Received: 19 May 2022 | Revised: 18 July 2022 | Accepted: 19 July 2022

DOI: 10.1111/iwj.13912

ORIGINAL ARTICLE

IWJ WILEY

Analysis of the clinical features and risk factors of device-related pressure injuries in the operating room

Ling-Yu Ma[1] | **Hong-Lin Chen**[2] | **Hai-Yan Gu**[1] | **Li Hua**[1] | **Xiao-Mei Gao**[1]

[1]Department of Operating Room, Second Affiliated Hospital of Nantong University, Nantong, China

[2]School of Public Health, Nantong University, Nantong, China

Correspondence
Hong-Lin Chen, MD, School of Public Health, Nantong University, No. 9 of Seyuan Road, Chongchuan District, Nantong 226001, China.
Email: chenhonglinchl312@21cn.com

Funding information
Project of Nantong Science and Technology Bureau of Jiangsu Province, Grant/Award Number: JCZ20027

Abstract

To describe the clinical features and risk factors of device-related pressure injuries (DRPIs) in the operating room. The clinical features of the DRPIs in patients undergoing elective surgery in a tertiary hospital in 2020 were investigated through prospective data collection. A DRPI-related questionnaire was designed for the patients, and those who did not experience any DRPI were selected according to a ratio of 1:2. Logistic regression analysis was performed in terms of the independent risk factors of operating-room DRPIs. A *P*-value of <.05 indicated a statistically significant difference. The incidence of operating-room DRPIs was 0.56%, and the proportion of stage I injuries was 73.53%. The injury-related devices included vital monitoring devices (31.62%), auxiliary therapy devices (27.94%), therapy devices (19.12%), and dressings (3.67%). Non-bone protuberances, such as the upper arms and thighs, were common injury sites. The patients' body mass index, mean arterial pressure, and instrument action time were independent risk factors for the operating-room DRPIs. To reduce the incidence of operating-room DRPIs, it is of great clinical significance to focus on the characteristics of the surgical patients and the types of surgery-related devices used and to take personalised preventive measures based on the relevant risk factors.

KEYWORDS

clinical features, device-related injury, operating room, pressure injury, risk factors

Key Messages

- according to the observation and analysis of 18 309 patients who underwent elective surgery in 2020 in a tertiary hospital, the incidence of operating-room device-related pressure injuries (DRPIs) was 0.56%, and the most common injury sites included non-bone protuberances, such as the upper arm and thigh
- there was a risk of DRPIs at bone protuberances, such as the *pars iliaca*, cheek, chest, heel, and auricle

- the preoperative albumin value, American Society of Anesthesiologists grade, and preoperative blood glucose value might be associated with the occurrence of operating-room DRPIs
- the patients' body mass index and intraoperative mean arterial pressure and device action time were the independent risk factors for operating-room DRPIs
- to reduce the risk of surgical DRPIs, it is of great clinical significance to focus on the characteristics of surgical patients and the types of surgery-related devices used, take personalised preventive measures based on the DRPI risk factors, and strengthen perioperative patient management

1 | INTRODUCTION

A device-related pressure injury (DRPI) refers to local damage to a patient's skin and/or subcutaneous tissues (including mucous membranes) caused by sustained pressure from an external medical device. The injury typically conforms to the pattern or shape of the device and may occur at any patch of skin or mucous membrane coming in contact with the medical device.[1] It has been reported that the number of pressure injuries due to medical devices is twice that of non-DRPIs.[2] The occurrence of a DRPI increases the patient's pain and medical care burden and affects their prognosis, with a pressure injury at stage III or above potentially leading to a medical dispute.

The operating room is the hospital department that involves the most extensive use of medical devices, including external medical equipment and built-in surgical instruments, and the patients in this department may be at high risk of pressure injuries due to underlying diseases, surgical- or anaesthesia-related factors, specific surgical positions, or the use of auxiliary medical instruments. However, there is a lack of prospective, large-sample studies on the clinical features and risk factors pertaining to operating-room DRPIs. Therefore, patients experiencing a DRPI that occurred in the operating room of a tertiary general hospital are selected as the subjects for this prospective study. The related clinical features are investigated and analysed to determine the underlying risk factors in view of providing a basis for improving skin care for surgical patients and establishing standardised operating procedures for the use of medical devices.

