Original article

Analysis of surgical wound characteristics and associated factors in patients undergoing orthopedic trauma surgery: A prospective longitudinal observational study at Hue University of Medicine and Pharmacy Hospital

Dang Thi Trinh[1], Nguyen Thi Dieu Huyen[1], Tran Thi Ngoc Cam[1], Nguyen Thi Thanh[2], Pham Thi Thuy Loan[1]*

[1]*Hue University of Medicine and Pharmacy, Hue University*

[2]*Hue University of Medicine and Pharmacy Hospital*

***Corresponding author:** Dang Thi Trinh; email: dttrinh@huemed-univ.edu.vn

Received: 15/08/2026; **Accepted**: 12/10/2026; **Published:** 15/11/2026

DOI:10.34071/jmp.2026.S-3.8

Abstract

Background: Analyzing surgical wound characteristics enables clinicians to monitor wound healing progression and detect postoperative complications early.

Objectives: To analyze surgical wound characteristics following orthopedic trauma surgery at the first dressing change and on postoperative day 5 using the SWAT tool and its associated factors.

Materials and Methods: A prospective longitudinal observational study was conducted among 205 patients with upper- and/or lower-limb fractures indicated for surgery at Hue University of Medicine and Pharmacy Hospital. Surgical wounds were assessed using the Surgical Wound Assessment Tool (SWAT) at the first dressing change and on postoperative day 5.

Results: Surgical wound characteristics improved significantly between the two assessment time points ($p < 0.001$). By day 5, well-approximated wound edges were observed in 68.8% of patients, epithelialization of the wound bed in 46.3%, clear serous exudate in 67.8%, and a dry/moist wound surface in 69.8%; most wounds were odorless and associated with mild-to-moderate pain. However, periwound erythema persisted in 46.3% of cases, and hematoma showed a slight but significant increase (16.1% to 19.5%; $p = 0.016$). Three factors were independently associated with a higher SWAT score: open fracture ($p < 0.001$), mobilization after 24 hours postoperatively ($p < 0.001$), and lower-limb surgery ($p = 0.028$).

Conclusion: Wound status improved significantly between the first dressing change and postoperative day 5. Factors such as open fractures, mobilization delayed beyond 24 hours post-surgery, and lower-limb surgical sites were significantly associated with higher SWAT scores on day 5. Periodic wound assessment facilitates the early identification of patients requiring closer monitoring.

Keywords: *Surgical wound; Surgical Wound Assessment Tool; orthopedic trauma surgery; wound healing.*

1. INTRODUCTION

Fractures resulting from musculoskeletal trauma are common and often require surgical treatment. Surgical wounds may develop abnormalities or complications, which can prolong hospital stay, increase healthcare costs, and affect patients' quality of life [1-3]. Therefore, early and systematic assessment of surgical wounds plays an important role in detecting abnormal wound healing and facilitating timely and appropriate wound care.

In nursing practice, surgical wound monitoring still relies substantially on clinical judgment, which may lead to inconsistencies in assessment and limit the early detection of abnormal wound signs. Several wound assessment tools have been developed worldwide, including the National Nosocomial Infections Surveillance System (NNIS), the Southampton wound scoring system, and the ASEPSIS scoring system [4-6]. However, these tools were developed for specific surgical populations and may not comprehensively reflect the clinical characteristics of surgical wounds or the factors associated with wound healing progression.

In Vietnam, the Surgical Wound Assessment Tool (SWAT) has been developed and standardized, demonstrating validity and reliability for monitoring wound healing and identifying factors associated with wound progression [7]. Assessing surgical wounds at different time points allows early postoperative wound status and subsequent changes to be documented, thereby providing a basis for evaluating the course of wound healing [7, 8]. However, the application of SWAT in clinical practice, particularly among patients undergoing orthopedic trauma surgery, remains limited.

Therefore, this study aimed to analyze surgical

wound characteristics at the time of the first dressing change and on postoperative day 5 using the SWAT, and to identify factors associated with wound progression among patients undergoing orthopedic trauma surgery at Hue University of Medicine and Pharmacy Hospital.

2. METHODS

2.1. Study design and setting

A prospective longitudinal observational study was conducted at the Department of Orthopedic, Trauma, and Thoracic Surgery, Hue University of Medicine and Pharmacy Hospital, from April to July 2026.

