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ORIGINAL ARTICLE

A prediction tool for hospital-acquired pressure ulcers among surgical patients: Surgical pressure ulcer risk score

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Surgical patients are prone to developing hospital-acquired pressure ulcers (HAPU). Therefore, a better prediction tool is needed to predict risk using preoperative data. This study aimed to determine, from previously published HAPU risk factors, which factors are *significant* among our surgical population and to develop a prediction tool that identifies pressure ulcer risk before the operation. A literature review was first performed to elicit all the published HAPU risk factors before conducting a retrospective case-control study using medical records. The known HAPU risks were compared between patients with HAPU and without HAPU who underwent operations during the same period (July 2015-December 2016). A total of 80 HAPU cases and 189 controls were analysed. Multivariate logistic regression analyses identified eight significant risk factors: age ≥ 75 years, female gender, American Society of Anaesthesiologists ≥ 3, body mass index < 23, preoperative Braden score ≤ 14, anaemia, respiratory disease, and hypertension. The model had bootstrap-corrected c-statistic 0.78 indicating good discrimination. A cut-off score of ≥6 is strongly predictive, with a positive predictive value of 73.2% (confidence interval [CI]: 59.7%-84.2%) and a negative predictive value of 80.7% (CI: 74.3%-86.1%). SPURS contributes to the preoperative identification of pressure ulcer risk that could help nurses implement preventive measures earlier.

KEYWORDS
nosocomial, pressure injury, surgery, surgical risk factors, risk assessment

1 | INTRODUCTION

Surgical patients are at a higher risk of developing pressure ulcers because of many factors such as a prolonged period of immobility, surgical/anaesthesia-related factors, and pre-existing medical conditions.[1,2] It is well-recognised that pressure ulcers are a significant cause of morbidity and lead to a lower quality of life for both patients and their carers.[3,4] In the United States, patients with hospital-acquired pressure ulcers (HAPU) had a longer length of stay, higher total hospitalisation costs, and greater odds of readmissions compared with patients with no HAPU.[5] Similarly, in Singapore, patients with HAPU had higher hospitalisation costs and lengths of hospitalisation.[6]

It is well recognised that HAPU is avoidable. Preventing HAPU involves accurate and ongoing risk assessments so that preventive measures can be implemented as early as possible and carried out throughout the period of immobility. The prevalence of HAPU among surgical patients is about 8.5% or higher depending on the type and the duration of the surgery.[7] Notably, patients with HAPU were more likely to be discharged to a skilled nursing or other facility compared with the home.[8]

Singapore General Hospital (SGH) is one of the oldest and largest acute care hospitals in Singapore. An estimated 47 000 surgeries are performed annually in SGH across the different surgical disciplines, including orthopaedics, urology, hepatobiliary, and surgical oncology. Currently, we use the Braden scale to assess pressure ulcer risk for both medical and surgical patients. The pressure ulcer risk assessment is usually conducted on the day before surgery or postoperatively, depending on the type of admission, that is, elective or emergency operation.

The Braden scale is a generic pressure ulcer risk assessment tool that consists of six subscales that evaluate a patient's sensory perception, activity level, mobility, and nutrition status and the skin's exposure to moisture, friction, and shear forces. A lower total Braden scale score indicates a higher risk of developing pressure ulcers.[9] The Braden scale is able to demonstrate at least 70% sensitivity and specificity for identifying inpatients at risk of pressure ulcers.[10] However, a meta-analysis concluded that the Braden scale's predictive validity of risk for pressure ulcers can only be interpreted at a moderate level because of heterogeneity between studies.[11] Although the Braden scale is well validated and accepted for use in the acute care setting, the preoperative Braden score may not accurately reflect postoperative risks as it does not include preoperative variables such as age, body mass index (BMI), or significant comorbidities that are associated with the development of pressure ulcers in surgical patients.[1,12] Moreover, following a meta-analysis, it was recommended that the Braden scale should not be used alone to assess pressure ulcer risk in surgical patients because of its low predictive validity.[13]

According to Torra i-Bou,[14] the ideal characteristics of a pressure ulcer risk assessment scale (PURAS) should include high sensitivity and specificity, good predictive value, be easy to use, have clear and well-defined criteria, and be applicable to different health care settings. We applied these criteria to the previously published tools for assessing pressure ulcer risk among surgical patients.[15–18] Details of these tools are summarised in Tables A2 and A3.

