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ORIGINAL ARTICLE

Risk factors associated with intraoperatively acquired pressure ulcers in the park-bench position: a retrospective study

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Key words
Core temperature; Perioperative nursing; Perspiration; Pressure ulcer prevention; Surgery

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Abstract

Patients undergoing surgery in the park-bench position are at high risk of developing intraoperatively acquired pressure ulcers (IAPUs). The purpose was to examine retrospectively risk factors associated with IAPUs in the park-bench position. This study was conducted at a general hospital during the period of September 2010 to September 2012. Twenty-one potential risk factors were evaluated using data obtained from the hospital database. IAPUs developed in 30 of 277 patients (11%). Perspiration was statistically found to be independently associated with IAPUs [OR 3·09, 95% confidence interval (CI) 1.07–8·58, $P = 0·037$]. A length of surgery of more than 6 hours was identified to be likely associated with IAPUs (OR 2·64, 95% CI 0·84–9·08, $P = 0·095$) compared with less than 6 hours. Furthermore, there was an interaction between the length of surgery and the core temperature; that is, when the length of surgery was more than 6 hours, a core temperature of more than 38·1°C at the end of surgery had a higher odds ratio (8·45, 95% CI 3·04–27·46, $P < 0·001$) than that at a lower core temperature (3·20, 95% CI 1·23–8·78, $P = 0·017$). These results suggest that perspiration and core temperature are preventable causative factors of pressure ulcers, even under conditions of prolonged surgery in the park-bench position.

Introduction

Pressure ulcers are defined as 'localized (sites of) injury to the skin and/or underlying tissue, usually over a bony prominence, as a result of pressure, or pressure in combination with shear' (1). Patients undergoing surgery constitute a high-risk group for pressure ulcers. The incidence of intraoperatively acquired pressure ulcers (IAPUs) is reported to range from 14% to 66% (2–4), as the patient must maintain the same position on the operating table for a prolonged time and is unable to move when under general anaesthesia. Although operating table mattresses and positioning devices are often used, repositioning, which is generally recommended to prevent pressure ulcers (1), is difficult during surgery because the safety and exposure of the surgical site are a priority.

Among the various surgical positions, including supine, prone and so on, the incidence of pressure ulcers is especially high in subjects placed in the park-bench position. The park-bench position is a specific lateral position used during neurosurgery to treat the cerebellopontine angle and vascular lesions (Figure 1) (5). IAPUs easily develop in the park-bench position because the area of contact in this position is only half

Key Messages

- the incidence of pressure ulcers in patients undergoing surgery, especially in the park-bench position, is high compared with that observed in the general unit
- we conducted a retrospective observational study of patients who underwent elective surgery in the park-bench position at the department of neurosurgery between September 2010 and September 2012
- this study identified three risk factors for intraoperatively acquired pressure ulcers (IAPUs) in the park-bench

position: perspiration, length of surgery and core temperature
- a length of surgery of 6 hours or longer increased the risk of pressure ulcers, and a core temperature of more than 38·1°C further increased the risk of pressure ulcers compared with a core temperature of less than 38·1°C for surgeries lasting more than 6 hours
- controlling perspiration and core temperature via collaboration with the anaesthesiologist may prevent IAPUs, even under conditions of prolonged surgery

that obtained in the supine position as the patient's head and part of the trunk are fixed along the outside of the operating table. In our operating theatre, the incidence of IAPUs in the park-bench position is as high as 30%, indicating the importance of preventing this complication (6).

Many previous studies have reported intrinsic factors for IAPUs, including age (7), gender (8), a low Braden scale score (9), low BMI (10), diabetes (11,12), hypertension (12) and congestive heart failure (7), and extrinsic factors, including the length of surgery (11–17), surgical positioning (18–21), surgical procedure (21–24), hypotension (25), hypothermia (9,26), amount of bleeding (27), American Society of Anesthesiologists Physical Status (ASA PS) classification (8,9) and use of an operating table mattress (28) in the supine, prone, lithotomy and lateral positions.

Risk factors in the park-bench position remain unclear, as some of these factors are not applicable for this position. For example, hypothermia rarely occurs in the park-bench position because the patient's core temperature is usually maintained at high level under a full drape using a warming device to prevent adverse effects. Additionally, skin moisture due to perspiration may occur in the park-bench position, whereas this factor is mostly caused by incontinence in the general unit and is not a factor in the operating theatre. However, the effects of perspiration on pressure ulcer formation are not well examined in surgical research because perspiration is rarely noted in other general surgical positions based on the surgical procedure, amount of bleeding and insensible water loss. Therefore, IAPU risk factors specific to the park-bench position must be investigated. The purpose of this retrospective study was to clarify the risk factors for IAPUs in the park-bench position.

