have investigated intrinsic and extrinsic factors

of HPI, but few studies have been conducted on the relationship with special medical treatment like ECMO. We compared the risk of HPI and the presence or absence of special treatment for the femoral vessels as variables of interest, which were determined through literature review. The risk factors identified in this study may be of value in the classification of patient groups at a high risk of developing HPI and can be used for informing HPI-preventive nursing interventions.

2 | MATERIALS AND METHODS

2.1 | Study design and setting

This was a retrospective case-control study of 92 critically ill patients who were admitted to the cardiovascular surgical ICU or coronary care unit (CCU) of an acute care hospital in South Korea with a capacity of >2000 beds

TABLE 1 Comparison of demographic and disease-related characteristics between the study groups (N = 92)

Variables	Categories	HPI group (n = 31) n(%) or M ± SD	Non-HPI group (n = 61) n(%) or M ± SD	χ^2 or t or F	P
Gender	Male	21 (67.7)	29 (47.5)	3.38	.079
	Female	10 (32.3)	32 (52.5)		
Age(years)	≥65	19 (61.3)	38 (62.3)	.009	1.000
	<65	12 (38.7)	23 (37.7)		
Height (cm)		164.16 ± 7.16	161.44 ± 6.70	1.379	.171
Weight (kg)		61.31 ± 14.03	62.62 ± 12.66	-.455	.651
BMI (Kg/m ²)		23.54 ± 7.81	24.04 ± 4.52	-.393	.695
	<18.5	5 (16.1)	6 (9.8)	.813	.370
	15.5 to 24.9	16 (51.6)	32 (52.5)		
	25 to 30	9 (29.0)	17 (27.9)		
	30 to 40	0	5 (8.2)		
	>40	1 (3.2)	1 (1.6)		
Diagnosis	Coronary artery disease	19 (61.3)	38 (62.3)	.009	1.000
	Valvular disease	12 (38.7)	23 (37.7)	3.440	.057
	Aortic artery disease	3 (9.7)	3 (4.9)	.764	.323
	Congenital heart disease	3 (9.7)	1 (1.6)	3.193	.109
	Peripheral artery obstructive disease	1 (3.2)	0 (0)	1.989	.337
Comorbidities	Hypertension	16 (51.4)	44 (72.1)	3.815	.065
	Diabetes mellitus	11 (35.5)	23 (37.7)	.044	1.000
	Neuropathy	3 (9.7)	3 (4.9)	.764	.323
	Haemodialysis	10 (32.3)	9 (14.8)	8.261	.061
	Paralysis	2 (6.5)	0 (0)	4.158	.106
	Stroke	2 (6.5)	4 (6.6)	.000	1.000
	Arthritis	0	5 (8.2)	2.687	.163
Spinal cord injury	2 (6.5)	0	4.023	.111	

Abbreviations: BMI, body mass index; HPI, heel pressure injury; M, mean.

between January and December 2017. The inclusion criteria were age ≥ 19 years and an ICU stay of >3 days. The exclusion criteria were contemplation of discontinuing and actual discontinuation of life-sustaining treatment. The HPI group included 31 patients who developed HPI during their ICU stay, whereas the non-HPI group included 61 patients who did not develop HPI. Non-HPI group was selected through a random generation program among hospitalised patients without HPI during the same period.

2.2 | Data collection

All patients' data were collected from the hospital's electronic medical records system using a standardised form.

To maintain consistency in reviewing the patients' records, we assigned a trained researcher to collect the data and another one to confirm the adequacy thereof. The data were classified according to demographic information, disease-related characteristics, ICU stay parameters, and HPI stages.

Demographic information included sex, age, height, weight, and body mass index. Disease-related characteristics consisted of medical diagnosis and comorbidities. ICU stay parameters encompassed cardiac surgery, cardiac intervention, time in surgery/intervention, Braden scale score, laboratory data (haemoglobin, serum creatinine, and serum albumin levels), use of a mechanical ventilator, use of vasopressors, use of sedative drugs, use of steroids, and special treatment (ECMO treatment, IABP treatment,

TABLE 2 Comparison of ICU treatments between the study groups (N = 92)