None of the PURAS has been validated except for the Prevention and Pressure Ulcer Risk Score Evaluation (prePURSE) tool, which was statistically validated using a bootstrapping method. The prePURSE has five items that predict pressure ulcers (PU) risk: age, weight at admission, abnormal appearance of skin, friction/shear problem, and surgery in the coming week.[15] Although it has the least number of items and appears easy to use, one of the items, abnormal skin appearance, is not clearly defined and, therefore, may be subjected to inaccurate assessment by inexperienced nurses. The prePURSE tool has only been validated for patients in the general wards care setting whose length of hospitalisation is short (<5 days), and the tool was reported to have a high false-positive prediction (40%).

Therefore, we need a prediction tool that is able to predict pressure ulcer risk before the operation, so preventive measures can be initiated earlier. Hence, this study aimed to determine, from previously published HAPU risk factors, which factors are *significant* among our surgical population and to develop a prediction tool that identifies pressure ulcer risk before the operation.

1.1 | Literature review

A search was conducted on PubMed and CINAHL databases from 2007 to 2018 using the following search terms: "pressure ulcers"; "surgery"; and "risk factors". The search was limited to only adult patients. Besides identifying the information gaps on the *known* risk factors, this literature review also served to inform the selection of preoperative predictors or confounders associated with the development of HAPU among surgical patients. However, only the preoperative risk factors are presented in Table A1.

Twenty-five relevant articles were reviewed, consisting of 22 primary studies of various study designs and three systematic/meta-analyses. Study design, targeted population, and pressure ulcer sites of interest varied across the 22 articles. Most of the studies only reported the stages of the pressure ulcer, and not all reported the location of the pressure ulcers except, for Campbell et al,[19] who only reported pressure ulcers that developed on heels.

Key Messages

- preventing hospital-acquired pressure ulcers (HAPU) among surgical patients requires the accurate identification of risk and early implementation of preventive interventions
- this study aimed to determine which previously published HAPU risk factors are significant among our surgical population and to develop a prediction tool that identifies pressure ulcer risk before the operation
- this study identified eight significant risk factors among our surgical population who developed hospital-acquired pressure ulcers: age ≥ 75 years, female gender, American Society of Anaesthesiologists ≥ 3, BMI ≤ 23, preoperative Braden score ≤ 14, anaemia, respiratory disease, and hypertension
- a prediction tool, called the surgical pressure ulcer score (SPURS), was developed using these eight significant factors to predict pressure ulcer risk, which can be used before the patient's operation

1.2 | Demographic risk factors

Most of the studies agreed that pressure ulcers occurred commonly in older patients,[8,12,20–25] but only Wright et al[26] found decreasing age to be associated with HAPU; however, Wright's study had a much smaller sample size (N = 88), and hence, it may be under-powered to detect statistical significance. There were also studies that did not find older age to be significantly associated with HAPU,[1,27–29] but their study population's mean age was between 48 and 58 years. Interestingly, Kopp et al[30] also did not find older age to be associated with HAPU even though their sample population was patients older than 70 years old who underwent surgery for hip fracture.

Another common risk factor associated with HAPU is gender. Most studies found no difference between men and women[1,12,23,31–33] in the development of HAPU except for Hayes et al,[21] who concluded that men were more likely to

develop pressure ulcers compared with women (65% vs 60%), and a recent systematic review has also agreed that the prevalence of postoperative pressure ulcers was higher in women than men (13% vs 10%).[34]

The impact of a patient's comorbidities on development of HAPU is rather uncertain. For example, Lin et al[33] did not find diabetes to be associated with development of HAPU; however, this could be because of the relatively young population in their study (mean age: 48 years). A systematic review on cardiac surgical patients has agreed that diabetes is a significant predictor of the development of HAPU. However, a meta-analysis on all types of surgical patients did not find any increase in the incidence of pressure ulcers in diabetic patients undergoing hip surgery compared with non-diabetic controls.[35]

A majority of the studies had focused on pre- or intraoperative risk factors associated with HAPU among surgical patients. However, the associated risk factors are still somewhat unclear. Therefore, it is of interest to ascertain the *significant* risk factors among the *known* risk factors for our surgical adult population in SGH. Specifically, we focus on the preoperative risk factors because knowledge of the preoperative risk factors would allow us to plan and implement preventive measures even before the surgical procedure.

Hence, this study aimed to (a) to determine the *significant* preoperative risk factors among the *known* preoperative risk factors associated with HAPU among surgical patients and (b) to develop a prediction tool to assess pressure ulcer risk before the patient's operation.