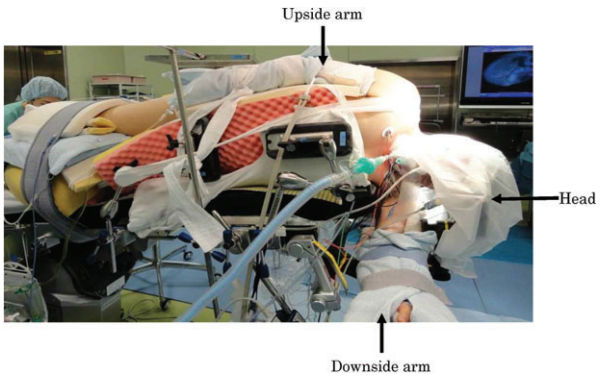

Figure 1 Park-bench position, The patient's head is clamped in a Mayfield frame, and the lateral trunk is fixed on the main operating table with the upside arm positioned along the lateral trunk and the downside arm fixed on an external arm board.

Methods

Study design

We conducted a retrospective, observational study of all patients consecutively hospitalised for surgery in a 500-bed acute care hospital in Japan between September 2010 and September 2012.

The institutional review board of Tokyo Metropolitan Police Hospital (#35) approved this study. Written informed consent for the use of data from the medical records was obtained from the patients on admission.

Setting and participants

Tokyo Metropolitan Police Hospital is an urban, acute care hospital. Approximately 5000 surgeries are performed at this hospital each year. We made the prediction that the incidence of pressure ulcers was 30%, $\alpha = 0{\cdot}05$, power of 80%, and the ratio of with and without perspiration was 1:6. Finally, we estimated that a sample size of 270 patients was needed for this study. The inclusion criteria, as determined according to the electronic records, were met in 309 patients. The exclusion criteria included patients who underwent emergency surgery or repeated surgery or demonstrated missing data for the risk assessment.

Procedures

In our hospital, surgery in the park-bench position is conducted in accordance with the following standard procedures.

Preoperative phase

Autologous blood collection (400 ml) is performed 2–3 weeks before the scheduled date of surgery. The patient is admitted to the hospital 2 days before the day of surgery, and a blood test is carried out on admission. There were no limitations of mobility after hospitalisation.

During hospitalisation, preventive care for pressure ulcers is provided based on the Japanese guidelines (29). Risk factors associated with pressure ulcer development are evaluated according to the Japanese Ohura-Hotta (OH) scale (30) on admission by unit nurses, which includes items of self-sustainable ability, morbid bony prominences, joint contractures and oedema. Self-sustainable ability to move unassisted is classified as assisted (3), intermediate (1·5) or unassisted (0). Morbid bony prominence is evaluated by the vertical interval between the centre of sacrum and the region 8 cm away from the sacrum and is classified as severe (3), intermediate (1·5) or none (0). Joint contracture is classified as presence (1) or none (0). Oedema is evaluated with the depth after releasing the gentle pressure of a finger at the dorsal foot,

and it is classified as presence (1) or none (0). In addition, dryness of the skin is assessed macroscopically throughout the patient's body.

Intraoperative phase

The patient's head is fixed in the Mayfield clamp under total intravenous anaesthesia, and the needle electrode is fixed for cranial nerve monitoring on the face. The patient is subsequently placed in the park-bench position on the operating table, which was a product of MAQUET; Gmph & Co. KG, Tokyo, Japan, made of urethane. And laid a urethane foam mattress and gel pads are used to achieve pressure distribution and a 'vacuum bean bag' and side plates are used for fixation, with the outside of the vacuum bean bag fixed at four locations to the side plate. The urethane foam mattress is composed of double layers measuring 6·5 cm in thickness (Soft Nurse Yellow Pink®, LAC Healthcare Ltd., Tokyo, Japan). The underside of the upper limbs in contact with the operating table is placed on armrests and the opposite side of the upper limbs is fixed along the trunk with cotton thread (8 cm in width) without being placed on the armrests. The lower limbs are fixed using few sponges (EM®, Toyo Soflantec Co., Tokyo, Japan) to prevent the knees from overlapping. During surgery, the patient's rectal temperature is monitored using a temperature probe (NOVATEMP® General Purpose Temperature Probes 10-Fr 5–15610,NIHON KOHDEN Co., Tokyo, Japan), and a warming device (Bair Hugger ™ Temperature Management Units model 750, 3M Japan Ltd., Tokyo, Japan) with a whole-body cover with preset temperature of 43°C is used to manage the core temperature prior to surgery by the anaesthesiologist for hypothermia prevention. Intraoperative warming device; Bair Hugger™, has three temperature settings, high 43°C, medium 38°C and low 32°C. The initial temperature was set at 43°C to reduce the magnitude of redistribution hypothermia. If the temperature rose up above the normal range, active warming was discontinued. The patient enters the intensive care unit (ICU) following extubation of the intratracheal tube after surgery.

