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Original Article

Risk factors for intraoperative pressure ulcers in surgical patients

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Abstract: Objective: To investigate risk factors for intraoperative pressure ulcers and provide a scientific basis for predicting the occurrence of pressure ulcers in the operating room. Methods: We used a prospective analysis design with single-factor analysis and a logistic regression method. Data were collected for 1052 patients, who underwent neurosurgery, orthopedic surgery, pediatric surgery, or heart surgery between October 2014 and April 2015 at Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital in China. Results: There were 26 cases (2.47%) of intraoperative pressure ulcer occurrence. The risk factors for intraoperatively acquired pressure ulcers included surgery length, anesthesia time, blood loss, blood transfusion, table tilt, necessary physical maneuvers during surgery, extracorporeal circulation, and intensive care unit stay ($P < 0.05$). Logistic regression analysis demonstrated that operation time, anesthesia time, blood loss, physical maneuvering, and surgical units were all independent risk factors for intraoperatively acquired pressure ulcers ($P < 0.05$, for all). Conclusion: Prolonged surgery and anesthesia, specific positions for different operations, excessive blood loss, and physical maneuvering were substantial risk factors for the occurrence of intraoperative pressure ulcers in patients. Thus, active monitoring and appropriate treatment are highly recommended.

Keywords: Operating room, pressure ulcers, intraoperative, elevated risk factors

Introduction

An intraoperative pressure ulcer is a pressure ulcer that occurs from several hours to 6 days post-surgery. Compared to inpatient pressure ulcers, which occur at a rate of 1-11%, intraoperative pressure ulcers occur at a higher rate of 4.7-66% [1]. The high prevalence rate is attributed to several necessary factors associated with surgery [2], such as patient fasting, special positioning post-anesthesia, and a moist skin surface resulting from skin prep [3]. Close observation of and interventions for intraoperative pressure ulcers have become standards for nursing care in the operating room. The occurrence of intraoperative pressure ulcers negatively affects patients because of pain, unexpected treatment of complication, need for additional surgery, prolonged inpatient admission, and scarring [4]. It also increases patients' financial burden and increases nursing workload by 50% [5], causing a corresponding increase in the cost of treatment that surpasses hospital budgets.

However, studies on intraoperative pressure ulcers are very limited and have shown inconsistent results. More than 100 different risk factors related to intraoperative pressure ulcers have been identified to date [6-8]. Intraoperative presser ulcers usually result from the interaction of several factors, causing the high prevalence in the operating room [9, 10]. Thus, this study focused on analyzing the risk factors for intraoperative pressure ulcers using a logistic regression method.

Patients and methods

Patients

Data were collected for patients, who underwent neurosurgery, orthopedic surgery, pediatric surgery, or heart surgery, between October 2014 and April 2015, at the Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital. The selection criteria were as follows: general anesthesia, elective surgery, length of surgery > 90 minutes, and patient consciousness level. Exclusion criteria included: patient refusal to participate in the study, critically ill status, limited range of motion per physician order, and death during or within 2 days after surgery.

Research methodology

Published domestic and international studies were reviewed and screened for factors affecting intraoperative pressure. A questionnaire was developed and subsequently revised by seven clinical nursing specialists, after three evaluations. The questionnaire contained 33 questions about the following: sex, age, weight, surgical history, preexisting comorbidities, body mass index (BMI), length of bed rest, glycemic index, glycemic load, mobility, skin sensation, state of consciousness, blood pressure, glucose level, and fever 1 day prior to surgery. Other factors included surgery length, anesthesia time, preoperative waiting time, recovery time, operating position, table tilting during surgery, physical maneuvering, wet linen, and hypothermia/hypotension. Data were also collected for lowest oxygen saturation during surgery, operating room temperature, emergency surgery status, cardiopulmonary bypass, intensive care unit (ICU) stay, anesthesia method, and American Society of Anesthesiologist classification.

Data collection

To ensure methodology and data collection accuracy, we trained nurse participants in various aspects of the study: subject recruitment, methods, tools, and process with special attention to localized injury and clinical manifestations of pressure ulcers. Four weeks prior to the study, 56 clinical nursing participants underwent a special 5-hour training provided by a wound care/stoma specialist. Knowledge of pressure ulcers was enhanced with pictures and case studies. Two weeks prior to the study, two of six project designers with master's degrees led the pre-survey. Data from the patients' preoperative, intraoperative, and postoperative nurse visits were collected. They were corrected and modified in regard to certain inconsistencies and unreasonable classifications in the questionnaire. Circulating nurses, surgical unit/ICU charge nurse, and wound care/stoma specialists collectively settled any differences in assessments.