2 | METHODS

2.1 | Ethical considerations

This study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. Permission from the ethical review board and the institution's data protection officer were sought before conducting this study (Centralised Institutional Review Board reference number 2016/2394).

2.2 | Setting and study sample

This retrospective medical record review was conducted in SGH, an academic teaching hospital in Singapore. Our study covered adult patients who underwent surgery at SGH between July 2015 and December 2016. Day surgery was excluded because of the short postoperative follow-up period, and cardiothoracic surgery was excluded because of institutional constraints. For patients who underwent multiple surgeries, we analysed their last surgery during the study period.

From this study group, we identified the cases to be any adult surgical patients with HAPU (stage 1 and above according to NPUAP/EPUAP classification)[36] listed in hard-copy medical records or in the hospital's risk management system (RMS). The RMS is an information system for mandatory reporting of incidents at SGH, including all pressure ulcers of stage 2 or above. Data pertaining to stage 1 pressure ulcers were extracted from hard-copy medical records.

Controls in this study were a random selection of adult surgical patients admitted for surgery during the same period but who did not develop HAPU. Control patients were identified via the operating theatre management system that captures all surgery-related information in SGH. Cases and control were compared on the *known* preoperative risk factors that were gathered from the literature. Two trained nurses performed all the data extraction manually.

2.3 | Data analysis

All analyses were performed using IBM SPSS Statistics version 23 and R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were presented as count and percentage as all variables were categorised into groups for analysis. Fisher exact or χ^2 tests were used to evaluate differences in demographic and clinical factors between patients who developed pressure ulcers and those who did not. Risk factors measured on a continuous scale were dichotomised at cut-off values based on the visual exploratory data display of the factors by pressure ulcer as well as from choice of cut-off values, yielding optimum sensitivity and specificity for the prognosis of pressure ulcer by receiver operating characteristics. All factors found to be significant at $P < 0.10$ in univariate analysis, as well as known risk factors for pressure ulcers, were considered in the construction of a multivariate logistic regression prediction model. Backward stepwise variable selection was used with exit criteria of $P > 0.10$ and entry criteria of $P < 0.05$. The regression coefficient of each factor found predictive in the logistic regression was converted into an integer to represent the risk score associated with that factor.

For each patient, the corresponding integer score was assigned to each of the risk factors when present and a score of zero when absent. The final score, which we call the surgical pressure ulcer risk score (SPURS), was defined as the sum of the integers corresponding to each independent variable.

Internal validation of the model was performed using an enhanced bootstrap technique with 200 resamples from our original dataset.[37] As a result of bootstrapping, performance measures of the derived tool were obtained, namely, the c-statistics and the calibration curve, both corrected for bias. The c-statistics assessed the discrimination of the model, that is, the ability of the model to distinguish those who had HAPU from those who did not. On the other hand, calibration is the correspondence between the predicted probability and the observed probability of HAPU. A c-statistic of 0.7 to

TABLE 1 Baseline patient characteristics by pressure ulcer group and univariate results