Hyperthermia due to the effects of surgery and heat accumulation induced by the cover draping the patient often occur during neurosurgery involving prolonged procedures in the park-bench position (31). In the present study, when the patient's core temperature reached 37·5°C to 38·0°C, the temperature management method was changed from active warming to thermal insulation. In patients undergoing neurosurgery, active surface cooling, which constitutes general care for hyperthermia during surgery, was not performed because postoperative shivering was induced by cooling, subsequently resulting in an increased oxygen uptake (32). Alternatively, treatment with medications (NSAIDs) and infusion was performed.

Determination of IAPUs

The patient's skin is assessed three times in the perioperative period: immediately after the induction of general anaesthesia, at the end of surgery and 24 hours after the surgery. The skin at regions of contact with the operating table is checked by two operating theatre nurses, and the presence of non-blanchable erythema is evaluated using finger pressure. The operating theatre nurses document the results of the patient's skin assessment, and the presence of pressure ulcers is diagnosed based on the appearance of localised signs that continue for 24 hours. All pressure ulcers are classified according to the National Pressure Ulcer Advisory Panel (NPUAP) staging.

Data collection

Data regarding the incidence of IAPUs were obtained from the patients' electronic records as the primary outcome variable. Pressure ulcers were diagnosed as IAPUs if the following conditions were documented in the nursing records: no sign of ulcers at the time of admission and the appearance of redness immediately after surgery that remained 24 hours later. The data extracted from the database records were independently checked by operating theatre nurses, and the medical records were subsequently referred to once a week by operating theatre nurses who were members of the Records Commission at our hospital.

The operating theatre nurses collected the demographic data at the time of admission and during the surgical procedure and assessed the risk factors associated with IAPUs based on the patients' medical records. A total of 21 potential risk factors were examined according to a review of the literature: a portion of the OH scale for joint contractures, oedema and skin moisture (perspiration), age (7), gender (8), diabetes (11,12), congestive heart failure (7), hypertension (12), rheumatism (33) , paralysis (33), history of smoking (12), skin dryness (34), body mass index (BMI) (10), haemoglobin level (11), length of surgery (13–17), core temperature at the end of surgery (6), amount of bleeding (27), ASA PS classification (8,9), bony prominences on the lateral thorax and iliac crest (6,35), use of rotation (36) and application of skin polyurethane film (37). The self-sustainable ability and morbid bony prominences based on the OH scale were not assessed because these factors were not applicable to our patients, who were placed in the park-bench position under general anaesthesia and received an indwelling bladder catheter during surgery. Although the core temperature was measured continuously during the surgical procedure, we collected data for the core temperature at the end of surgery as an independent variable, as other surgery-related factors were evaluated only at the end of surgery. The core temperature data of this study were extracted every 30 minutes from the anaesthesia records. The threshold for classifying the length of surgery was more or less than 6 hours based on the guidelines of the Japanese Society of Pressure Ulcers (38) and a previous study (6).

Data analysis

Univariate analyses for each independent variable were performed using the χ^2 test or Fisher's exact test for categorical variables and the unpaired *t*-test or Mann–Whitney *U* test for continuous variables. Variables with a *P*-value of less than 0·05 were included in the subsequent multivariate analysis.