Statistical analysis

EXCEL 2010 was used for the data entry, while R 3.1.2 software was used for statistical analysis. Measurement and enumeration data are expressed as average ± standard deviation and percentage, respectively. The X^2 test or Fisher's exact test was used to compare enumeration data. Student's *t* test was used to compare normally distributed data; Wilcoxon signed rank test was used to compare data with an unbalanced distribution and an unconditioned Logistic regression method was used for analyzing risk factors related to pressure ulcer. Values of $P < 0.05$ were considered statistically significant.

Results

Intraoperative pressure ulcer statistics

This study collected the surgical data of 1052 patients from October 2014 to April 2015. The male to female ratio was 1:0.897 with an average age of 50.58 years. A total of 26 patients (2.47%) developed pressure ulcers post-surgery: 10 after cardiac surgery, 9 after neurosurgery, six after orthopedic surgery, and one after pediatric surgery. Among the 26 patients, a total of 37 localized pressure ulcers developed, including 27 cases of stage I (erythematous area over bony process or ridge does not blanche with pressure) and 10 of stage II (serous blisters). The size varied from 0.2 × 0.3 to 5 × 6 cm. (Pressure ulcers are classified as per the international NPUAP/EPUAP system.)

Single-factor analysis of intraoperative pressure ulcers

All collected data were divided into two groups for the statistical analysis. Discrete variable single-factor analysis was performed using the X^2 test or Fisher's exact test. The results showed a lower intraoperative pressure ulcer occurrence compared to the control group, when the factors of table tilting, physical maneuvering, cardiac bypass, and ICU stay

Table 1. Comparison of clinical features between the control and intraoperative pressure ulcer groups (discrete variables)

Project	Normal	Pressure ulcer	*P*
Gender			0.036
Male	494	19	
Female	532	7	
Combined diabetes			0.8
Yes	46	1	
No	980	25	
Fever one day before operation (body temperature > 37.5°C)			0.26
Yes	12	1	
No	1014	25	
Operative position			0.4
Horizontal position	1	0	
Lateral position	680	0	
Prone position	159	14	
Fowler position	162	3	
Lithotomy position	11	9	
Lateral position + Prone position	2	0	
Lateral position + Fowler position	4	0	
Lateral position + lithotomy position	1	0	
Prone position + Fowler position	5	0	
Lateral position + Prone position + Fowler position	1	0	
Tilt of operating bed			< 0.001
Yes	196	18	
No	830	8	
Physical maneuver			< 0.001
Yes	385	20	
No	641	6	
Hypotension			0.41
Yes	41	2	
No	985	24	
Hypothermia (body temperature < 36°C)			0.67
Yes	91	0	
No	935	26	
Emergency operation			0.73
Yes	134	1	
No	892	25	
Cardiopulmonary bypass			< 0.001
Yes	114	9	
No	912	17	
ICU stay			< 0.001
Yes	311	20	
No	715	6	
Anesthesia			0.92
General Anesthesia	939	26	
Combined spinal-epidural anesthesia (CSEA)	35	0	
Epidural Block	1	0	
Nerve Block	32	0	
Local Infiltration Anesthesia	9	0	
General Anesthesia + CSEA	1	0	
General Anesthesia + Nerve Block	7	0	
CSEA + Nerve Block	2	0	

Table 2. Comparison of factors contributing to intraoperative pressure ulcer development (continuous variables)