Factors		Pressure ulcer (N = 80)	No pressure ulcer (N = 189)	*P*-value
Demographics				
Age	≥75 years	35 (43.8%)	31 (16.4%)	0.001
Gender	Female	44 (55%)	84 (44.7%)	0.122
Race	Chinese	72 (90%)	141 (75%)	0.041
	Malay	5 (6.3%)	25 (13.3%)	
	Indian	1 (1.3%)	13 (6.9%)	
	Others	2 (2.5%)	9 (4.8%)	
BMI	<23	44 (56.4%)	68 (39.3%)	0.012
	≥23	34 (43.6%)	105 (60.7%)	
Smoking history	Yes	13 (16.3%)	34 (18.9%)	0.610
Clinical variables				
ASA grade	1-2	18 (22.5%)	118 (62.4%)	0.001
	≥3	62 (77.5%)	71 (37.6%)	
Preoperative Braden score	≤14	21 (26.3%)	11 (5.9%)	0.001
	≥15	59 (73.8%)	175 (94.1%)	
Case type	Emergency	33 (41.3%)	52 (27.7%)	0.029
	Elective	47 (58.8%)	136 (72.3%)	
Surgical type	Integumentary	11 (17.2)	39 (25.3%)	0.529
	Musculoskeletal	18 (28.1)	50 (32.5)	
	Respiratory	1 (1.6)	6 (3.8)	
	Hemic & Lymphatic	1 (1.6)	3 (1.9)	
	Digestive	25 (39.1)	39 (25.3)	
	Urinary-gynaecology	0	6 (3.9)	
	Endocrine	2 (3.1)	4 (2.6)	
	Nervous system	2 (3.1)	6 (3.9)	
Comorbidities				
Anaemia		14 (17.5%)	4 (2.1%)	0.001
Diabetes mellitus		26 (32.5%)	43 (22.8%)	0.094
Heart disease		22 (27.5%)	26 (13.8%)	0.007
Hypertension		48 (60%)	68 (36%)	0.001
Stroke		3 (3.8%)	4 (2.1%)	0.442
Renal disease		21 (26.3%)	16 (8.5%)	0.001
Vascular disease		9 (11.3%)	11 (5.8%)	0.121
Neurological disease		0 (0%)	6 (3.2%)	0.107
Respiratory disease		11 (13.8%)	6 (3.2%)	0.001
Outcomes				
Pressure ulcer site	Sacrum and coccyx	51 (63.8%)	0 (0%)	NA
	Heel	6 (7.5%)	0 (0%)	
	Iliac crest	1 (1.3%)	0 (0%)	
	Others	22 (27.5%)	0 (0%)	
Pressure ulcer stage	Stage 1	43 (53.8%)	0 (0%)	NA
	Stage 2	26 (32.5%)	0 (0%)	
	Stage 3	1 (1.3%)	0 (0%)	
	Stage 4	0 (0%)	0 (0%)	
	Stage 5	10 (12.5%)	0 (0%)	
ICU stay	Yes	15 (19%)	0 (0%)	0.068
Hospitalisation length of stay, days		39 (14, 82)	4 (2, 9)	0.001

Abbreviations: ASA, American Society of Anaesthesiologists'; BMI, body mass index; ICU, intensive care unit; NA, not applicable to do statistical test.
Significance taken at $P \leq 0.10$.

0.9 is indicative of fair to good discrimination, and a calibration plot close to the ideal equality $y = x$ line is indicative of good calibration.

A visual display of the distribution of SPURS by subgroup of HAPU via a dot plot was used to aid in stratifying three risk groups. Following the creation of the risk stratification, the

TABLE 2 Factors found to be predictive by the multivariate analysis and their assigned scores

Predictive factors	OR (95% CI)	β coefficient	Score assigned
Age ≥ 75 years	2.75 (1.35-5.58)	1.01	2
Female	1.94 (0.99-3.8)	0.66	1
ASA grade ≥ 3	3.12 (1.51-6.44)	1.14	2
BMI < 23	2.3 (1.16-4.56)	0.83	1
Preoperative Braden score ≤ 14	3.89 (1.49-10.14)	1.36	2
Anaemia	5.17 (1.43-18.69)	1.64	2
Respiratory disease	6.36 (1.67-24.25)	1.85	3
Hypertension	2.36 (1.18-4.75)	0.86	1

Abbreviations: ASA, American Society of Anaesthesiologists; BMI, body mass index; CI, confidence interval; OR, odds ratio.

correspondence between the rate of observed HAPU and the increasing risk group was tested by χ^2 test for trend.

3 | RESULTS

A total of 269 unique patient data records were available for analysis. There were 80 cases of HAPU and 189 controls with no HAPU. Mean age of the patients was 63 years (SD = 16 years). There were significantly older patients (≥75 years old) in the HAPU group compared with the control group ($P = 0.001$). The most common pressure site was the sacrum, and almost all pressure ulcer stages were 1 and 2. About 19% (n = 15) of HAPU cases required intensive care unit admission. Total length of hospital stay was much longer for the HAPU cases compared with the control group (median of 39 days vs 4 days, $P = 0.001$, Table 1). The univariate statistical testing in Table 3 found significance at $P < 0.10$ for the older age group; Chinese ethnicity; lower BMI category; higher American Society of Anaesthesiologists (ASA) grade; lower pre-op Braden score; emergency cases; and almost all comorbidities, except stroke, vascular disease, and neurological disease. Gender ($P = 0.122$ by univariate testing), being a commonly known risk factor, was also considered for inclusion in the multivariate analysis.

Multivariate logistic regression analysis that considered the above-mentioned factors identified eight independent risk factors that are associated with pressure ulcers: (a) age ≥ 75 years, (b) female gender, (c) ASA grade ≥ 3, (d) BMI < 23, (e) preoperative Braden score ≤ 14, (f) anaemia, (g) respiratory disease, and (h) hypertension. Table 2 showed the result of the multivariate analysis. The association between ASA grade and respiratory disease and ASA grade and hypertension were investigated, but the kappa measurement of agreement between these factors was low ($\kappa = 0.054$ and 0.263, respectively).