2.2. Participants and sampling

The target population comprised patients who underwent surgery for upper- and/or lower-limb fractures. Inclusion criteria: age ≥ 18 years, open surgical treatment, including internal fixation or joint replacement and informed consent after explanation of the study's purpose and participant rights. Exclusion criteria: minimally invasive/endoscopic surgery or concurrent skin grafting; a chronic wound (> 6 weeks) prior to surgery; repeat surgery on a pre-existing surgical wound; initial surgery performed at another facility with subsequent transfer; altered consciousness precluding cooperation during follow-up; or amputation/death before assessment could be completed.

Participants were selected using a convenience sampling method. Patients who met the inclusion criteria and did not violate any exclusion criteria during the study period were invited to participate; upon providing voluntary consent, they were enrolled in the study until the target sample size of 205 individuals was reached.

2.3. Sample size

The study sample size was determined based on the sample size rule for multivariable regression models, applying a ratio of 20 subjects per independent candidate variable included in the analysis. According to the study by Do Thi Thu Hien, a multivariable generalized linear model (GLM) was applied to the SWAT score at the second evaluation point (postoperative day 5/Assessment 2) to identify prognostic factors for surgical wound complications. The initial analytical model comprised 10 candidate independent variables, including: age, BMI, history of diabetes, smoking habit, prolonged corticosteroid use, risk of malnutrition, surgical wound contamination classification, duration of surgery, prophylactic antibiotic use, and type of surgery. Accordingly, the required theoretical sample size was 10 x 20 = 200 patients. In practice, a total sample of 205 patients was recruited [7, 9].

2.4. Data Collection

Wound characteristics were assessed using the Surgical Wound Assessment Tool (SWAT), the SWAT toolkit developed by Do Thi Thu Hien demonstrates high reliability, as evidenced by an Internal Confidence Coefficient (ICC) of 0.81 (95% CI 0.68 - 0.89, $p < 0.001$) and Cohen's kappa index ranging from 0.5 to 1, comprising three parts: **Part A – Patient and comorbidity related factors (9 items, score range: 0 - 13):** age (≥ 65 years), body mass index (BMI), diabetes mellitus, smoking status, steroid use, chemotherapy, immunosuppression, risk of malnutrition, trauma (time from injury to surgery: < 6h/> 6h). **Part B – Surgery related factors (5 items, score range: 0 - 10):** surgical wound classification (clean, clean-contaminated, contaminated, or dirty/infected), emergency surgery, duration of surgery (hours), preoperative antibiotic prophylaxis, type of surgery (abdominal surgery, hip replacement, colorectal surgery, cardiovascular surgery, or fracture surgery). Part C - clinical wound characteristics (12 items, 0 - 17 points). The total SWAT score (0 - 40) is the sum of all three parts, with higher scores indicating greater risk of delayed healing and wound complications [7].

The wounds were assessed at two time points [7, 8]. The first assessment was conducted on postoperative day 2 - the time of the initial dressing change at the study site. The fifth postoperative day was selected as the second assessment time point for three reasons. First, the acute inflammatory phase of wound healing typically lasts for the first four days after surgery; while mild signs of inflammation are normal during this period, persistent inflammation or increased discharge beyond day 4 is considered abnormal and indicative of infection [10]. Second, complications at the surgical site tend to become more apparent from the fifth day onwards [11]. Finally, in Vietnam, patients typically have much longer hospital stays than in Western countries; consequently, they may still be hospitalized on the fifth day after surgery.

A data collection team (comprising two nurse-researchers, a nursing lecturer, and a head nurse) underwent training and standardization regarding assessment criteria using a sample clinical case prior to commencing data collection. Personal information and data for the SWAT toolkit are collected from medical records and through direct patient assessment.

Factors associated with surgical wound characteristics: (1) Patient related factors: sex. (2) Injury and surgery related factors: mechanism of injury, characteristics of the fracture, surgical site (upper/lower limb), surgical method (internal

fixation/arthroplasty). (3) Postoperative factors: The time to initiation of mobilization is defined as the interval from surgery to the first instance the patient is instructed to actively use the operated limb-including weight-bearing or ambulation for lower-limb surgery, or active/passive joint exercises for upper-limb surgery [12, 13], and is categorized into two groups: ≤ 24 hours and > 24 hours [14].

