Relationship between predisposing and facilitating factors: Does it influence the risk of developing peri-operative pressure injuries?

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Abstract
This study examined the relationship between the personal predisposing factors of patients and the severity of pressure injuries (PIs) developed during surgery. This retrospective cohort study collected 439 cases of peri-operative PIs. Using binary logistic regression to identify the variables associated with PI severity, the effects of interactions between associated variables were then tested. The results of this study revealed that among the personal predisposing factors, only higher patient age (P = .001) and higher body mass index (P < .001) posed a greater risk of stage 2 PIs or higher. Among the surgery-related facilitating factors, only patients who were placed in the prone position during surgery and patients who lost ≥1000 mL of blood during surgery were at greater risk of stage 2 PIs or higher, compared, respectively, to those placed in the supine position and those who lost ≤100 mL of blood. Furthermore, the amount of blood lost during surgery moderated the influence of age on PI severity. For elderly patients who are expected to lose a large blood volume during surgery or lose an immeasurable amount of blood due to the use of cardiopulmonary bypass, taking more precautionary measures to prevent PIs is recommended.

Keywords
decubitus ulcer, multifactorial causality, peri-operative period, predisposing factors, pressure ulcer

Key Messages
• factors that influence the formation of peri-operative pressure injuries (PIs) are complex
• the predisposing factors of patient health, there are also facilitating factors that cause PIs during surgery
• peri-operative PI severity increased with patient age, and patients who lost 1000 mL of blood during surgery suffered more severe PI than those who lost 100 mL, and the amount of blood lost during surgery moderated the influence of age on PI severity
INTRODUCTION

In 2016, the National Pressure Ulcer Advisory Panel of the United States held a consensus conference that changed the term pressure ulcer to pressure injury (PI) and revised the definition of PIs and their staging. A PI is defined as ‘localized damage to the skin and underlying soft tissue usually over a bony prominence or related to a medical or other device. The injury can present as intact skin or an open ulcer and may be painful. The injury occurs as a result of intense and/or prolonged pressure or pressure in combination with shear. The tolerance of soft tissue for pressure and shear may also be affected by microclimate, nutrition, perfusion, co-morbidities and condition of the soft tissue’. Based on the definition of PI formation, surgical patients are at greater risk of PIs during surgery due to loss of sensation and immobility. Known as peri-operative PIs, they refer to pressure-induced injuries to local tissue from various causes during surgery. Although inpatients with limited mobility are at increased risk of PIs, the risk is even greater in patients who have been anaesthetised for surgery. However, the incidences of peri-operative PIs obtained in studies have varied widely, from 12% to 66%. Scott and Buckland noted that peri-operative PIs account for over 40% of all inpatient PIs.

The treatment of peri-operative PIs depends on the stage and severity of the PI. The discovery of any local redness in the skin requires immediate elimination or dispersion of pressure on the reddened skin to prevent further injury. The formation and thus treatment of PIs lengthen a patient’s hospital stay, increase medical costs, and even exert an adverse effect on the quality of care in the hospital. For these reasons, preventing PI formation, especially severe PIs, is extremely crucial.

The factors that influence peri-operative PI formation are complex, which mainly include predisposing factors that affect personal health, such as age, gender, comorbidities (eg, diabetes, cancer, or nervous system diseases), malnutrition or obesity, anaemia, and smoking, as well as facilitating factors, which refer to factors that exacerbate PIs during surgery, such as the method of anaesthesia, the duration of anaesthesia, the amount of blood loss, and patient positioning.

The above discussion demonstrates that both facilitating factors during surgery and personal predisposing factors influence the severity of PIs in patients. Some predisposing factors such as patient age and overall health status cannot be controlled; thus, risk factors that can be controlled by the medical team in the operating room are paramount. Facilitating factors and personal predisposing factors are significantly associated with PI severity; however, there has been no research on whether interactions exist between these factors. We, therefore, investigated whether any significant moderating variables exist in the relationship between the predisposing factors of the patients and the severity of PIs occurring during patient surgery and whether any factors during surgery increase the severity of PIs in patients with risk attributes. In other words, we examined whether facilitating factors during surgery moderate the influence of personal predisposing factors on the severity of peri-operative PIs.