The derived model with the eight identified factors had a good discrimination with a bootstrap-corrected c-statistic of 0.78. The calibration plot also showed good performance of the predictive model (Figure 1). The average absolute difference between the predicted and bias-corrected actual probabilities, called the mean absolute error, was low at 0.027.

In calculating a score for SPURS (see Table 2), three risk factors were assigned one point each: female gender, BMI < 23, and presence of hypertension. Four risk factors were assigned two points each: age ≥ 75, ASA grade ≥ 3, pre-op Braden score ≤ 14, and presence of anaemia. Finally, the presence of respiratory disease was assigned three points. The minimum possible score is zero, and the maximum possible score is 14.

The dot plot in Figure 2 shows the frequency of SPURS in the groups with and without HAPU, and its visualisation helped in the creation of low-, moderate-, and high-risk groups of patients with HAPU. Therefore, three risk stratification categories were subsequently derived: low (SPURS = 0-3), moderate (SPURS = 4-5), and high (SPURS = 6-14) (Table 3).

There was a significant trend towards the increasing rate of HAPU with the corresponding high-risk group ($P = 0.001$). A cut-off score of SPURS ≥6 is strongly predictive, with a positive predictive value of 73.2% (95% confidence interval [CI], 59.7%-84.2%) and a negative predictive value of 80.7% (95% CI, 74.3%-86.1%).

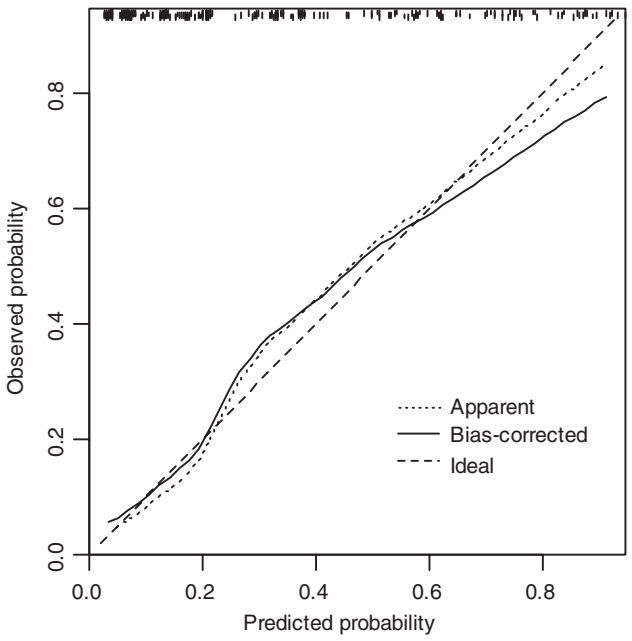

FIGURE 1 Calibration plot of actual vs predicted probability of pressure ulcer. The dashed line indicates an ideal calibration curve, the dotted line represents the calibration curve derived from the original sample, and the solid line shows the bias-corrected calibration curve developed from bootstrap resamples

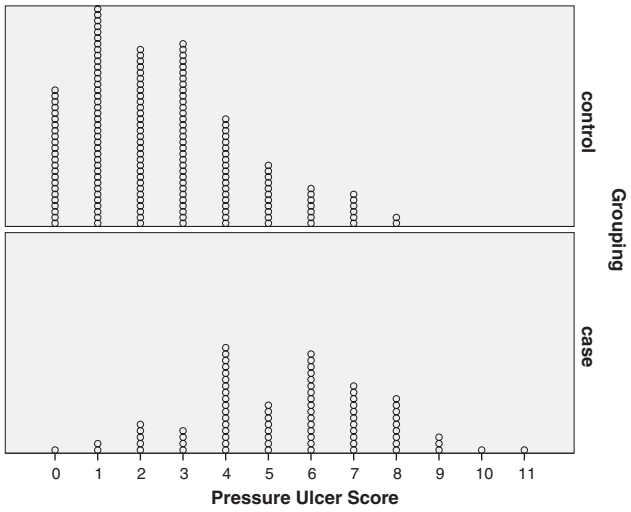

FIGURE 2 Dot plot of the pressure ulcer score by the subgroup of pressure ulcer

4 | DISCUSSION

Knowledge about preoperative risk factors is important so that nurses can implement preventive interventions before tissue injury begins. Many preventive intervention opportunities exist, such as the use of prophylactic multi-layer dressing, using alternative pressure mattress and vesico-elastic polymer pad (gel pad) on the operating table during surgery, patients' and caregivers' education on nutrition and skin care, frequent repositioning, and the use of positioning wedges.[38–40]

Although many of these interventions had clinically demonstrated benefits for preventing PUs or accelerating the healing of PUs, some are costly or burdensome. Therefore, to avoid excessive cost and burden, we need to be able to identify cases of high risk and apply appropriate levels of prevention according to need.