2 | SUBJECTS AND METHODS

2.1 | Subjects

Patients who underwent surgery in the elective operating rooms of a tertiary general hospital from January 2020 to December 2020 were selected as the research subjects. This study was conducted with approval from the Ethics Committee of Second Affiliated Hospital of Nantong University (No. 2020KT013). This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants.

The inclusion criteria were as follows: (a) patients who successfully underwent surgery, (b) patients with intact skin at the pressure site before surgery, and (c) patients who were willing to participate in the study, while the exclusion criteria were (a) outpatients who underwent minor local anaesthesia surgery, (b) patients with severe skin abnormalities that affected skin observation, (c) patients with incomplete information, and (d) patients with a medical-adhesive-related skin injury.

2.2 | Methods

2.2.1 | Collection of related factors

An intraoperative DRPI-related questionnaire was designed based on the existing literature and evidence-based information[3-6] to assess the risk factors for suffering an intraoperative pressure injury in the operating room, including various demographic factors, laboratory data, and intraoperative-related factors, as well as the risk scores for pressure injuries.

The preoperative demographics of the patients included gender, age, height, weight, body mass index (BMI), body temperature, blood pressure (BP), and any underlying diseases, while the laboratory data included the blood glucose, albumin, total protein, haemoglobin (Hb), red blood cell, and platelet values. The intraoperative-related factors included various surgery-related factors (surgical method, operative position, anaesthesia method, American Society of Anesthesiologists [ASA] grade, intraoperative mean arterial pressure, oxygen saturation level [SpO_2], and hypoperfusion) and specific device-related factors (device type/material and action time). Finally, the factors related to the

pressure injury itself included the Nutrition Risk Screening (NRS-2002) score and the Braden score.

2.2.2 | Conditional logistic regression matching group

Using a 1:2 individual matching method, patients with an intraoperative DRPI were included in the DRPI group, and those without were included in the non-DRPI group. The matching method and sequencing were adopted to compare the cases based on three characteristics: operation date, operative method, and age of the patient. The relevant patient data were obtained from the anaesthesia information system in the operating room and ward nursing information system, and any cases with patients who had experienced a DRPI and any incomplete cases were eliminated.

2.2.3 | Device-related pressure injury assessment

With the patient in the operating room, the circulating nurse examined the patient's skin for any existing pressure injuries and re-examined it following surgery immediately after the removal of a medical device. The skin evaluation was performed with reference to the definition, and general staging/classification criteria of DRPIs provided in the *Prevention and Treatment of Pressure Injury: A Quick Practice Guide* (2019).[1] At 2 to 3 days after surgery, the circulating nurse made the first return visit to evaluate the DRPIs, with the visits continuing until the wound had healed. During the return visit, the nurse observed the skin at the injury site, checked for any new sites of skin injury caused by tissue congestion and reperfusion, and updated the documentation regarding DRPIs in surgical patients.

2.3 | Statistical analysis

All the data were checked by two individuals independently and entered into an Excel spreadsheet. The SPSS™ v25.0 software was used for the data analysis. First, a descriptive analysis of the DRPI-related clinical characteristics was performed, including in terms of population, site, type of device, surgical department, and skin injury stage. For the continuous variables, the results were expressed as the mean ± SD, with the independent sample *t*-test used for intergroup comparisons, while for the categorical variables; the results were expressed in terms of frequencies and percentages, with the chi-square test or Fisher's exact test used for the intergroup comparisons. Univariate analysis was conducted for the risk factors, and any variables with statistical significance were incorporated into the multivariate logistic regression model for further analysis. The risk was expressed in terms of an odds ratio (OR) with a 95% confidence interval (CI). A bilateral test was also carried out, with a *P*-value <.05 indicating that the difference was statistically significant.