MATERIALS AND METHODS

Design and participants

We collected patient cases from a teaching hospital in northern Taiwan. A retrospective cohort study design was adopted using the hospital’s Adverse Event Reporting System (AERS). We selected patients who were recognised as having peri-operative PIs in the AERS between 1 June 2014, and December 31 2021. To confirm the integrity of the patients’ skin before surgery, we excluded patients who were already suffering from existing PIs before surgery.

Sample size

Binary logistic regression analysis was performed using the statistical software program G-power to determine the number of samples needed for this study. For a type-I error of 5%, a power of 80%, and an odds ratio (OR) of 2.5, we estimated that at least 434 samples were needed; as such, 439 samples were included in this study.

Data collection

We first searched the AERS of the hospital to obtain the medical record number, date of PI occurrence, and PI-related data of the patients with peri-operative PIs and then used the medical record numbers to obtain their data in the electronic medical record (EMR) system. We prepared a structured survey to collect data, including personal data, surgical data, and PI report data.

Personal data

This included age, gender, haemoglobin levels 3 days before surgery, body mass index (BMI) within 3 days before surgery, smoking habits, and medical history (ie, cancer, diabetes, and cerebrovascular accident). We obtained the above data from the EMR system.
2.3.2 | Surgical data

Surgical data included the method of anaesthesia, the duration of anaesthesia, patient positioning, and the amount of blood loss. The method of anaesthesia included general anaesthesia and local anaesthesia. The duration of anaesthesia referred to the length of time from the beginning to the end of anaesthesia. Patient positioning included the supine position, lateral position, prone position, and lithotomy or orthopneic position. Furthermore, heart or vascular surgery often involves cardiopulmonary bypass (CPB), in which hemoperfusion is conducted outside of the body, thereby requiring anticoagulants to prevent the formation of blood clots. Such procedures are often more time-consuming, and the amount of blood loss is greater and cannot be estimated. We, therefore, divided the amount of blood loss into ≤100 mL, 101 to 999 mL, ≥1000 mL, and immeasurable due to the use of CPB. We obtained the above data from the surgical records in the EMR system.

2.3.3 | PI report data

The AERS stages PIs based on the PI stages defined by the National Pressure Injury Advisory Panel. Based on the extent of damage caused to the blood supply to tissues, PIs are divided into six stages. Stage 1 PIs present intact skin that remains locally reddened 30 minutes after pressure has been removed. Stage 2 PIs show pink wounds or blisters with some damage to the epidermis. Stage 3 PIs refer to full-thickness skin damage that reveals subcutaneous fat but not any bone, tendons, or muscles. Stage 4 PIs show full-thickness skin tissue damage revealing bone, tendons, or muscles. Unstageable PIs present full-thickness skin or tissue damage with the wounds completely covered by slough or eschar. Deep tissue pressure injuries show locally purple or maroon skin or blood-filled blisters. As stage 1 PIs have intact skin, immediately removing or dispersing the pressure on the reddened skin can prevent further injury. PIs over stage 1, however, have damaged skin, and therefore,

| Predictors | All | Stage 1 | Stage 2 or higher | P  |
|------------|-----|---------|------------------|----|
| Number of patients (n [%]) | 439 (100) | 244 (55.6) | 195 (44.4) |    |
| Personal predisposing factors |       |         |                  |    |
| Age (y, mean [SD]) | 64.40 (14.86) | 60.68 (15.56) | 69.06 (12.50) | <.001 |
| Male (n [%]) | 341 (77.7) | 184 (75.4) | 157 (80.5) | .202 |
| Haemoglobin level (g/dL, mean [SD]) | 12.61 (2.08) | 12.35 (2.07) | 12.93 (2.05) | .003 |
| BMI (kg/m², mean [SD]) | 24.50 (5.55) | 22.76 (4.97) | 26.68 (5.47) | <.001 |
| Smoking (n [%]) | 129 (29.4) | 70 (28.7) | 59 (30.3) | .720 |
| Cancer (n [%]) | 159 (36.2) | 94 (38.5) | 65 (33.3) | .261 |
| Diabetes (n [%]) | 117 (26.7) | 61 (25.0) | 56 (28.7) | .381 |
| Cerebrovascular accident (n [%]) | 51 (11.6) | 29 (11.9) | 22 (11.3) | .845 |