Project	Normal	Pressure ulcer	P
Age	50.6±16.6	49.7±17.9	0.79
BMI	22.8 (20.6, 25.0)	20.9 (19.9, 24.8)	0.52
Preoperative hemoglobin	130±23.4	132±31.9	0.58
Preoperative white blood cell	8.2±6.4	6.8±2.2	0.07
Preoperative serum albumin	40.9±6.7	41.3±4.9	0.78
Operation time	130 (80, 202)	260 (198, 316)	< 0.001
Anesthesia time	175 (115, 250)	290 (245, 360)	< 0.001
Preoperative waiting time	50 (30, 80)	50 (20, 123)	0.15
PACU residence time	30 (0, 30)	0 (0, 0)	< 0.001
Intraoperative blood loss	150 (50, 300)	600 (400, 950)	< 0.001
Intraoperative blood transfusion	0 (0, 0)	575 (312, 750)	< 0.001
Minimum oxygen saturation	100 (100, 100)	100 (100, 100)	0.92
Operating room temperature	22 (21.2, 23)	22 (21.6, 23)	0.22

post-surgery were involved. The intergroup differences were statistically significant (**Table 1**). All collected patient data were divided into groups for statistical analysis. Student's *t* test was used for normally distributed data in the continuous variable single-factor analysis. The pressure ulcer occurrence was higher in patients who had a prolonged operation time, anesthesia time, or recovery time than in patients without pressure ulcers. Bed rest time, blood loss, and transfusion during surgery were identified as risk factors as well (**Table 2**).

Multiple-factor analysis of intraoperative pressure ulcers

A binary multivariate logistic regression analysis was performed with the occurrence of intraoperative pressure ulcers as the dependent variable and statistically meaningful results via single-factor analysis as the independent variables. The factors on single-factor analysis with values of $P < 0.05$ were entered into the multiple-factor analysis (**Table 3**). The results showed that operation time, anesthesia time, blood loss, and physical maneuvering were entered into the regression equation (**Table 4**).

Discussion

The occurrence of intraoperative pressure ulcers was 2.47% in this study, lower than that in the UK (15.6%) according to the Nixon report [11]. The results showed that four independent variables (operation time, anesthesia time, blood loss, physical maneuvering) were entered into the intraoperative pressure ulcer decision tree model as the risk factors for intraoperative pressure ulcers [12-14]. However, many other studies mentioned other factors related to pressure ulcer risk, such as patient BMI, serum albumin, and surgical position, that could not be entered into the regression equation [15-17]. This may be due to differences in research methods, risk factor entry, or demographic characteristics that contribute to differences in patient intraoperative pressure ulcer study outcomes. Here, we report our findings of risk factors for intraoperative pressure ulcer. Prolonged operation time is commonly acknowledged as a substantial risk factor for the occurrence of intraoperative pressure ulcers [18]. Our study showed that surgery length is an important risk factor (odds ratio [OR], 2.86×10^4; P < 0.001).

Our study reveals that patients with acquired pressure ulcers have a mean surgery time twice as long as that of the control group. Increased surgery time, decreased circulation, ischemia within the local compressed tissue, and decreased skin temperature of the compressed area caused the pressure ulcers. Moreover, the effect was more significant when patients were obese, thin, elderly, fragile, or had poor skin elasticity. Our study also showed that anesthesia time was another important high-risk factor for the occurrence of intraoperative pressure ulcers (OR, 7.2×10^6; P < 0.001). Under the influence of anesthesia, 55% of patients developed hypoxemia and decreased circulation in the compressed area. Furthermore, under the influence of anesthesia, patients had a slower or temporary loss of response to abnormal body changes [19]. Those factors contributed to skin and soft-tissue ischemia and anaerobic metabolites, predisposing patients to pressure ulcers.

A previous study demonstrated that patients administered epidural anesthesia had a higher incidence of intraoperative pressure ulcers

Table 3. Classification assignment of independent variables

Project	Classification assignment
Preoperative bed rest	0 day = 1; 1~3 days = 2; 4~10 days = 3; > 10 days = 4
Operation time	0~30 min = 1; 31~120 min = 2; 121~240 min = 3; 241~360 min = 4; > 361 min = 5
Anesthesia time	0~60 min = 1; 61~120 min = 2; 121~240 min = 3; > 240 min = 4
Intraoperative blood loss	0 ml = 1; 1~100 ml = 2; 101~400 ml = 3; 401~1000 ml = 4; > 1000 ml = 5
Intraoperative blood transfusion	0 ml = 1; 1~100 ml = 2; 101~400 ml = 3; 401~1000 ml = 4; > 1000 ml = 5
Physical maneuver	Yes = 1; No = 0

Table 4. Multiple logistic regression analysis results of risk factors for intraoperative pressure ulcers