3 | RESULTS

3.1 | Analysis of clinical features

A total of 18 309 surgical patients met the inclusion criteria, among which 103 hours and 136 stage I (or above)

TABLE 1 Distribution and proportion of different injury sites

Site	Quantity	Proportion (%)
Upper limb (30.15%)		
Upper arm	36	26.47
Finger	4	2.94
Front arm	1	0.74
Lower limb (37.5%)		
Thigh	25	18.38
Pars iliaca	16	11.76
Heel	3	2.21
Pretibial	2	1.47
Knee	2	1.47
Ankle	2	1.47
Toe	1	0.74
Cheek (8.09%)		
Forehead	5	3.68
Nasal part	2	1.47
Lower jaw	2	1.47
Forehead	1	0.74
Auricle	1	0.74
Torso (18.38%)		
Chest	20	14.71
Abdomen	1	0.74
Acromion	1	0.74
Back	3	2.94
Others (5.88%)		
Sacrococcygeal region	4	2.94
Hip	4	2.94
Total	136	100

DRPIs and 206 were matched as non-DRPI surgical patients. The average age of the patients in the DRPI group was 58.05 ± 14.43 years, and the group included 47 males (45.63%) and 56 females (54.36%), while the average age of the patients in the non-DRPI group was 59.54 ± 10.89 years, with the group including 113 males (54.85%) and 93 females (45.15%). The incidence of DRPIs was 0.56%, with the proportion of stage I DRPIs the highest (73.53%), while the proportion of stage II DRPIs was 25.74%, and that of deep tissue injuries was 0.74%.

The majority of the patients were middle-aged or younger elderly people. The main injury sites were the upper and lower limbs, accounting for 30.15% and 37.50%, respectively. The most common injury sites are listed in Table 1.

3.2 | Device types most likely to cause device-related pressure injury

A total of 136 skin pressure injuries occurred in 103 surgical patients due to the use of medical devices. Among them, 38.97% (53/136) were caused by vital sign monitoring devices, such as a sphygmomanometer cuff, electrocardiogram cable/electrode, or a SpO_2 monitoring clip, 27.94% (38/136) were caused by auxiliary therapy equipment, such as postural appliances, 26.47% (36/136) were caused by therapeutic devices, while 4.41% (6/136) were caused by dressings and 2.21% (3/136) by other devices. The device type distribution is shown in Figure 1.

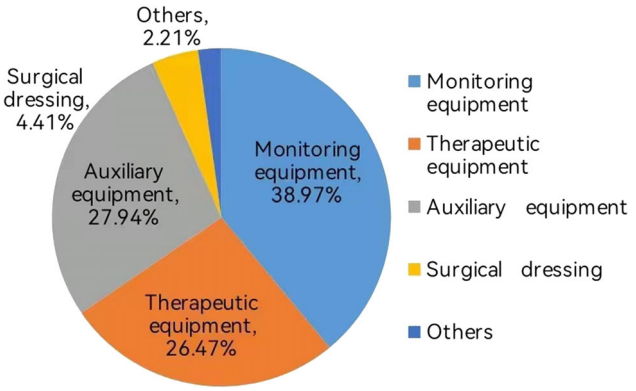

FIGURE 1 Proportion of device types for device-related pressure injury in operating room

3.3 | Risk factor analysis of device-related pressure injuries in the operating room

3.3.1 | Device-related pressure injury univariate analysis

According to the results of the univariate analysis, there were statistically significant differences between the patient groups in terms of blood glucose level, ASA grade, device action time, and intraoperative mean arterial pressure (all $P < .05$). However, there were no significant differences between the groups in terms of age, Braden score, NRS-2002 score, SpO_2 level, surgical position, anaesthesia method, albumin, total protein, Hb, red blood cell, and platelet value, or preoperative mean arterial pressure (all $P > .05$) (Table 2).

3.3.2 | Device-related pressure injury multivariate analysis

Binary variable logistic regression analysis was conducted using preoperative blood glucose level, BMI, ASA grade, device action time, and mean arterial pressure as the independent variables and DRPI occurrence as the dependent variable, while BMI was also incorporated into the multivariate logistic regression equation as a classification variable.

The results indicated that the risk of DRPI was higher when the intraoperative mean arterial pressure was >105 mm Hg (reference range: 70-105 mm Hg) (OR = 2.23, 95% CI = 1.20-4.14, $P = .011$). Using 18.5 to 23.9 kg/m^{2}in the normal BMI group as a reference range, a BMI of >28 kg/m^2 was considered to be a risk factor, with the higher the BMI, the higher the risk of DRPI (OR = 2.79, 95% CI = 1.30-6.01, $P = .009$). Meanwhile, the longer the device action time, the higher the risk of DRPI (OR = 1.01, 95% CI = 1.00-1.01, $P = .038$). Overall, the mean arterial pressure, BMI, and device action time were the independent risk factors for operating-room DRPIs (Table 3).