This study has identified eight *significant* risk factors that are associated with HAPU among our surgical patients: age ≥ 75 years; female gender; ASA grade ≥ 3, a low BMI; a low preoperative Braden score ≤ 14; and comorbidities of anaemia, respiratory disease, and hypertension. Using these eight risk factors, we developed a prediction tool called SPURS that is capable of assessing a patient's pressure ulcer risk before the operation.

Our study found low BMI and low preoperative Braden score to be significant predictors of HAPU, which is consistent with other similar studies.[7,12,21,24] However, there are also studies that identified the postoperative Braden score as a significant predictor of HAPU.[33,34,41] Therefore, we performed an additional secondary analysis on the postoperative Braden score and found that it was also statistically significant in our univariate analysis. However, we did not include it in our prediction model because we wanted to use variables that are available preoperatively to determine a patient's pressure ulcer risk. Future research could expand the retrospective analysis to include postoperative Braden score in addition to HAPU outcome.

The evidence on gender and ASA grade among the published papers on HAPU in surgical patients was inconsistent.[7,12,21,25,26] Only a few studies have reported using ASA grade to predict a patient's risk of developing pressure ulcer postoperatively.[7,21,23,26] ASA grade is used to assess a patient's "sickness" or "physical state" before surgery; the higher the ASA grade, the more ill the patient.[42] Our study found an ASA grade ≥ 3 to be a significant predictor of HAPU. Similarly, O'Brien et al also found that a higher ASA grade was associated with HAPU.[23] In Fred et al, it was reported that a 1-point increase in ASA grade increased the odds of a pressure ulcer by 149%.[43] In contrast, Lin et al and Wright et al did not find ASA grade to be significant, but their studied population was younger (mean age between 47 and 55 years) and only underwent spinal or head and neck surgery,[26,33] whereas our study included all types of surgery (except day surgery and cardiac cases), and our sample population's mean age was 70 years.

In our study, female gender was significantly associated with HAPU development. This finding agrees with a systematic review and meta-analysis that found postoperative pressure ulcers to be higher in women than men[34] but disagrees with two other studies that found men more likely to develop pressure ulcers than women.[7,21] One possible explanation for the discrepancy is that gender-specific risks may depend on geography and ethnicity because these factors affect sweating, moisture, and skin microclimate. Women sweat less than men because of differences in sudomotor activity (stimulation of sweat glands by the sympathetic nervous system). Sudomotor activity is also affected by ethnicity and geography.[44] A humid environment delays evaporation of sweat, but residents of tropical areas sweat less and more slowly than residents of temperate areas.[45,46] Sweat and climate affect the skin microclimate, which affects skin vulnerability to pressure ulcers from friction and shearing.[47,48]

In our patient cohort, we found that gender had no significant association with many of the expected risk variables, such as BMI, ASA grade, pre-op Braden score, and age. However, a recent nationwide survey in Singapore reported that older Singaporean females were more malnourished and frail compared with their male counterparts.[49] Given that there is an association

TABLE 3 Risk stratification for SPURS: rate of pressure ulcer in low-, moderate-, and high-risk groups

	Risk group for SPURS		
	Low risk (N = 137)	Moderate risk (N = 55)	High risk (N = 56)
SPURS	0-3	4-5	6-14
Patients with pressure ulcer risk	12 (8.8%)	25 (45.5%)	41 (73.2%)

Abbreviation: SPURS: surgical pressure ulcer risk score.

between frailty and adverse clinical events,[50,51] it may be possible that the women in this study were frailer than men, although we did not measure frailty directly. Hence, future research should consider frailty status among older adults when assessing their risk of developing pressure injuries.

Pressure ulcers are often associated with comorbidities that disrupt tissue perfusion, including diabetes, hypertension, and non-specific cardiac issues.[2,22] Similarly, in our study, we found anaemia, hypertension, and respiratory disease to be significant. However, diabetes and cardiac conditions were not significant, and this could be because of our small sample size (ie, only 26% of our sample population had diabetes, and 18% had cardiac conditions).