Project	β	SE	P	OR	95% CI
Preoperative bed rest	1.56	0.22	0.033	4.76	1.14-20.00
Operation time	10.26	$8.82 * 10^2$	< 0.001	$2.86 * 10^4$	0-0.6
Anesthesia time	13.48	$1.74 * 10^3$	< 0.001	$7.2 * 10^6$	0-0.4
Intraoperative blood loss	16.33	$9.43 * 10^2$	< 0.001	$1.24 * 10^7$	0-0.4
Intraoperative blood transfusion	2.29	0.45	< 0.001	9.89	2.99-32.73
Physical maneuver	1.57	0.46	< 0.001	4.81	1.92-12.04

than those administered general anesthesia [20]. Surgical and anesthesia time also play important roles. It is worth mentioning that anesthesia time and surgical time are not the same in our practice. A few previously reported factors that increases pressure ulcer risk included inadequate preparation for anesthesia and poorly coordinated anesthesia and surgery times, causing unnecessary prolongation of anesthesia time [21].

Our study shows that intraoperative blood loss (OR, 1.24×10^7; $P < 0.001$) and blood transfusion (OR, 9.89; $P < 0.001$) are important high-risk factors for the occurrence of pressure ulcers. Lyder's retrospective study showed seven common risk factors for pressure ulcers: decreased mobility, poor nutrition, incontinence, medication influence (sedative, anesthetic), hypoxia, decreased artery flow, and age [22]. Our data also demonstrated that increased intraoperative blood loss also resulted in an increased incidence of pressure ulcers. Crum et al. reported equivalent results via multivariate logistic regression for pressure ulcer occurrence during abdominal surgery [23]. In fact, another report stated that excessive blood transfusions is the single greatest risk factor for pressure ulcer development in abdominal surgery.

Tissues become hypoxic when intraoperative blood loss increases. Physicians often order blood transfusions when excessive blood loss occurs during surgery. The oxygenated muscles might produce superoxide anion when the hypoxia is relieved by perfusion, causing capillary damage and neutrophil infiltration. Furthermore, it damages the skin and increases the occurrence of pressure ulcers.

Our study showed that intraoperative physical maneuvering is a risk factor for the occurrence of pressure ulcers (OR, 4.81; $P < 0.001$). Manipulation during surgery, such as for instrument placement and retractors, is another factor contributing to an increased pressure ulcer occurrence. Hu et al. stated that surgical staff press against a patient's limb during surgery is another cause of intraoperative pressure ulcers [24]. Intraoperative physical maneuvers include the additional impact and vibration to the surgical sites by nails, chisels, drills, and saws [25], all of which increase the pressure and shear force upon the surgical site and greatly increase the risk of intraoperative pressure ulcers.

Routine usage of pressure to stop bleeding, restraints, and fasteners are common physical maneuvers in our practice. The use of pressure to stop bleeding will directly cause capillary shutdown and hypoxia when the physical pressure exceeds the normal capillary interface pressure (23-32 mmHg) [26]. Likewise, inappropriate application of fasteners causes excessive restraint force and exceeds the capillary interface pressure.

According to a national study, there is a higher incidence of pressure ulcer development in cardiac, vascular, spinal, and head and neck units, e.g. general surgery (9.5%), open heart surgery (17.3%), and major orthopedic surgery (11.82%) [27, 28]. Our data showed that cardiac surgery features one of the highest incidences of pressure ulcers. The risk of developing a pressure ulcer increases 15.9 times when a patient undergoes cardiopulmonary bypass (CPB). One study indicates that 40% of patients on CPB machine will develop redness at the tail bone and heel within 24 hours post-surgery. This might be related to poor capillary circulation due to hypothermia during surgery, the use of a warm blanket post-CPB, and a lack of protection of the subcutaneous tissue around the heel [29]. Thus, we must further provide adequate prevention during and after surgery for patients who undergo CPB surgery.

Our study's limitations include its limited follow-up time and the lack of assessing patient emotional stage, although both factors can be addressed in future studies.

In conclusion, here we verified some risk factors related to intraoperative pressure ulcer development. Our findings stress that we must closely monitor, continue to actively assess risk factors, enhance recognition rates, and actively treat patients with potential risk factors of intraoperative pressure ulcers. Nursing administrators should establish protocols, perfect the pressure ulcer monitoring model, and enhance overall nursing skills to prevent and manage pressure ulcers.

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Disclosure of conflict of interest

None.

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