4 | DISCUSSION

4.1 | Analysis of clinical features of device-related pressure injuries in the operating room

4.1.1 | Incidence and stage of device-related pressure injuries

The results indicated that the overall incidence of operating-room DRPIs was 0.56%. The proportion of stage I

TABLE 2 Univariate analysis of two groups of patients

Variable	Device-related pressure injury occurs			
	Yes	No		
	n = 103(%)	n = 206(%)	*t*/*z*/χ2	*P*
Age (yr)	58.13 ± 14.60	59.68 ± 10.00	−1.08	.28
Gender			2.34	.126
Male	47(45.6)	113(54.9)		
Female	56(54.4)	93(45.1)		
BMI (kg/m^2)	25.64 ± 4.20	24.26 ± 3.59	−3.00	.003*
Preoperative blood glucose (mmol/L)	6.17 ± 1.85	5.76 ± 1.11	−2.07	.040*
Preoperative albumin (g/L)	39.44 ± 5.33	38.83 ± 3.98	−1.02	.309
Preoperative total protein (g/L)	128.58 ± 21.53	133.17 ± 15.27	−0.60	.554
Red blood cell (RBC) 10^{12}/L	3.90 ± 0.80	4.34 ± 0.49	−1.63	.118
Haemoglobin (Hb) (g/L)	129.33 ± 20.06	131.50 ± 16.21	1.06	.774
Thrombocyte 10^9/L	232.08 ± 76.03	230.67 ± 107.70	0.04	.971
Preoperative body temperature (°C)	36.57 ± 0.23	36.47 ± 0.26	3.15	.081
NRS2002 (points)	0.43 ± 0.09	0.40 ± 0.07	0.02	.892
Braden score (points)	20.76 ± 2.64	20.57 ± 2.64	−0.57	.574
Device action time (min)	173.92 ± 11.66	140.98 ± 20.78	−2.79	.006*
SPO_2 (%)	98.91 ± 1.05	99.15 ± 1.36	−1.54	.132
Intraoperative mean arterial pressure (mm/Hg)	99.20 ± 13.31	91.31 ± 15.04	−4.50	.001*
Operative position			8.30	.077
Lateral position	15 (14.56)	33 (16.02)		
Prone position	43 (41.75)	74 (35.92)		
Lithotomy position	2 (1.94)	6 (29.13)		
Horizontal position	36 (34.95)	92 (44.66)		
Cervical spine hyperextension lateral position	7 (6.80)	3 (0.49)		
Specialist surgery			2.88[a]	. 911
General surgery	11 (10.68)	16 (7.77)		
Cardio-thoracic surgery	9 (8.74)	27 (13.11)		
Orthopaedics department	65 (63.11)	125 (60.68)		
Obstetrics and gynaecology	3 (2.91)	5 (2.43)		
Urology	3 (2.91)	7 (3.40)		
Burns	2 (1.94)	4 (1.94)		
ENT	4 (3.88)	8 (3.88)		
Neurosurgery	6 (5.83)	14 (6.80)		
Anaesthesia method			1.55[a]	.668
General anaesthesia	92 (89.32)	188 (91.26)		
Lumbar anaesthesia + lumbar epidural anaesthesia	7 (6.80)	11 (5.34)		
Brachial plexus	1 (0.97)	4 (1.94)		
General anaesthesia + lumbar anaesthesia	3 (2.91)	3 (1.46)		
ASA			12.54[a]	.008*
I	13 (12.62)	58 (28.16)		
II	74 (71.84)	131 (63.59)		
III	10 (9.71)	12 (5.83)		

TABLE 2 (Continued)

Variable	Device-related pressure injury occurs: Yes n = 103(%)	Device-related pressure injury occurs: No n = 206(%)	t/z/χ2	P
IV	4 (3.88)	5 (2.43)		
V	1 (0.97)	0		

[a]Fisher exact test.
*$P < .05$.