Surgery-related facilitating factors

| Patient positioning (n [%]) |       |         |                  |    |
| Supine position | 288 (65.6) | 192 (78.7) | 96 (49.2) | <.001 |
| Lateral position | 27 (6.2) | 16 (6.6) | 11 (5.6) |    |
| Prone position | 105 (23.9) | 22 (9.0) | 83 (42.6) |    |
| Lithotomy or orthopneic position | 19 (4.3) | 4 (1.7) | 5 (2.6) |    |
| Amount of blood loss (n [%]) |       |         |                  | <.001 |
| ≤100 mL | 117 (26.7) | 77 (31.6) | 40 (20.5) |    |
| 101–999 mL | 205 (46.7) | 126 (51.6) | 79 (40.5) |    |
| ≥1000 mL | 80 (18.2) | 15 (6.1) | 65 (33.4) |    |
| Immeasurable | 37 (8.4) | 26 (10.7) | 11 (5.6) |    |
| Duration of anaesthesia (min, mean [SD]) | 540.51 (283.20) | 510.27 (276.46) | 578.36 (287.68) | .012 |

Abbreviation: BMI, body mass index.
require a longer time for recovery or wound care. The PI records in this study were based on observations of a patient’s skin 30 minutes after surgery and were divided into two groups for analysis: stage 1 and stage 2 or higher.

2.4 Ethical considerations

This study was reviewed and approved by the Taipei Medical University—Joint Institutional Review Board (TMU-Joint IRB) before data collection began (Project No. N202106059). During this process, we explained to the hospital our study objective and method of collection before collecting data and then gained approval to collect data from the AERS and the EMR systems without the need for patients to sign consent forms. Codes replaced the name and medical record number of each patient in each data survey, and the code name list and data survey were stored separately. Only the researchers could access the data obtained for this study, and the content was for research purposes only to ensure that the treatment and care rights of the patients were not affected.

2.5 Data analysis

We computer-coded and filed the data and then performed statistical analyses using SPSS 25.0 for Windows. Quantity, mean, percentage, and standard deviation were used to describe the personal predisposing factors and surgery-level data of the collected cases. We then conducted independent sample t-tests and chi-square tests to compare the personal predisposing factors and surgery-related facilitating factors of patients with PIs of varying severity. To understand the impact of personal predisposing factors and surgery-related facilitating factors on the severity of PIs in patients, we first analysed all of the personal predisposing factors (including age, gender, haemoglobin level, BMI, smoking, cancer diabetes, and cerebrovascular accident) and surgery-related facilitating factors (including patient positioning, amount of blood loss, and duration of anaesthesia) and then conducted multiple analyses of variance (MANOVAs) to analyse the interaction effects of the factors. We then selected the factors with a signiificant effect size as the independent variables for logistic regression analysis. We used SPSS 25.0 for Windows to perform the logistic regression analyses.