5 | LIMITATIONS

Prevention of HAPU requires the timely implementation of intervention strategies aimed at minimising risk among high-risk surgical patients. SPURS has been designed to reflect a patient's preoperative risk, but other contributions to HAPU risk may arise intra- or postoperatively because risk is dynamic throughout the hospitalisation period.

Shaw et al[12] concluded that the number of nursing interventions played a significant role in preventing HAPU; however, our medical records did not capture the number of nursing interventions per patient. Hence, we are unable to measure any association between the number of nursing interventions and the rate of HAPU.

Duration of surgery is another common variable that is often associated with HAPU among surgical patients. In this study, we did not include duration of surgery because operational data from our institution showed that less than 50% of the surgical cases end within 80% to 120% of the predicted duration.[52] Although there are efforts to improve this, the current imprecision in the predicted surgery duration will affect the utility of this variable. In addition, the current evidence on duration of surgery and pressure ulcers is inconclusive.[53–57] There is no high-quality evidence from systematic review or meta-analysis to confirm the relationship between surgical duration and development of HAPU. Nevertheless, future studies may consider using predicted surgical duration when examining the effect of surgical duration on HAPU.

This study was conducted in only one hospital, and our study excluded patients who underwent cardiac surgery or day surgery. Future studies should consider validating SPURS in other clinical settings and other surgical populations.

6 | CONCLUSION

Health care resources are finite; hence, every conscientious effort is needed to prevent the development of HAPU through the early identification of risk and early implementation of preventive measures. SPURS may help to identify surgical patients at increased risk for HAPU before surgery so that preventive measures can be initiated early. It is recommended that future studies validate SPURS in other clinical settings and compare its performance with other PURAS.

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Author contributions

F.A., A.S.Y., G.M.M., P.Y.: Conception of ideas, study methodology, and implementation of study; N.A., A.F., A.S.Y.: Data collection and helping to evaluate and edit the manuscript; F.C.S., A.F., A.S.Y.: Performed analysis, interpreted data, wrote manuscript; and S.F.C., R.C.S., L.T.K., A.F., A.S.Y., G.M.M., Y.P.: Helped to critically review and edit the manuscript.

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APPENDIX A

TABLE A1 Tools that assess/predict pressure ulcers for surgical patients

No	Name of scale[a]	Items/components	Scoring method	Characteristic of PURAS					
				High specificity	High sensitivity	Good predictive value	Easy to use	Clear and define criteria	Applicable to different health care setting
1	The Prevention and Pressure Ulcer Risk Score Evaluation (prePURSE)	Five items: Age, weight at admission, abnormal appearance of skin, friction/shear problem, surgery in coming week	Total score range from 0 to 55. <20: no risk, >20: high risk	The AUC of the model after bootstrapping was 0.71.	× The proposed prediction rule would result in 40% false-positive predictions	×	✓	Unclear: Abnormal skin is considered present when the skin is discoloured, dry, damaged, or when oedema localised is present.	× Tested to only detect grade 2 PU or higher. Excluded patients who were admitted to ICU and those with LOS <5 days
2	Munro scale	Assess pre-, intra-, and postoperative risk factors. Pre-op six items: Mobility, nutritional state, BMI, weight loss, age, comorbidities. Intra-op 7 items: Physical status/ASA, anaesthesia, body temperature, hypotension, moisture, surface, position. Post-op two items: Length of perioperative duration, blood loss	Each phase has its own score. Greater the score, higher the risk and a final cumulative score that will give the overall risk indicator: <15 low risk, 16 to 28 moderate risk and >29 high risk	Not assessed	Not assessed	Not assessed	× Need to calculate the % change in BP and need to know the weight loss in the last 30 to 180 days.	✓	× Validity of the scale has not been determine
3	ELPO (version 2)	Seven items: Type of surgery, duration of surgery, type of anaesthesia, support surface, limb position, comorbidities, age	The score ranges from 1 to 5 points. The total score from 7 to 35 points. The higher the score, the greater the risk of developing PU because of surgical positioning	Not assessed	Not assessed	Predictive criterion validity conducted: Logistic regression analysis indicated an odds ratio of 1.44 (OR = 1.44), which means that, for each additional point on the ELPO, the chance of developing PU increases by 44%.	✓	✓	× Only to be used during intraoperative period. Further research is needed to assess its use in clinical practice
4	Price[a]	Includes preoperative risk and intraoperative risk in the scale. Pre-op six items: Age, comorbidities, nutritional status, preoperative haematocrit/haemoglobin, and preoperative Braden score.	Not mentioned	Not assessed	Not assessed	Not assessed	×	× On some variables, had low inter-rater reliability (kappa less than 0.3) when using the scale	× Further research is needed to assess its use in clinical practice