TABLE 3 Multi-factor regression analysis on DRPI in the operating room

Variable	Group	β	SE	Wald	P	OR	95% CI: Lower limit	95% CI: Upper limit
Mean arterial pressure (reference: 70-105)								
	<70	−2.15	1.08	3.95	.051	0.12	0.01	0.97
	>105	.80	0.32	6.49	.011*	2.23	1.20	4.14
BMI (kg/m^2) (reference: 18.5-23.9)								
	<18.5	.83	0.96	0.73	.392	2.28	0.35	15.09
	24.0-27.9	.35	0.29	1.53	.216	1.42	0.81	2.49
	≥28	1.03	0.39	6.90	.009*	2.79	1.30	6.01
Preoperative blood glucose (reference: ≤6.2)								
	>6.2	.40	0.31	1.64	.200	1.49	0.81	2.75
	Instrument action time	.00	0.00	4.31	.038*	1.00	1.00	1.01
	ASA grade	.31	0.22	2.02	.155	1.36	0.89	2.08

*$P < .05$.

injuries was the highest at 73.33%, while the proportion of stage II injuries was 26.67%, and that of deep tissue injuries was 0.74%. Compared with previous findings on the incidence of pressure injuries in surgical patients, which was found to be 0.23% to 24.8%,[7] the incidence rate in the present study was relatively low. However, huge differences between the incidence rate (10.3%)[2] and the DRPI stage (stage I, stage II, and mucosal injuries, accounting for 24%, 49%, and 40%, respectively) have been reported.[8] This could be associated with the different research methods used as well as the subjects chosen.

The subjects included in the present study were patients undergoing elective surgery in 2020 who met the study criteria (e.g., patients undergoing specialist surgeries with a high risk of pressure injuries, such as spinal, neuro, and cardiac surgery, as well as more general patients), while the investigation was related to the device type, quantity, and material, as well as the action time and site, surgery type, anaesthesia method, and surgical position. The percentage of DRPIs caused by a tracheal catheter (1.47%) obtained in the present study was lower than that reported in the existing literature (7.7%).[9] However, the incidence rate of DRPIs caused by vital sign monitoring devices was 31.62% in the present study, a similar value to those reported in previous studies (30%-70%).[10,11]

4.1.2 | Correlation between common device-related pressure injury sites and the medical device

A DRPI may occur at any patch of skin or mucous membrane coming in contact with a medical device, and the primary sites tend to differ from those pertaining to traditional pressure injuries suffered at the bone protuberances, which include the sacrococcygeal region, *pars iliaca*, bone tuberosity, foot, occipito-posterior, and auricle. According to the existing reports, the common sites of DRPIs include the head, face, neck, anterior superior spine, and other parts lacking adipose tissue, while the auricle is the most common site.[12] However, there exists some diversity in terms of pressure due to the operation method used, the patient's body position, and the reduced body motion of the patient following anaesthesia.

According to the results of the present study, the DRPIs in the patients occurred most frequently at the point where the cuff of the sphygmomanometer was attached to the upper arm, followed by the thigh and bone protuberances of the chest, head, face, buttocks, sacrum, and heel. A previous study[11] found that the posterior cervical region (66%) and the nose (40%) were the most common injury sites, with these prevalence levels higher than those obtained in the present study. Compared with traditional pressure injuries at bone protuberances, a DRPI is more likely to occur at a location rich in fat tissue, while it is also related to the parts, materials, and use of the surgical instruments and equipment.

Non-invasive BP monitoring is the most commonly used method for monitoring the BP of surgical patients, with the upper arm being the preferred site for the sleeve. The routine BP measurement frequency is generally set to once every 3 to 5 minutes, meaning the skin of the upper arm is at an increased risk of injury due to the external pressure and the friction and sheer force generated by the inflation and deflation of the sleeve.

Furthermore, using an air pressure tourniquet in orthopaedic lower extremity surgery generates 300 to 350 mm Hg of pressure for 60 to 90 minutes through continuous inflation, which not only blocks the arterial blood flow of the affected limb and reduces any intraoperative bleeding but can also lead to the insufficient blood supply to the local tissues, resulting in erythema or blisters that cannot heal under pressure.

Fixation of the pubic symphysis, sacrococcygeal region, back, and *pars iliaca* in the lateral position involves the application of extra pressure to the local skin tissue, while the frequent use of traction, fixation, bone chisels, and hammers in fracture reduction procedures also exerts corresponding pressure or sheer force on the local skin and tissue, increasing the risk of damage. The occurrence of DRPIs is related to the size of the positioning pad, its material, and the contact area with the skin; the higher the pressure, the higher the probability of injury and the greater the severity of the injury.[13] In the present study, two patients undergoing orthopaedic surgery suffered pressure injuries at the heel following continuous traction on a traction bed.