### Table 2: Logistic regression analysis of variables influencing PI severity in patients (N = 439)

| Independent variable                  | B     | OR (95% CI) | Wald's $\chi^2$ | P     | OR (95% CI) | Wald's $\chi^2$ | P     |
|--------------------------------------|-------|-------------|-----------------|-------|-------------|-----------------|-------|
| Personal predisposing factors        |       |             |                 |       |             |                 |       |
| Age                                  | 0.03  | 1.04 (1.02–1.05) | 13.43           | <.001 | 0.03        | 1.03 (1.01–1.05) | 10.28 | .001 |
| Male                                 | 0.15  | 1.16 (0.65–2.08) | 0.26            | .610  |             |                 |       |      |
| Haemoglobin level                    | 0.03  | 1.03 (0.92–1.16) | 0.32            | .572  |             |                 |       |      |
| BMI                                  | 0.09  | 1.10 (1.04–1.15) | 13.19           | <.001 | 0.10        | 1.10 (1.05–1.16) | 16.41 | <.001|
| Smoking                              | 0.47  | 1.60 (0.94–2.72) | 2.96            | .086  |             |                 |       |      |
| Cancer                               | 0.02  | 1.02 (0.56–1.85) | 0.003           | .959  |             |                 |       |      |
| Diabetes                             | −0.004| 1.00 (0.59–1.67) | 0.003           | .987  |             |                 |       |      |
| Cerebrovascular accident             | −0.03 | 0.97 (0.48–1.95) | 0.01            | .927  |             |                 |       |      |
| Surgery-related facilitating factors |       |             |                 |       |             |                 |       |      |
| Patient positioning                  |       |             |                 |       |             |                 |       |      |
| Supine position                      | Ref.  |             |                 |       |             |                 |       |      |
| Lateral position                     | 0.46  | 1.58 (0.63–3.93) | 0.96            | .327  | 0.36        | 1.44 (0.60–3.46) | 0.66  | .417 |
| Prone position                       | 1.27  | 3.56 (1.81–7.00) | 13.53           | <.001 | 1.20        | 3.31 (1.80–6.09) | 14.90 | <.001|
| Lithotomy or orthopneic position     | −0.03 | 0.97 (0.32–2.97) | 0.003           | .954  | −0.12       | 0.89 (0.30–2.66) | 0.05  | .833 |
| Amount of blood loss                 |       |             |                 |       |             |                 |       |      |
| ≤100 mL                              | Ref.  |             |                 |       |             |                 |       |      |
| 101–999 mL                           | −0.10 | 0.90 (0.51–1.60) | 0.13            | .723  | −0.003      | 1.00 (0.59–1.70) | 0.001 | .992 |
| ≥1000 mL                             | 1.33  | 3.79 (1.73–8.31) | 11.07           | 0.001 | 1.43        | 4.19 (1.98–8.86) | 14.07 | <.001|
| Immeasurable                         | −0.29 | 0.74 (0.31–1.81) | 0.41            | .520  | −0.24       | 0.79 (0.34–1.85) | 0.30  | .585 |
| Duration of anaesthesia              | 0.001 | 1.00 (1.00–1.002) | 3.57            | .059  |             |                 |       |      |

Note: PI severity was the predictor variable.

Abbreviations: B, unstandardised coefficients; BMI, body mass index; CI, confidence interval; OR, odds ratio; PI, pressure injury; Ref., refers to reference group.
blood loss, and duration of anaesthesia) using binary logistic regression to identify the variables associated with PI severity. We then conducted binary logistic regression analysis using the aforementioned associated personal predisposing factors and surgery-related facilitating factors to determine whether these factors interacted with PI severity. We, therefore, added the interaction term of the two to the logistic regression model. A significant interaction meant that the surgery-related facilitating factor had a moderating effect on the influence of the personal predisposing factor on PI severity. Statistical significance was determined using $P < .05$.

**TABLE 3** Moderating effects of surgery-related facilitating factors on influence of personal predisposing factors on PI severity (N = 439)