2.5. Data analysis

Statistical analysis was performed using SPSS version 27.0. As the SWAT score was non-normally distributed, changes between the two assessment time points were compared using the Marginal Homogeneity Test (ordinal variables with ≥ 3 categories), the McNemar test (binary variables), and the Wilcoxon signed-rank test (continuous, repeated-measures SWAT score). Variables with $p < 0.05$ at univariate analysis were considered for the multivariable model. Because the SWAT score is continuous, strictly positive, and right-skewed, we therefore used a Generalized Linear Model with a Gamma distribution and log-link function to identify factors independently associated with wound characteristics. Multicollinearity among independent variables was assessed using the variance inflation factor (VIF). Model fit was evaluated using the deviance and Pearson chi-square statistics scaled by degrees of freedom, and the omnibus likelihood ratio test.

2.6. Ethical considerations

This study was approved by the Institutional Review Board for Biomedical Research, Hue University of Medicine and Pharmacy, Hue University (Decision No. H2026/103, dated March 31, 2026). All participants provided written informed consent after being informed of the study's purpose; personal and clinical data were coded and kept confidential for research purposes only.

3. RESULTS

3.1. General characteristics of the study population

Table 1. Characteristics related to patients and comorbidities

Characteristics related to patients and comorbidities (N = 205)		**N**	**%**
Age ≥ 65 years	No	155	75.6
	Yes	50	24.4
Gender	Male	119	58
	Female	86	42
BMI (kg/m²)	< 18.5	11	5.4
	18.5 – 22.9	163	79.5
	23.0 – 27.5	25	12.2
	> 27.5	6	2.9
Diabetes mellitus	No	183	89.3
	Yes (preoperative HbA1c unknown or HbA1c ≤ 7%)	22	10.7
Smoking status	Non-smoker	142	69.3
	Former smoker (quit ≥ 4 weeks prior to surgery)	12	5.9
	Current smoker (continued smoking until surgery)	51	24.9
Corticosteroid use	None or used within ≤ 30 days prior to surgery	205	100
Chemotherapy	No	205	100
Immunodeficiency	No	205	100
Risk of malnutrition	No	180	87.8
	Yes	25	12.2
Trauma to surgery interval	Trauma case, interval from injury to surgery < 6 hours	39	19.0
	Trauma case, interval from injury to surgery ≥ 6 hours	166	81.0

Most patients were under 65 (75.6%) and male (58.0%), with a normal BMI (79.5%) and diabetes mellitus in 10.7%. Current smokers made up 24.9% of the sample. No patient had recent steroid use, chemotherapy, or immunosuppression, and 12.2% were at malnutrition risk. Among those with a traumatic wound, 81.0% underwent surgery ≥ 6 hours after injury.

Table 2. Characteristics related to surgery

Characteristics related to surgery (N=205)		N	%
Cause of fracture	Domestic accident	24	11.7
	Workplace accident	34	16.6
	Traffic accident	147	71.7
Fracture type	Closed	178	86.8
	Open	27	13.2
Post-operative wound classification	Clean	178	86.8
	Clean-contaminated	22	10.7
	Contaminated	5	2.4
	Dirty-infected	0	0
Emergency surgery	No	101	49.3
	Yes, due to medical condition	0	0
	Yes, due to trauma	104	50.7
Surgery duration (hours)	Less than 1 hour	71	34.6
	1 – 3 hours	134	65.4
Preoperative prophylactic antibiotics	Administered > 120 minutes prior to surgical incision	205	100
Surgical site	Lower limb	100	48.8
	Upper limb	105	51.2
Surgical method	Fracture fixation	195	95.1
	Hip replacement	10	4.9
Post-operative mobilization	Within 24 hours post-op	165	80.5
	After 24 hours post-op	40	19.5

Traffic accidents were the leading mechanism of injury (71.7%). Most fractures were closed (86.8%) and wounds were classified as clean (86.8%). Half of surgeries were emergency procedures for trauma (50.7%), most lasted 1 - 3 hours (65.4%), and all patients received antibiotic prophylaxis within 120 minutes preoperatively. Surgical site was fairly evenly split between upper (51.2%) and lower limb (48.8%); internal fixation was the predominant method (95.1%), and 80.5% of patients were mobilized within 24 hours.