In addition, various surgical dressings can cause DRPIs,[14] with improper use, uneven dressing and folding, an inappropriate size, and other such factors potentially leading to the occurrence of intraoperative DRPIs. In the present study, there was one case of stage I pressure injury due to underwear folding and two cases of a cord-like blister (with a similar shape as the dressing) on the skin that was pressed against a fold in the sheet underneath the patient.

Following the updating of the catalogue of medical devices, the China Food and Drug Administration issued a document stipulating that dressings with water-resistant, bacteria-resistant, breathable, and bidirectional protective functions, such as surgical gowns and sheets, should be included as category III medical devices, a proposal that was implemented in January 2018.[15] However, the hydrophobicity of bacteria-blocking and water-blocking soft instruments leads to changes in the microcirculation of local skin tissues as well as skin sweating, moisture, and temperature changes. Therefore, clinical nursing staff must determine whether there is a risk of DRPI when controlling the infection.

4.1.3 | Correlation between device-related pressure injuries and specialist surgery

As a common occurrence in patients who receive therapy involving numerous medical devices, DRPIs are associated with the device type, its material, and the action time. In the present study, the incidence of DRPIs was the highest (62.14%) in patients undergoing orthopaedic specialist surgery (joint, trauma, and spine), especially specialised spinal surgery, which could be related to the prone position of the patients during spinal surgery. In short, in this position, the blood flow is redistributed, resulting in skin lesions on the face, chest, shoulder, *pars iliaca*, and anterior tibial areas coming in contact with the postural appliances. The incidence of operating-room DRPIs can be reduced by focusing on the key population, carefully selecting the medical devices, and reducing the sheer force and friction at the contact sites between the device and the skin.

4.2 | Risk factor analysis of device-related pressure injuries in the operating room

4.2.1 | Impact of body mass index on intraoperative device-related pressure injuries

The BMI is an important index for measuring a patient's nutritional status. Patients who are overweight have a higher risk of pressure injuries, as the greater amount of cellulite will compress the blood vessels and the dependent neural structures, as well as reduce the tissue perfusion, leading to injury. A BMI value of >30 kg/m^2 is considered to be a risk factor for perioperative pressure injury.[16] The results of the present study indicated that there was indeed a correlation between the DRPIs and a

high BMI, with the risk of DRPI increasing when the BMI was >28 kg/m^2 (obesity). This could be related to how the surgeon presses the vascular clusters in the subcutaneous fat by pulling, squeezing, or applying external pressure using a medical device, resulting in ischemia and hypoxia of the skin and subcutaneous tissue at the pressure site. Alternatively, patients with higher BMIs have a larger body mass than other patients, and the devices used during surgery, such as bed positioning devices, are relatively small for such patients, resulting in greater pressure and a higher DRPI incidence rate. Furthermore, previous studies have demonstrated that patients with an extremely low BMI (extreme emaciation) are more prone to suffering a DRPI at the pressure sites,[17] which may be related to malnutrition and the lack of fat protection for the subcutaneous tissues at the bone protuberances. Clearly, the occurrence of DRPIs requires further investigation in this regard.

4.2.2 | Influence of intraoperative mean arterial pressure on the occurrence of device-related pressure injuries

The mean arterial pressure can reflect the pressure exerted on the skin under the cuff of a sphygmomanometer. Both extremely high and extremely low mean arterial pressure values affect the blood supply of the tissues and organs.[18] If the mean arterial pressure is too low, the vital organs, such as the heart and the brain, receive an insufficient blood supply, resulting in hypoperfusion of the small blood vessels throughout the body. Moreover, the local middle and small arteries of the skin become involved when the mean arterial pressure exceeds the normal value, affecting the perfusion from the capillaries to the tissues.

As reported in previous studies, the mean arterial pressure or diastolic pressure value can predict the risk of skin pressure injury.[18,19] According to the results of the present study, the patients with an intraoperative mean arterial pressure of >105 mm Hg were more prone to DRPIs than those with an intraoperative mean arterial pressure of <70 mm Hg. One possible reason for this is that the inflation pressure of the sphygmomanometer increases accordingly, when the intraoperative mean artery BP is increased, placing the local skin and capillaries under high pressure for a long period of time. Meanwhile, multiple factors can jointly result in reduced skin perfusion and skin temperature changes beneath and around the cuff, including the pressure and friction generated by the air inflation around the skin at the cuff site, the sheer force generated by soft tissue folding beneath the cuff, and direct contact between the skin and the cuff.