| Independent variable | $B$       | OR (95% CI) | Wald's $\chi^2$ | $P$  |
|----------------------|-----------|-------------|-----------------|------|
| **Personal predisposing factors** |           |             |                 |      |
| Age                  | $-0.001$  | $1.00 (0.97–1.03)$ | $0.01$         | $.944$ |
| BMI                  | $0.15$    | $1.16 (1.05–1.28)$ | $8.31$         | $.004$ |
| **Surgery-related facilitating factors** |           |             |                 |      |
| **Patient positioning** |           |             |                 |      |
| Supine position      | Ref.      |             |                 |      |
| Lateral position     | $-4.62$   | $0.01 (0.001–32.47)$ | $1.25$         | $.264$ |
| Prone position       | $1.89$    | $6.61 (0.01–4665.34)$ | $0.32$         | $.573$ |
| Lithotomy or orthopneic position | $-0.58$ | $0.56 (0.001–2246.97)$ | $0.02$         | $.892$ |
| **Amount of blood loss** |           |             |                 |      |
| $\leq 100$ mL        | Ref.      |             |                 |      |
| $101–999$ mL         | $0.87$    | $2.39 (0.07–77.50)$ | $0.24$         | $.623$ |
| $\geq 1000$ mL       | $-11.64$  | $0.001 (0.001–0.41)$ | $4.51$         | $.034$ |
| Immeasurable         | $-13.01$  | $0.001 (0.001–0.97)$ | $3.86$         | $.050$ |
| **Interaction terms of personal and surgery-related factors** |           |             |                 |      |
| Age $\times$ patient positioning |           |             |                 |      |
| Supine position      | Ref.      |             |                 |      |
| Lateral position     | $0.03$    | $1.03 (0.96–1.12)$ | $0.74$         | $.390$ |
| Prone position       | $0.12$    | $1.01 (0.94–1.09)$ | $0.10$         | $.747$ |
| Lithotomy or orthopneic position | $0.03$ | $1.03 (0.95–1.12)$ | $0.51$         | $.477$ |
| Age $\times$ amount of blood loss |           |             |                 |      |
| $\leq 100$ mL        | Ref.      |             |                 |      |
| $101–999$ mL         | $0.01$    | $1.01 (0.98–1.05)$ | $0.48$         | $.490$ |
| $\geq 1000$ mL       | $0.12$    | $1.13 (1.04–1.23)$ | $7.93$         | $.005$ |
| Immeasurable         | $0.19$    | $1.21 (1.06–1.39)$ | $7.90$         | $.005$ |
| BMI $\times$ patient positioning |           |             |                 |      |
| Supine position      | Ref.      |             |                 |      |
| Lateral position     | $0.12$    | $1.13 (0.88–1.44)$ | $0.93$         | $.336$ |
| Prone position       | $-0.50$   | $0.95 (0.84–1.08)$ | $0.58$         | $.445$ |
| Lithotomy or orthopneic position | $-0.06$ | $0.94 (0.72–1.22)$ | $0.22$         | $.643$ |
| BMI $\times$ amount of blood loss |           |             |                 |      |
| $\leq 100$ mL        | Ref.      |             |                 |      |
| $101–999$ mL         | $-0.07$   | $0.93 (0.83–1.04)$ | $1.51$         | $.219$ |
| $\geq 1000$ mL       | $0.19$    | $1.21 (0.92–1.58)$ | $1.81$         | $.178$ |
| Immeasurable         | $-0.02$   | $0.98 (0.78–1.24)$ | $0.03$         | $.874$ |

Note: PI severity was the predictor variable.

Abbreviations: $B$, unstandardised coefficients; BMI, body mass index; CI, confidence interval; OR, odds ratio; PI, pressure injury; Ref., refers to reference group.
3 RESULTS

3.1 Personal predisposing factor and surgery-related facilitating factor data

All of the patients with peri-operative PIs received general anaesthesia. As shown in Table 1, regarding the personal predisposing factors, the mean age of the patients with peri-operative PIs was 64.40 (SD = 14.86) years old. In terms of gender, most of the patients were male (341 patients; 77.7%). The mean haemoglobin level of the patients was 12.61 (SD = 2.08) g/dL, and their mean BMI was 24.50 (SD = 5.55) kg/m². Among the patients, 129 (29.4%) had a smoking habit, 159 (36.2%) had cancer, 117 (26.7%) had a cerebrovascular accident. In the surgery-related facilitating factors, over half of the patients (288 patients, 65.6%) were placed in the supine position during surgery. Comparisons of the personal predisposing factor data and surgery-related facilitating factors on the influence of personal predisposing factors and surgery-related facilitating factors on PI severity were presented in Table 2.