3.2. Surgical wound characteristics at the first dressing change and on postoperative day 5

Table 3. Clinical wound characteristics at the first dressing change and on postoperative day 5 (N = 205)

Characteristic	Assessment 1, n (%)	Assessment 2, n (%)	p
Wound edges			< 0.001[a]
Well approximated	55 (26.8)	141 (68.8)	
Approximated, under tension	143 (69.8)	54 (26.3)	
Not approximated, under tension	7 (3.4)	10 (4.9)	
Wound bed			0.059[a]
Closed	198 (96.6)	100 (48.8)	
Epithelializing	0 (0.0)	95 (46.3)	
Granulating	7 (3.4)	8 (3.9)	
Sloughy	0 (0.0)	2 (1.0)	

Periwound edema			< 0.001[b]
Absent	62 (30.2)	127 (62.0)	
Present	143 (69.8)	78 (38.0)	
Periwound erythema			< 0.001[b]
Absent	57 (27.8)	110 (53.7)	
Present	148 (72.2)	95 (46.3)	
Hematoma			0.016[b]
No sign of hematoma	172 (83.9)	165 (80.5)	
At least one sign of hematoma	33 (16.1)	40 (19.5)	
Exudate color			< 0.001[b]
Predominantly clear/serous	33 (16.1)	139 (67.8)	
Predominantly blood-stained	172 (83.9)	66 (32.2)	
Exudate volume			< 0.001[a]
Dry/moist	95 (46.3)	143 (69.8)	
Wet	97 (47.3)	52 (25.4)	
Saturated	13 (6.3)	10 (4.9)	
Wound odor			0.500[b]
Absent	203 (99.0)	201 (98.0)	
Present after dressing removal	2 (1.0)	4 (2.0)	
Wound cleansing solution			
0.9% normal saline	205 (100)	205 (100)	
Wound-site pain			< 0.001[a]
Mild	16 (7.8)	127 (62.0)	
Moderate	142 (69.3)	75 (36.6)	
Severe	47 (22.9)	3 (1.5)	

[a] Marginal Homogeneity Test (ordinal variables with ≥3 categories); [b] McNemar test (binary variables).

Most clinical wound characteristics improved significantly ($p < 0.05$) from Assessment 1 to Assessment 2: the proportion of well-approximated wound edges increased from 26.8% to 68.8%, pain intensity decreased markedly (severe pain decreased from 22.9% to 1.5%), and both periwound edema and erythema decreased by more than half. The wound bed characteristic alone did not reach statistical significance ($p = 0.059$), although 46.3% of wounds that were closed at Assessment 1 had transitioned to an epithelializing state by Assessment 2. Hematoma showed a slight but statistically significant increase ($p = 0.016$); notably, all 33 cases with hematoma at Assessment 1 persisted at Assessment 2, with an additional 7 new cases identified. Regarding exudate volume, the proportion of dry/moist wounds increased from 46.3% to 69.8%, while saturated exudate decreased from 6.3% to 4.9% ($p < 0.001$). Exudate color also changed markedly, with the proportion of predominantly clear exudate increasing sharply from 16.1% to 67.8% ($p < 0.001$). Wound odor did not change significantly ($p = 0.500$), with a very low prevalence at both time points (1.0% and 2.0%, respectively).

Table 4. SWAT scores at the two assessment time points (N = 205)

SWAT score	Median (IQR) Assessment 1	Median (IQR) Assessment 2	p
Part A (0 - 13 points)	3.00 (2.00 - 4.00)	Not reassessed	-
Part B (0 - 10 points)	3.00 (2.00 - 4.00)	Not reassessed	-
Part C (0 - 17 points)	5.00 (3.00 - 6.00)	2.00 (1.00 - 5.00)	< 0.001[c]
Total SWAT score (0 - 40 points)	11.00 (8.50 - 13.50)	8.50 (6.00 - 11.25)	< 0.001[c]

IQR: interquartile range. [c] Wilcoxon signed-rank test.

The total SWAT score decreased significantly, from a median of 11.00 (Assessment 1) to 8.50 points (Assessment 2) ($p < 0.001$), reflecting a marked improvement in wound status over the postoperative period.