However, DRPIs caused by the passive inflation and deflation pressure and the sheer force of the cuff tend not to receive clinical attention and are often misinterpreted as a normal phenomenon. The main reason for this is that while the anaesthetist monitors the patient's BP, they pay less attention to the patient's skin. Therefore, operating room nurses should strengthen their communication with the anaesthetist, paying attention to the patient's BP *and* skin during surgery, and maintaining the mean arterial pressure within the normal range as far as possible. For patients with high basic BP, in addition to skin protection at the cuff site of the sphygmomanometer (condition permitting), it is recommended that anaesthetists appropriately extend the BP measurement interval, measure the BP alternately on both arms, use invasive rather than non-invasive arterial BP monitoring, or place an elastic cotton tubular sleeve beneath the cuff of the sphygmomanometer to protect the arm from the influence of moisture and cuff material and prevent DRPIs caused by the sphygmomanometer cuff.[20]

4.2.3 | Correlation between device action time and intraoperative device-related pressure injuries

In this study, the medical device action time was found to be positively correlated with the incidence of DRPIs. Previous research has suggested that exerting local tissue compression for over 2.5 hours is a risk factor for pressure injury, with each extension of 30 minutes significantly increasing the attendant risk.[15] A number of studies also demonstrated that there is a risk of pressure injury if the tissue is placed under pressure for over 2 hours, while others found that only a compression period of >3 hours is significant.[21] Elsewhere, a cohort study involving 175 patients undergoing anaesthetic resuscitation, cardiovascular surgery, neurosurgery, and chest disease treatment across five intensive care units revealed that the occurrence of DRPIs increased with the increased use of medical devices.[22]

In the present study, the optimal surgical threshold for the occurrence of pressure injury caused by the use of postural appliances in surgical patients was found to be 181 minutes.[23] In fact, the device action time was found to be an independent risk factor for DRPIs, with the risk increasing by 13% for each additional 30 minutes of use. In clinical practice, it is crucial to minimise the medical device action time, regularly observe the skin changes around the device, and

perform decompression at regular intervals to avoid long-term pressure on the skin.

In summary, DRPIs result from the joint action of multiple factors but can also occur when a single factor reaches a certain threshold. Surgical patients with a BMI of >28 kg/m^2 (obesity), a mean arterial pressure of >105 mm Hg, or an operation duration of >3 hours are at a higher risk of a DRPI, meaning close attention should be paid to these factors in clinical settings.

5 | CONCLUSION

Based on the observation and analysis of 18 309 patients who underwent elective surgery in 2020 in a tertiary hospital, the incidence of operating-room DRPIs was found to be 0.56%, with the most common injury sites found to include non-bone protuberances, such as the upper arm and thigh. However, there was also a risk of the occurrence of a DRPI at bone protuberances such as the *pars iliaca*, cheek, chest, heel, and auricle. The preoperative albumin value, ASA grade, and preoperative blood glucose value are potentially associated with the occurrence of operating-room DRPIs. In this study, the patient's BMI, intraoperative mean arterial pressure, and device action time were the main independent risk factors for operating-room DRPIs. To reduce the risk of surgical DRPIs, it is of great clinical significance to focus on the characteristics of the patient and the type of surgery-related devices used, with personalised preventive measures taken based on the DRPI risk factors, and the perioperative patient management strengthened.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