A multivariate logistic regression analysis was conducted according to the stepwise selection method. Before the analyses, correlations between potential independent variables were examined in order to avoid multi-collinearity. If the correlation

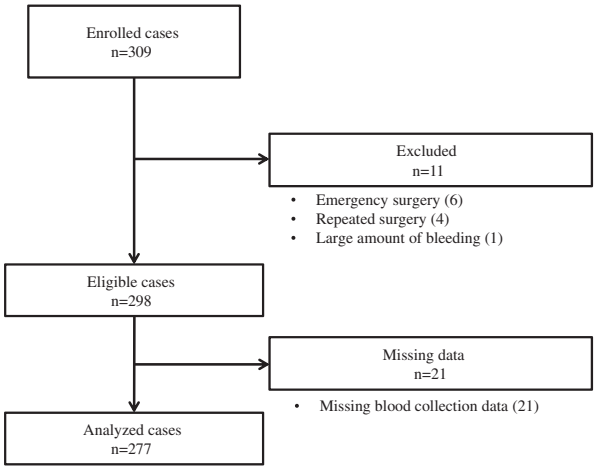

Figure 2 Flow of the participants throughout the study, 309 patients were enrolled. Excluding 31 patients, 277 patients were finally included in the analysis.

coefficients exceeded 0·4, either variable was selected. The optimal thresholds for the extracted continuous variables were then examined using a receiver operating characteristic (ROC) curve at the point showing the highest sum of the sensitivity and specificity. Interactions between the remaining independent variables were also assessed. If a significant interaction was observed, the combination of the interacting variables was alternatively included as an independent variable.

The statistical analyses were performed using the JMP for Windows ver. 10.0.2 software program (SAS Institute, Tokyo, Japan). The level of statistical significance was set at a *P*-value of less than 0·05.

Results

Overall patient characteristics

Of the 309 patients enrolled in this study, 277 were finally selected for the analysis (Figure 2). Ten patients were excluded because they underwent emergency surgery ($n = 6$) or repeated surgery ($n = 4$). One patient was excluded because the amount of bleeding in that case was an outlier (2835 ml) ($n = 1$). An additional 21 patients were excluded because blood data were not available in their records. In total, 118 males and 159 females were included in the analyses. The mean ± SD age was 45·5 ± 13·8 years (range: 10–82). Comorbidities included hypertension ($n = 19$), diabetes ($n = 9$) and congestive heart failure ($n = 1$). A total of 151 patients were classified as having an ASA PS of 1, 124 were classified as having a PS of 2 and two were classified as having a PS of 3. The surgical procedures included cerebellopontine angle tumour removal in 266 cases and microvascular decompression in 11 cases. The mean ± SD length of surgery was 376 ± 89 minutes, and the mean ± SD core temperature at the end of surgery was 37·7 ± 0·7°C.

Pressure ulcers developed in 30 of the 277 patients 24 hours after surgery (11%). Twenty-nine patients had stage I ulcers, and one patient had a stage II ulcer with a blister. Neither stage I nor stage II pressure ulcers were exacerbated to become deeper ulcers. The locations of pressure ulcer in the park-bench position were the lateral thorax, greater trochanter, iliac, lateral knee and lateral malleolus. The sites of the pressure ulcers included the lateral thorax ($n = 12$), iliac crest ($n = 6$), greater trochanter ($n = 5$), lateral thorax and/or greater trochanter ($n = 4$), lateral thorax and/or iliac crest ($n = 1$) and other sites ($n = 2$).

Five variables were found to be significantly associated with IAPUs in the univariate analyses, including perspiration, a prolonged length of surgery, a high core temperature at the end of surgery and a large amount of bleeding (Table 1). We excluded the amount of bleeding from the following analysis because of its moderate correlation with the length of surgery (Pearson's $r = 0{\cdot}43$).

We then examined the threshold for the core temperature at the end of surgery using ROC curves. Consequently, the development of pressure ulcers was more likely to occur at a core temperature of more than 38·1°C (Figure 3). In addition, the core temperatures were higher in the patients with pressure ulcers (38·2 ± 0·5°C) than in those without pressure ulcers (37·7 ± 0·7°C). Hence, the optimal cut-off point for the core temperature was determined to be 38·1°C, with a sensitivity of 74·9% and a specificity of 73·4%. As the interaction between the length of surgery and the core temperature at the end of surgery was significant, we classified the patients into three groups for the logistic regression analysis: subjects with a length of surgery less than 6 hours, those with a length of surgery of 6 hours or longer with a core temperature of <38·1°C and those with a length of surgery of 6 hours or longer with a core temperature of ≥38·1°C. As the number of patients with a length of surgery less than 6 hours and a core temperature of ≥38·1°C was small ($n = 5$), this category was integrated into the first group.