Variables	Categories	HPI group (n = 31) n(%) or M \pm SD	Non-HPI group (n = 61)	χ^2 or t	P
Cardiac surgery	Yes	18 (58.1)	10 (16.4)	16.858	<.001
	No	13 (41.9)	61 (83.6)		
Cardiac Intervention	Yes	9 (29.0)	28 (45.9)	2.433	.090
	No	22 (71.0)	33 (54.1)		
Surgery Time(min)		296.480 \pm 196.74	131.82 \pm 176.21	3.465	.001
Braden scale		16.97 \pm 3.66	18.13 \pm 3.29	-1.543	.126
Body temperature($^{\circ}$ C)		36.01 \pm 1.08	36.53 \pm .91	-2.412	.018
Laboratory data	Haemoglobin (g/dL)	11.18 \pm 2.88	11.71 \pm 2.56	-.895	.373
	Serum creatinine(mg/dL)	2.60 \pm 2.63	1.95 \pm 2.11	1.280	.204
	Serum albumin (mg/dL)	3.03 \pm .66	3.23 \pm .67	-1.418	.160
Use of mechanical ventilator	Yes	31 (100)	34 (55.7)	19.421	<.001
	No	0	27 (44.3)		
Use of vasopressor	Yes	29(93.5)	34 (55.7)	13.614	<.001
	No	2(6.5)	27 (44.3)		
Type of vasopressor	Vasopressin	17 (54.8)	5 (8.2)	24.576	<.001
	Norepinephrine	29 (93.5)	34 (55.7)	13.614	<.001
Use of sedative drugs	Yes	30 (96.8)	30 (49.2)	20.525	<.001
	No	1 (3.2)	31 (50.8)		
Use of steroids	Yes	14 (45.2)	16 (26.2)	3.352	.099
	No	17 (54.8)	45 (73.8)		
Special treatment	ECMO	15 (48.4)	16 (26.2)	31.2661	<.001
	IABP	2 (6.5)	1 (1.6)	1.509	.262
	CRRT	7 (22.6)	7 (11.5)	1.965	.220
	Lumbar puncture catheter	1 (3.2)	1 (1.6)	.243	1.000
	no treatment	15(48.4%)	58 (95.1)	27.349	<.001

Abbreviations: CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; HPI, heel pressure injury; IABP, intra-aortic balloon pump; ICU, intensive care unit; M, mean.

continuous renal replacement treatment, or lumbar puncture catheterization).

2.3 | Statistical analysis

Statistical analysis was conducted using SPSS/WIN 23.0. The statistical significance of the variables (demographic information, disease-related characteristics, and ICU stay parameters) was evaluated using independent *t* test, χ^2 test, and analysis of variance. The HPI stages were analysed using descriptive statistics. Data were expressed as frequencies (percentages) or mean \pm standard deviation values as appropriate.

2.4 | Ethical considerations

This study was approved by the hospital's Institutional Review Board (deliberation number: 4-2018-0741). Patients' personal information, other than the data corresponding to approval limits, was not collected. The study groups were formed by assigning a non-personally identifiable management number to each patient, and all data were stored in a password-protected computer file.

TABLE 3 Heel pressure injury characteristics in the HPI group

	Categories	n(%) or M \pm SD
First detected day of HPI during ICU stay	Average day of first detection	13.16 \pm 19.16
	0 to 3 days	7 (22.6)
	4 to 10 days	12 (38.7)
	11 to 30 days	10 (32.3)
	31st day	2 (6.5)
First stage of HPI	Stage I	2 (6.5)
	Stage II	5 (16.1)
	Stage III	0
	Stage IV	0
	Unstageable	2 (6.5)
	DTPI	22 (71.0)
HPI site	Single heel	25 (80.6)
	Both heel	6 (19.4)
Special treatment at HPI site	ECMO	16 (51.6)
	CRRT	7 (22.6)
	No treatment	8 (25.8)

Abbreviations: CRRT, continuous renal replacement therapy; DTPI, deep tissue pressure injury; ECMO, extracorporeal membrane oxygenation; HPI, heel pressure injury; ICU, intensive care unit; M, mean.

3 | RESULTS

This study compared cardiovascular surgical ICU/CCU patients who developed HPI (HPI group; $n = 31$) with those who did not develop HPI (non-HPI group; $n = 61$). Table 1 presents the results of the comparison of the demographic and disease-related characteristics between these groups, with the differences being statistically insignificant. By contrast, as demonstrated in Table 2, the differences between the groups in terms of the following ICU stay parameters were statistically significant ($P < .05$), surgery time ($P = .01$), body temperature at the time of ICU admission ($P < .018$), use of a mechanical ventilator ($P < .001$), use of vasopressors ($P < .001$), use of sedative drugs ($P < .001$), and ECMO treatment ($P < .001$).

Table 3 summarises the characteristics of HPI among the patients. HPI developed an average of 13.16 days after ICU admission. DTPI comprised the highest proportion (71%) of HPIs. Six patients (19.4%) developed HPI on both heels; moreover, 16 (51.6%) receiving ECMO treatment and 7 (22.6%) on continuous renal replacement therapy developed HPI.