ORCID

Hong-Lin Chen https://orcid.org/0000-0001-8848-0552

REFERENCES

1. European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel, Pan Pacific Pressure Injury Alliance, *Prevention and treatment of pressure ulcers/injuries: clinical practice guideline*. Clinical practice guideline[S]. EPUAP/NPIAP/PPPIA; 2019. https://www.internationalguideline.com/
2. Black J, Alves P, Brindle CT, et al. Use of wound dressings to enhance prevention of pressure ulcers caused by medical devices. *Int Wound J*. 2015;12(3):322-327.
3. Rashvand F, Shamekhi L, Rafiei H, Nosrataghaei M. Incidence and risk factors for medical device-related pressure ulcers: the first report in this regard in Iran. *Int Wound J*. 2020;17(2):436-442.
4. Suh D, Kim SY, Yoo B, Lee S. An exploratory study of risk factors for pressure injury in patients undergoing spine surgery. *Anesth Pain Med*. 2021;16(1):108-115.
5. Klestil T, Röder C, Stotter C, et al. Impact of timing of surgery in elderly hip fracture patients: a systematic review and meta-analysis. *Sci Rep*. 2018;8(1):13933-13940.
6. Wound O. WOCN 2016 guideline for prevention and management of pressure injuries (ulcers): an executive summary. *J Wound Ostomy Continence Nurs*. 2017;44(3):241-246.
7. Lu CX, Chen HL, Shen WQ, Feng LP. A new nomogram score for predicting surgery-related pressure ulcers in cardiovascular surgical patients. *Int Wound J*. 2017;14(1):226-232.
8. Hitchcock J, Savine L. Medical adhesive-related skin injury: VADS and dressings. *Br J Nurs*. 2015;24(14):S13.
9. Pittman J, Gillespie C. Medical device-related pressure injuries. *Crit Care Nurs Clin North Am*. 2020;32(4):533-542.
10. Jackson D, Sarkic AM, Betteridged R, Brookebe J. Medical device-related pressure ulcers: a systematic review and meta-analysis. *Int J Nurs Stud*. 2019;10(92):109-120.
11. Galetto SGDS, do Nascimento ERP, PMV H, Busanello J, de Malfussi LBH, Lazzari DD. Medical device-related pressure injuries in critical patients: prevalence and associated factors. *Rev Esc Enferm USP*. 2021;55:e20200397.
12. Huang Q, Zhang J, Nong L, et al. Construction and application of closed-loop management system for ICU medical device-related stress injury. *Chin J Nurs*. 2021;56(4):545-549.
13. Padhye NS, Bergstrom N, Rapp MP, Etcher L, Redeker NS. Pressure ulcer risk detection from complexity of activity. *Annu Int Conf IEEE Eng Med Biol Soc*. 2017;2(17):2304-2307.
14. Litchford MD. Putting the 2019 nutrition recommendations for pressure injury prevention and treatment into practice. *Adv Skin Wound Care*. 2020;33(9):462-468.
15. State Food and Drug Administration. Administration of medical device classification catalogue of announcement no. 104; 2017. http://www.sda.gov.cn/WS01/CL0087/177089.html.
16. Oliveira KF, Pires PDS, De-Mattia AL, et al. Influence of support surfaces on the distribution of body interface pressure in surgical positioning. *Rev Lat Am Enfermagem*. 2018;29(26):e3083.
17. Gao L, Yang L, Li X, et al. The use of a logistic regression model to develop a risk assessment of intraoperatively acquired pressure ulcer. *J Clin Nurs*. 2018;27(15–16):2984-2992.
18. Lu X, Yang Q, Zhu L, et al. Correlation analysis of sacrococcygeal pressure and operation time in patients undergoing general anesthesia in the supine position. *J Int Med Res*. 2021;49(7):1-6.
19. Fred C, Ford S, Wagner D, VanBrackle L. Intraoperatively acquired pressure ulcers and perioperative normothermia: a look at relationships. *AORNJ*. 2012;96(3):251-260.
20. Owens L, Stamps H. Eliminating medical device-related pressure injury from blood pressure cuffs during continuous monitoring in the perioperative setting: a novel approach. *J Perianesth Nurs*. 2018;33(4):444-447.
21. Choi MA, Kim MS, Kim C. Incidence and risk factors of medical device-related pressure injuries among patients undergoing prone position spine surgery in the operating room. *J Tissue Viability*. 2021;30(3):331-338.

22. Hanonu S, Karadag A. A prospective, descriptive study to determine the rate and characteristics of and risk factors for the development of medical device-related pressure ulcers in intensive care units. *Ostomy Wound Manage*. 2017;62(2):12-22.
23. Ueno T, Kabata T, Kajino Y, et al. Risk factors for pressure ulcers from the use of a pelvic positioner in hip surgery: a retrospective observational cohort study in 229 patients. *Patient Saf Surg*. 2020;14:10.

How to cite this article: Ma L-Y, Chen H-L, Gu H-Y, Hua L, Gao X-M. Analysis of the clinical features and risk factors of device-related pressure injuries in the operating room. *Int Wound J*. 2023; 20(3):706-715. doi:10.1111/iwj.13912