In terms of the amount of blood loss, the largest group comprised those who had lost 101 to 999 mL of blood (205 patients, 46.7%), followed by those who had lost ≤100 mL (117 patients, 26.7%).

3.2 Comparison of personal predisposing factors and surgery-related facilitating factors of patients with PIs of varying severity

A total of 244 patients (55.6%) developed stage 1 PIs and 195 patients (44.4%) developed stage 2 or higher PIs during surgery. Comparisons of the personal predisposing factors revealed significant differences between the two patient groups in age (P < .001), haemoglobin level (P = .003), and BMI (P < .001). In surgery-related facilitating factors, the two patient groups presented significant differences in patient positioning (P < .001), amount of blood loss (P < .001), and the duration of anaesthesia (P = .012) (Table 1).

3.3 Influence of personal predisposing factors and surgery-related facilitating factors on PI severity

We considered the relationships between all of the variables and PI severity. The results in Table 2 show that the variables that reached significance included age (B = 0.03, OR = 1.04, P < .001), BMI (B = 0.09, OR = 1.10, P < .001), the prone position in patient positioning (B = 1.27, OR = 3.56, P < .001), and ≥1000 mL in the amount of blood loss (B = 1.33, OR = 3.79, P = .001), meaning that these were the variables associated with PI severity.

We then included the personal predisposing factors age and BMI as well as the surgery-related facilitating factors patient positioning and amount of blood loss into binary logistic regression analysis. This model could successfully explain the PI severity of cases with an accuracy rate of 73.6%. The regression results indicated that the regression coefficient of the following were all significantly positive: age (B = 0.03, OR = 1.03, P = .001), BMI (B = 0.10, OR = 1.10, P < .001), the prone position in patient positioning (B = 1.20, OR = 3.31, P < .001), and ≥1000 mL in the amount of blood loss (B = 1.43, OR = 4.19, P < .001).

3.4 Moderating effects of surgery-related facilitating factors on influence of personal predisposing factors on PI severity

We next tested the moderating effects of the surgery-related facilitating factors on the influence of the personal predisposing factors on PI severity. The results in Table 3 show that only the regression coefficients of ≥1000 mL (B = 0.12, OR = 1.13, P = .005) and immeasurable (B = 0.19, OR = 1.21, P = .005) in age×amount of blood loss reached the level of significance, thereby indicating that when a patient's amount of blood loss was ≥1000 mL or immeasurable, the impact of patient age on PI severity was different from that when the amount of blood loss was ≤100 mL.

| Amount of blood loss | Independent variable | B     | OR (95% CI)      | Wald's χ² | P    |
|---------------------|----------------------|-------|------------------|-----------|------|
| ≤100 mL             | Age                  | 0.01  | 1.01 (0.99–1.03) | 0.72      | .396 |
| 101–999 mL          | Age                  | 0.03  | 1.03 (1.01–1.06) | 6.93      | .008 |
| ≥1000 mL            | Age                  | 0.11  | 1.12 (1.05–1.19) | 12.58     | <.001|
| Immeasurable        | Age                  | 0.17  | 1.18 (1.05–1.33) | 7.88      | .005 |

Note: PI severity was the predictor variable.
Abbreviations: B, unstandardised coefficients; CI, confidence interval; OR, odds ratio.
We then analysed the main effects separately by performing logistic regression analysis on the influence of age on PI severity at varying amounts of blood loss. The results in Table 4 indicate that when a patient’s amount of blood loss was 101 to 999 mL (B = 0.03, OR = 1.03, P = .008), ≥1000 mL (B = 0.11, OR = 1.12, P < .001), or immeasurable (B = 0.17, OR = 1.18, P = .005), the regression coefficient was significantly positive.