According to the multivariate logistic regression analysis (Table 2), the risk factor independently associated with IAPUs included perspiration [$P = 0{\cdot}037$, OR 3·09, 95% confidence interval (CI) 1·07–8·58], and the combination of the length of surgery and the core temperature showed a significant association with the development of pressure ulcers. In particular, when the core temperature was below 38·1°C, the likelihood of developing IAPUs increased for a length of surgery of more than 6 hours ($P = 0{\cdot}095$, OR 2·64, 95%CI 0·84–9·08). Additionally, when the core temperature was more than 38·1°C, the odds ratio increased to 8·45 [$P < 0{\cdot}001$, 95% confidence interval (CI) 3·04–27·46] compared with a length of surgery of <6 hours, and a core temperature of more than 38·1°C demonstrated an increased odds ratio for developing IAPUs compared with a core temperature below 38·1°C when the length of surgery was more than 6 hours ($P = 0{\cdot}017$, OR 3·20, 95%CI 1·23–8·78).

Discussion

This study is the first to show that hyperthermia of more than 38·1°C was a risk factor for IAPUs in the park-bench position, and that there was a synergetic effect between length of surgery and core temperature. These relationships could not be fully showed in our previous study because of the small sample size.

The incidence rate of IAPUs in the present report is 11%, although it was 30% in the author's previous report (6). We

Table 1 Univariate analysis of risk factors associated with intraoperatively acquired pressure ulcers*

	With pressure ulcers ($n=30$)	Without pressure ulcers ($n=247$)	*P* value
Joint contractures, *n* (%)			
Yes	0	0	
No	30 (12·1)	247 (87·9)	-
Oedema, *n* (%)			
Yes	0	0	
No	30 (12·1)	247 (87·9)	-
Perspiration, *n* (%)			
Yes	9 (34·6)	17 (65·4)	
No	21 (8·4)	230 (91·6)	<0·001
Age (years, mean ± SD)	45·5 ± 11·5	45·5 ± 14·0	0·456
Gender, *n* (%)			
Male	12 (10·7)	100 (89·3)	
Female	18 (10·9)	147 (89·1)	0·884
Diabetes, *n* (%)			
Yes	1 (11·1)	8 (88·9)	
No	29 (10·8)	239 (89·2)	0·978
Congestive heart failure, *n* (%)			
Yes	0	1 (100·0)	
No	30 (10·9)	246 (89·1)	0·727
Hypertension, *n* (%)			
Yes	2 (11·1)	16 (88·9)	
No	28 (10·8)	231 (89·2)	0·968
Rheumatism, *n* (%)			
Yes	0	0	
No	30 (10·8)	247 (89·2)	-
Paralysis, *n* (%)			
Yes	1 (50·0)	1 (50·0)	
No	29 (10·5)	246 (89·5)	0·074
History of smoking, *n* (%)			
Yes	4 (6·0)	63 (94·0)	
No	26 (12·4)	184 (87·6)	0·142
Skin dryness, *n* (%)			
Yes	2 (16·7)	10 (83·3)	
No	28 (10·6)	237 (89·4)	0·506
Body mass index (mean ± SD)	23·5 ± 4·1	22·0 ± 3·1	0·988
Haemoglobin level (g/dL; mean ± SD)	13·6 ± 1·62	13·8 ± 8·22	0·357
Length of surgery (minute, mean ± SD)	443 ± 69·0	367·9 ± 87·9	<0·001
Core temperature at the end of surgery (°C, mean ± SD)	38·2 ± 0·5	37·7 ± 0·66	<0·001
Amount of bleeding (ml, mean ± SD)	306·9 ± 241·7	218·5 ± 199·2	0·008
ASA-Physical status classification, *n* (%)			
1	16 (10·6)	135 (89·4)	
2	14 (11·2)	110 (88·8)	
3	0	2 (100·0)	0·928
Bony prominence, *n* (%)			
Yes	7 (6·6)	99 (93·4)	
No	23 (13·5)	148 (86·5)	0·075
Use of rotation, *n* (%)			
Yes	2 (9·5)	19 (90·5)	
No	28 (10·9)	228 (89·1)	0·841
Use of skin polyurethane film, *n* (%)†			
Yes	30 (10·8)	244 (89·2)	
No	0	3 (100·0)	0·544

ASA-Physical status classification, American Society of Anesthesiologists Physical status Classification.