4 | DISCUSSION

No significant difference was found between the HPI and non-HPI groups in the demographic and disease-related characteristics. We identified the following risk factors that contributed to the patients' HPI development during surgical ICU/CCU stay: cardiac surgery, surgery time, body temperature at the time of ICU admission, use of a mechanical ventilator, use of vasopressors, use of sedative drugs, and ECMO treatment. Delmore et al refine predictors of HPI; seven variables were significant associated with HPIs: diabetes mellitus, vascular disease, perfusion issues, impaired nutrition, age, mechanical ventilation, and surgery.⁸ 'Perfusion issues', 'mechanical ventilation', 'surgery' were the same result in Delmore's research. In this study, we focused on cardiovascular ICU patients who could be exposed to the risk of hypoperfusion and whose medical diagnosis did not show significant differences in PI. Delmore et al defined 'perfusion issues' following evidence: cardiovascular disease class IV, dehydration, oedema, hereditary oedema of legs, heparin-induced thrombocytopenia, myocardial infarction diagnosed during admission, severe anaemia (haemoglobin < 7 g/dL), cardiac arrest sustained during current admission, prolonged hypotension-unspecified, postoperative, because of shock from injury, cardiogenic shock, hypovolemic shock, and haemorrhagic shock. This study controlled 'perfusion issues' as variables; almost all patients had perfusion issues.

Patients undergoing cardiac surgery are a high-risk population. Pressure exposure during prolonged surgery and hypotension because of cardiopulmonary bypass (CPB) and blood loss can cause pressure injuries.²⁰ Some cardiac surgeries require cardiopulmonary bypass, which provides oxygenated systemic blood flow to patients intraoperatively. Cardiopulmonary bypass (CPB) is accompanied by non-pulsatile flow, which could lead to disturbances in microcirculatory perfusion and affect skin tissue perfusion, thereby making patients more vulnerable to PI.^{21,22} Moreover, body temperature, which is another risk factor for HPI identified in this study and in previous research, decreases during cardiac surgery.²³ Another study suggested that patients with therapeutic hypothermia should be considered to be at high risk for pressure ulcer development.²⁴ Rao et al identified risk factors associated with PI development in cardiac surgery. Variables are classified into three categories: preoperative risk factors, intraoperative risk factors, and postoperative risk factors. In this study, as in Rao's study, use of vasopressors, mechanical ventilation, and application of sedative drugs are also significant variables.²⁵

Certain ICU treatments can be regarded as risk factors for HPI, including mechanical ventilation, use of vasopressors, and use of sedative drugs, which are supported by previous systematic reviews.^{20,25,26} Research on mechanical ventilation has confirmed that the use of a ventilator for 72 hours has a significant effect on the occurrence of PI.²⁷ The relationship between mechanical ventilation and PI can be attributed to the prolonged duration of patient immobility under mechanical ventilation. Immobility was an independent risk factor in previous study.⁸ Similarly, orthopaedic patients have been identified as a high-risk population for the development of HPI.^{28,29} If a patient is maintained on mechanical ventilation, then such a patient is likely to be in a severe state of illness. Without controversy, previous studies have demonstrated that the use of vasoconstrictors, such as norepinephrine and vasopressin, plays a crucial role in the occurrence of PI as these agents facilitate the contraction of peripheral blood vessels and can lead to ischaemia of peripheral tissues.^{11,25,30,31}

Recently, many patients in the intensive care unit (ICU) are receiving ECMO or similar device. Intravascular catheterization of blood vessels like ECMO or IABP can inhibit blood flow to the lower extremities. Peripheral cannulation is probably the most common approach to initiating ECMO treatment,¹⁴ for which the femoral artery and vein are the preferred sites for percutaneous venous access. In adults, 17- or 19-Fr cannulas (e.g., Maquet HLS Cannula; diameter, 5.7-6.3 mm) and 21- or 23-Fr cannulas (e.g., Maquet HLS Cannula; diameter, 7-7.7 mm) are typically used for femoral artery cannulation and femoral venous cannulation, respectively. The average diameter of the common femoral artery is 6.6 ± 1.2 mm,³² whereas that of the common femoral

vein at rest is 11.84 mm.³³ Considering the ratio between the diameter of the femoral artery and that of the femoral vein, it can be inferred that the diameter of the catheter required is significantly large, which may reduce blood flow to the lower extremities. A decrease in blood flow may, in turn, increase the risk of PI.

In this study, a significant number of DTPIs were recorded. It is expected that many DTPIs are because of low blood flow, which is a characteristic of people with heart disease.

The severity of ICU patients is different, and resources in ICU are limited. It is important to identify the patient group at high risk of PI and provide guidelines to implement preventive interventions with more interest. Nurses can pay more attention to identifying high-risk patients.

This study has limitations in that a small number of study groups were selected in a limited time and limited ICU.

5 | CONCLUSION

In summary, this study found that cardiac surgery, operation time, use of a mechanical ventilator, use of vasoconstrictors, use of sedative drugs, body temperature at ICU admission, and ECMO treatment are significant risk factors for HPI. Our findings can be used to create nursing interventions that aim to prevent HPI in cardiovascular surgical ICU/CCU patients who are particularly at a high risk of developing it.

ACKNOWLEDGEMENTS

This research did not receive any specific grants from any funding agency in the public, commercial, or not-for-profit sector.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated, or the article describes entirely theoretical research

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How to cite this article: Lee HJ, Han MY, Hwang JH, et al. Risk factors for heel pressure injury in cardiovascular intensive care unit patients. *Int Wound J*. 2022;19(5):1158-1164. doi:10.1111/iwj.13711