4 | DISCUSSION

All of the patients with peri-operative PIs in this study received general anaesthesia. Although past studies have identified a number of causes for peri-operative PIs, the results of this study revealed that among the personal predisposing factors associated with PI severity, only higher patient age and BMI posed a greater risk of stage 2 PIs or higher. After controlling other factors, we found that among the surgery-related facilitating factors associated with PI severity, only patients who were placed in the prone position during surgery were at greater risk of stage 2 PIs or higher compared to those placed in the supine position. Moreover, patients who lost ≥1000 mL of blood during surgery were at greater risk of stage 2 PIs or higher than those who lost ≤100 mL. We also discovered that among the surgery-related facilitating factors, only the amount of blood loss moderated the influence of age on PI severity; when the patient’s amount of blood loss was ≥1000 mL or immeasurable, the impact of patient age on PI severity was greater than that when the amount of blood loss was ≤100 mL.

Similar to our study, Shaw et al. also reported that the development of peri-operative PIs was associated with receiving general anaesthesia. This is likely because patients lose the ability to remove pressure or change their position on their own when they are under general anaesthesia. In PI severity, we found that 55.6% of the patients with peri-operative PIs had stage 1 PIs, which is similar to the proportions described in the literature. For example, Ahmadabad et al observed that 41.4% of the patients who underwent open-heart cardiac surgery and suffered from peri-operative PIs had stage 1 PIs. Furthermore, studies have established a connection between patient age and peri-operative PI occurrence; PIs are more likely to occur as the age of the patient undergoing surgery increases. This is due to the reduced proliferation or decreased number of cells at the surface of the skin as people age. Therefore, age is a primary risk factor for PI development. Indeed, the formation of PIs in patients over the age of 65 heal less easily than those of patients under the age of 65. Moreover, patients over the age of 65 generally have a thinner dermis and are in the process of losing collagen, muscle, and adipose tissue, all of which lower the elasticity of their skin and increase the chance of PI occurrence. The results of this study were consistent with the above findings in previous research. We found that among the personal predisposing factors associated with PI severity, the risk of stage 2 PIs or higher is higher as age increases.

Most researchers believe that a U-shaped relationship exists between BMI and PIs, meaning that the probability of PIs occurring in patients with an abnormally high or low BMI is higher than that in patients with a normal BMI. From a bioengineering perspective, the soft tissues around bony prominences bear greater loads in patients with an abnormally high or low BMI than in those with a normal BMI. In any case, obesity reduces the elastic fibres in the dermis, which lowers the resistance load pressure and shear force of the skin. However, some researchers believe that the opposite is true, whereby individuals with a higher BMI have more subcutaneous fat, which may reduce the mechanical pressure on tissue, prevent local loads, and thereby prevent PIs. The mean BMI of the patients in this study was 24.50 (SD = 5.55) kg/m², and there were no extremely thin patients. Thus, we can only conclude that PI severity increased with a higher BMI.

Choi et al. observed that patients placed in the prone position during surgery were most likely to suffer from PIs, accounting for 63.9% of the PIs resulting from all patient positions. We found that among the various positions in surgery-related facilitating factors, only the prone position resulted in a higher PI severity compared to the supine position. The prone position reduces the venous return and compresses the inferior vena cava in patients, which results in reduced local tissue perfusion. In addition, the prone position is most often used in spine surgery; among such surgeries, spinal fusion leads to blood loss and may lengthen surgery time, thereby increasing PI severity.

We also discovered that after controlling other factors, only an amount of blood loss of ≥1000 mL among surgery-related facilitating factors resulted in greater PI severity compared to an amount of blood loss of ≤100 mL. Past studies have found a strong connection between blood loss and PI occurrence during surgery. Blood loss during surgery lowers the mean arterial pressure of the patient, and anaesthetics affect the patient’s autonomic thermoregulatory responses, which lowers their body temperature and vasoconstriction and in turn reduces soft tissue perfusion, particularly where there is continuous pressure.