*The data are reported as the mean ± SD for continuous variables or *n* (%) for categorical variables. Differences were assessed using the unpaired *t*-test or Mann–Whitney *U* test for continuous variables and the chi-square test or Fisher's exact probability test for categorical variables.

†Use of skin polyurethane film, *n* (%): use for pressure ulcer prevention as a result of shear and friction.

had changed the pressure distribution and fixation methods in the park-bench position between this study and previous study. Although we have introduced additional intervention for interface pressure management by using a support surface as pressure ulcer prevention in the park-bench position, the incidence of pressure ulcer is still higher than that in other positions. Therefore, it is necessary to consider the risk factor of pressure ulcer development other than interface pressure. It should be noted that our participants were generally younger than patients who develop pressure ulcers in the general unit or in nursing homes (39). In addition, the young participants displayed a good general condition on admission, with the exception of neurological disorders, indicating that general risk factors may not contribute to pressure ulcer development in this population. In this study, perspiration, length of surgery and core temperature were identified to be the risk factors for IAPUs, and there was a synergistic relationship between the core temperature and the length of surgery, in that a core temperature above 38·1°C exacerbated the effects of prolonged surgery for more than 6 hours on the development of pressure ulcers by approximately three-fold. Although the length of surgery is not necessarily modifiable, regulating perspiration and the core temperature is a preventable strategy from a nursing perspective and entails collaboration with the anaesthesiologist for controlling the patient's thermal condition.

An increased core temperature was found to be a particular risk factor for IAPUs in the park-bench position. In the park-bench position, the patient's core temperature is increased because their body is covered with a full drape, except for the head. An increased core temperature further increases the skin temperature at areas of contact with the operating table. In a study of healthy individuals, an increase in skin temperature by 1·0°C was shown to activate tissue metabolism by 10% requiring the supply of more oxygen and nutrients (40). In addition, high interface pressure during surgery reduces or interferes with the blood flow, resulting in poor supply relative to the increased demand, thus causing tissue damage (41). This result is surprising because hyperthermia has been demonstrated to be a protective factor in the general unit based on the effects of vasodilation associated with an increased blood flow and oxygenation (39).

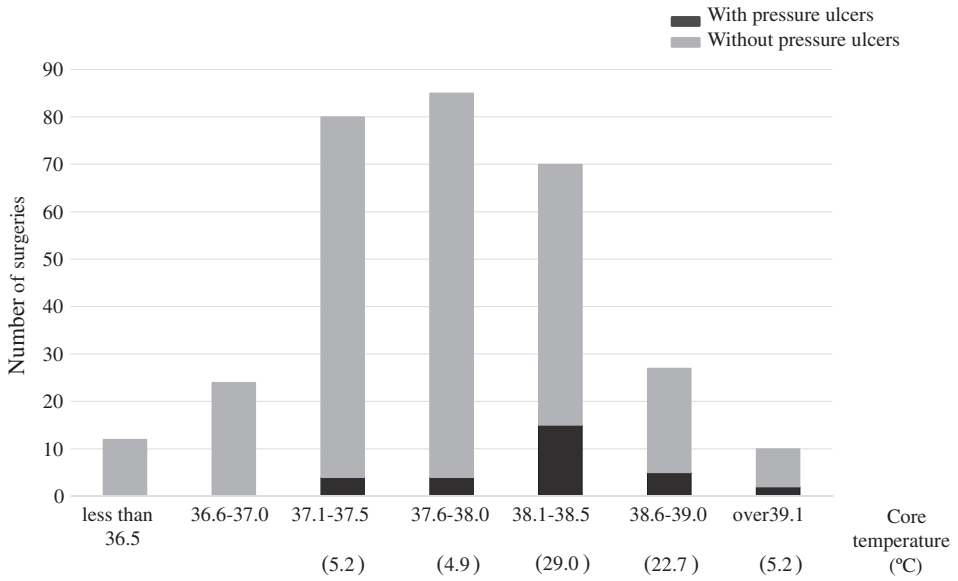

Figure 3 Relationship between the core temperature at the end of surgery and the incidence of pressure ulcers, The core temperature at the end of surgery was measured according to the rectal temperature at the end of surgery. The values below each range of core temperature show pressure ulcer incidence (%). The number of surgeries associated with pressure ulcers increased for a core temperature of more than 38·1°C at the end of surgery. No pressure ulcers developed at a core temperature of less than 37·1°C at the end of surgery.