TABLE A1 (Continued)

No	Name of scale[a]	Items/components	Scoring method	Characteristic of PURAS					
				High specificity	High sensitivity	Good predictive value	Easy to use	Clear and define criteria	Applicable to different health care setting
		Intraoperative 13 items: Surgical time, surgical position, type of surgery, patient's temperature, use of bypass, hypotensive episodes, use of warming device, type of padding and positioning devices, use of retractors, operative support surface, aesthetic agent, type of skin preparation, and skin exposure to moisture							
5	3S intraoperative RAS	Pre-op four items: Conditions of skin (whole body), pre-operation limb exercise, body height/weight ratio, skin under stress Intraoperative five items: Amount of bleeding, operating time, intraoperative stress, body temperature, operative position	The score ranges from 1 to 4 points. The total score from 9 to 36 points. The higher the score, the greater the risk of developing PU	Not assessed	Not assessed	Not assessed	×	×	× Further research is needed to assess its use in clinical practice

Abbreviations: ASA, American society of anaesthesia; AUC, area under curve; BMI, body mass index; BP, blood pressure; ELPO, risk assessment scale for the development of injuries due to surgical positioning; ICU, intensive care unit; LOS, length of stay; OR, odds ratio; PU, pressure ulcers; PURAS, pressure ulcer risk assessment scale; RAS, risk assessment scale.

[a] Author's name will be reported if scale has no name.

TABLE A2 Literature review on the known preoperative risk factors (2007-2018)

	Authors											
Demographic factors	**Aronovitch et al**	**Campbell et al**	**Chen et al**	**Corniello et al**	**Connor et al**	**Engels et al**	**Fred et al**	**Gardiner et al**	**Hayes et al**	**Kang & Zhai**	**Kim et al**	**Kopp et al**
Age				Older	NS			Older	Older			NS
Gender				Female			Male		Male			Male
BMI				High	NS		Low	Low	Low			
Race (non-white)				y								
Comorbidities												
Smoker				y								
Diabetes mellitus	y									y		
Cardiac issues	y											
Peripheral vascular disease	y											
Respiratory diseases	y	y										
Multiple comorbidities								y				
Altered mental state		y										
Incontinence						y[a]						
Critically ill							y					
Surgical-related factors												
Duration of operation			y		y	y						
Operation type			y									y
Type of positioning					y							
Other factors												
Low Braden score				y	NS	y	y				y	
ASA grade							y					
Low haemoglobin		y									y	
Haematocrit value				y								
Albumin level											y	
Lactate level											y	

Abbreviations: ASA, American Society of Anaesthesiologists; BMI, body mass index; NS, not significant; Y, yes.
[a] Did not specify types of incontinence.

TABLE A3 Literature review on the known preoperative risk factors (2007-2018)

	Authors												
Demographic factors	**Lin et al**	**Liu et al**	**Lumbley et al**	**Nassaji et al**	**Nilsson**	**O'Brien et al**	**Primiano et al**	**Rao et al**	**Shaw et al**	**Tschannen et al**	**Uzun et al**	**Webster et al**	**Wright et al**
Age				Older	NS	Older		Older	Older	NS	NS	Older	Young
Gender					NS	NS	Male			NS	NS		
BMI						Low		Low		Low	NS		
Race (non-white)													
Skin condition before operation								y				y	
Comorbidities													
Smoker				y									
Diabetes mellitus		y	y	y		y		y		y	y		
Hypertension			y			NS							
Renal failure						y							
Liver disease						y							
Respiratory diseases						y							
Cardiac issues			y			y					y		
Trauma cases				y									
Anaemia				y				y					
Multiple comorbidities											y		
Incontinence								Faecal			Urine		
Surgical-related factors													
Duration of operation			y					y		y			y
Operation type	y		y			y			y				
Type of positioning			y				y		y				
Other factors													
Number of nursing interventions									y				
Low Braden score							y	y	y	y	y		
ASA grade						y							NS
Low albumin											y		
Low haemoglobin								y					
Risk of mortality										y[a]			
Corticosteroid use						y							
Admit not from home												y	

Abbreviations: ASA, American Society of Anaesthesiologists; NS, not significant; Y, yes.

[a] Risk of mortality was obtained by using all patients' refined diagnosis-related group (APR DRG) software.