We also found that when patients undergo CPB during surgery, which causes an immeasurable amount of blood loss, the impact of age on PI severity becomes even greater than that in patients who lost ≥1000 mL of blood loss during surgery increases.
During surgery, this is because heart and major vessel surgeries require CPB to temporarily replace the heart and lung of the body in blood circulation and respiration, which involves diverting venous blood out of the body to undergo CPB processing and then injecting it back into the patient’s arterial or venous system to maintain the oxygen supply of the body’s other organs and tissues. During CPB, anticoagulants and large quantities of solutions are used, which lead to blood thinning, fibrinolysis, platelet dysfunction, and coagulation factor consumption. At the same time, there is also systemic hypothermia and reduced blood flow to organs that are not sensitive to increases in perfusion pressure, such as skin and skeletal muscle. As a result, patients undergoing CPB are the most likely to suffer from PI’s.

In a progressive prospective cohort study, Campanili et al. observed 370 patients admitted to cardiopulmonary intensive care after surgery, 210 (57.0%) of whom had required CPB during surgery. Out of the 370 patients, 40 were confirmed as having peri-operative PIs, and multivariate analyses revealed that the CPB duration of these 40 patients was significantly longer than that of patients who had not suffered from PIs.

Patients may suffer from PIs regardless of age; however, skin elasticity, collagen content, the degree of vascular sclerosis, subcutaneous fat, and muscle thickness in patients vary with age, which causes the local blood supply and tissue blood perfusion during surgery to differ. Increased blood loss during surgery leads to hemodynamic fluctuations that reduce blood filling pressure and blood pressure, increased cellular hypoxia, and a greater possibility of PIs forming or worsening. This study, therefore, demonstrated that older patients who lose more blood during surgery or lose an immeasurable amount of blood due to the use of CPB are more likely to suffer from stage 2 PIs or higher.

Clinically, we cannot control the age of patients; therefore, some PIs may be unavoidable in elderly patients. However, hemodynamic instabilities due to blood loss cause poor peripheral perfusion, local tissue ischaemia, lymphedema, and persistent cell deformation, all of which worsen PIs. If possible, using minimally invasive surgery or stabilising the body temperature of patients during surgery can help to reduce the amount of blood loss.

Thus, for elderly patients who are expected to lose more than 1000 mL of blood during surgery or an immeasurable amount of blood due to the use of CPB, transfusing adequate blood is necessary to prevent severe PIs.

5 | CONCLUSION

We collected data from retrospective medical records and found that among the personal predisposing factors of patients, only higher patient age and BMI posed a greater risk of stage 2 PIs or higher. Among the surgery-related facilitating factors, patients who were placed in the prone position during surgery and patients who lost ≥1000 mL of blood during surgery were at greater risk of stage 2 PIs or higher than those placed in the supine position and those who lost ≤100 mL of blood, respectively. We further discovered that the amount of blood loss during surgery is a moderating variable of the influence of age on PI severity. When patients lost ≥1000 mL of blood during surgery or lost an immeasurable amount of blood due to the use of CPB, the impact of patient age on PI severity was greater than that when the amount of blood loss was ≤100 mL.

We performed statistical analyses on cases of peri-operative PIs in a hospital in Taiwan. Thus, the applicability of the results to other hospitals is limited. There are also many other facilitating factors that may influence the severity of peri-operative PIs, such as the type of surgery performed, the surgical department, or the anaesthetic drug used. Including these factors, in future research will enhance the findings from our research. In another aspect, we collected data via a retrospective medical record review. With no randomisation or blinding, it was difficult to control for bias or confounding factors. Furthermore, each medical record contained records entered by multiple and different medical personnel; therefore, the quality, consistency, and accuracy of the written records may have also affected the validity of our results. Finally, we employed binary logistic regression, which can only explain the correlation between the severity of peri-operative PIs in patients and their predisposing and facilitating factors but cannot serve as the foundation of causal inferences. These are also the limitations of this study.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data analyzed during the current study are available from the corresponding author upon reasonable request.

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**How to cite this article:** Weng P-W, Lin Y-K, Seo J-D, Chang W-P. Relationship between predisposing and facilitating factors: Does it influence the risk of developing peri-operative pressure injuries? *Int Wound J*. 2022;19(8):2082-2091. doi:10.1111/iwj.13811