Table 2 Multivariate analysis of risk factors associated with intraoperatively acquired pressure ulcers ($n=277$)

Variables	Odds ratio	(95% CI)	*P* value
Perspiration			
No	1·00		
Yes	3·09	(1·07-8·58)	0·037
Length of surgery and core temperature			
Less than 6 hours	1·00		
More than 6 hours and less than 38·1°C	2·64	(0·84-9·08)	0·095
More than 6 hours and more than 38·1°C	8·45	(3·04-27·46)	<0·001

In contrast, vasodilation does not occur in the park-bench position as a result of persistent pressure on contact areas, which is higher than the pressure observed in the capillary. Therefore, the adverse effects of hyperthermia on tissue become apparent. Because the anaesthesiologists prioritised the prevention of adverse events caused by hypothermia, approximately one-third of the patients showed a core temperature >38·1°C, even though we usually provided several interventions when the core temperature of the patient reached 37·5–38·0°C as advised by our anaesthesiologists. We, along with our anaesthesiologists, may be able to provide alternative interventions against hyperthermia considering the risk of PU by early cessation of active warming of the device or increasing heat exchange in local skin temperature on the operating table using sheets.

An interaction was observed between the core temperature and length of surgery in this study. The length of surgery is a well-known risk factor for pressure ulcers in surgical units (13–17). However, the length of surgery is mostly dependent on the difficulty of the procedure, including factors such as the size or location of neoplasms and the amount of bleeding. It is difficult to shorten the length of surgery directly, considering the safety of the surgery. On the other hand, the core temperature can be adjusted by the operating theatre nurses by controlling the warming device and consulting the anaesthesiologist. In an experimental study, tissue damage within the deep and superficial layers was shown to be enhanced by increasing skin temperature, even under consistent pressure–time loads (42). These observations suggest that IAPUs may be prevented by maintaining the patient's core temperature at the appropriate level, even during prolonged surgeries.

Perspiration was also found to be independently associated with IAPUs in the park-bench position in the present study. Perspiration may be associated with the presence of skin moisture, which subsequently weakens the crosslinks among collagen fibres in the dermis and thus promotes skin fragility (43). Moreover, the park-bench position often produces a shearing force as a result of elevation of the patient's head on the operating table and the incline of the operating table towards the patient's abdomen so as to secure the surgeon's field of vision. Therefore, skin moisture resulting from perspiration is thought to increase the degree of friction (41), ultimately resulting in pressure ulcer development. Although perspiration is a reaction to hyperthermia in the general setting, perspiration may also occur independently from the core temperature in the park-bench position. In the current study, perspiration was observed in only 10 of the 58 patients with a core temperature of more than 38·1°C. This inconsistency may be attributed to the effects of cytokines induced by surgical invasiveness and the use of anaesthesia, which increase the threshold of the core temperature for perspiration by altering the central temperature regulatory centre (44).

Strengths of the present study include the fact that the surgery-related procedures were standardised and a relatively

large sample size was used. Furthermore, all staff received adequate training for the position fixation method because scheduled surgery was conducted almost 3 days per week. In addition, anaesthesia was performed using total intravenous anaesthesia. Finally, the surgeries were conducted by the same neurosurgical procedure operator and the IAPUs were observed by the same individuals. Therefore, the effects of bias due to facility-related factors were small.

Limitations

The first limitation of this study is the unclear timing of perspiration, hyperthermia and pressure ulcer development during the course of surgery. If the precise onset of these complications is identified in a future study using monitoring devices, the most appropriate timing to initiate proper interventions could be determined. The second limitation is the lack of measurements of the interface pressure in the retrospective data. However, the influence of interface pressure was not considered to be large because BMI and bony prominences were not extracted as risk factors in our results.

Conclusion

The present study identified specific risk factors, including perspiration, the length of surgery and the core temperature, for pressure ulcer development in the park-bench position. In particular, a core temperature of more than 38·1°C demonstrated an interactive effect with a length of surgery of more than 6 hours, and perspiration was found to be independently related to IAPUs based on the core temperature. These findings suggest that clinicians may prevent IAPUs by managing the level of perspiration and controlling the patient's core temperature to less than 38·1°C in collaboration with the anaesthesiologist under conditions of prolonged surgery.

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