3.3. Factors associated with surgical wound characteristics

The SWAT score on postoperative day 5 (Assessment 2) was used as the primary outcome measure in the analysis of associated factors.

Table 5. Association between the SWAT score (Assessment 2) and sex and injury and surgical characteristics (N = 205)

Characteristic	N	SWAT score (Assessment 2)		p
		Median	IQR	
Sex				
Male	119	8.00	6.00 - 11.00	
Female	86	9.00	6.50 - 12.00	0.415[d]
Mechanism of injury				
Domestic accident	24	12.00	9.50 - 14.50	
Occupational accident	34	7.50	5.38 - 10.25	
Traffic accident	147	8.00	6.00 - 11.00	< 0.001[e]
Surgical method				
Internal fixation	195	8.00	6.00 - 11.00	
Hip arthroplasty	10	11.25	8.125 - 14.125	0.047[d]
Time to postoperative mobilization				
≤ 24 hours	165	7.50	6.00 - 10.00	
> 24 hours	40	13.00	9.50 - 14.50	< 0.001[d]
Fracture type				
Closed	178	8.00	6.00 - 11.00	
Open	27	11.00	8.00 - 14.50	0.004[d]
Surgical site				
Lower limb	100	10.00	7.625 - 12.875	
Upper limb	105	7.00	6.00 - 8.75	< 0.001[d]

[d] Mann-Whitney U test. [e] Kruskal-Wallis test.

The SWAT score did not differ significantly between male and female patients ($p=0.415$). All injury- and surgery-related characteristics examined were significantly associated with the SWAT score on univariable analysis ($p < 0.05$ for all).

Table 6. Generalized linear model (Gamma distribution, log-link function) of factors associated with the SWAT score (Assessment 2)

Variable	Exp(B)	95% CI	p
Intercept	16.286	12.120 - 21.884	< 0.001
Mechanism of injury			
Domestic accident	1.108	0.922 - 1.333	0.275
Occupational accident	0.957	0.847 - 1.082	0.484
Traffic accident	1		
Fracture type			
Closed	0.679	0.594 - 0.777	< 0.001
Open	1		

Time to postoperative mobilization			
≤ 24 hours	0.732	0.627 - 0.855	< 0.001
> 24 hours	1		
Surgical method			
Internal fixation	0.924	0.744 - 1.147	0.473
Hip arthroplasty	1		
Surgical site			
Lower limb	1.120	1.012 - 1.239	0.028
Upper limb	1		

No evidence of multicollinearity was found among the independent variables, with VIF values ranging from 1.02 to 1.76. The overall model was statistically significant compared with the intercept-only model (likelihood ratio $\chi^2 = 74.618$, df = 6, $p < 0.001$), and the deviance and Pearson chi-square statistics scaled by degrees of freedom (0.111 and 0.119, respectively) indicated no overdispersion and an adequate model fit.

Multivariable generalized linear model (GLM) analysis with a Gamma distribution and log-link function identified three factors independently and significantly associated with the total SWAT score at Assessment 2 ($p < 0.05$). The mean SWAT score of patients who underwent lower-limb surgery was 1.12 times that of patients who underwent upper-limb surgery (Exp(B) = 1.120, 95% CI 1.012 - 1.239; p = 0.028). The mean SWAT score of patients with closed fractures was 0.68 times that of patients with open fractures (Exp(B) = 0.679, 95% CI 0.594 - 0.777; $p < 0.001$), and that of patients mobilized within 24 hours after surgery was 0.73 times that of patients mobilized after 24 hours (Exp(B) = 0.732, 95% CI 0.627 - 0.855; $p < 0.001$). Mechanism of injury and surgical method were not significantly associated with the SWAT score in the multivariable model ($p > 0.05$ for all).

4. DISCUSSION

4.1. Surgical wound characteristics at the first dressing change and on postoperative day 5

Wound healing by primary intention progresses through four sequential phases (hemostasis, inflammation, proliferation, and tissue remodeling), during which the clinical characteristics of the wound directly reflect the progression of each phase [10]. The total SWAT score decreased significantly between the two assessment time points ($p < 0.001$), reflecting an improvement in wound characteristics from the first dressing change to postoperative day 5, consistent with the trajectory of early-phase wound healing and with domestic studies using the same SWAT instrument [7, 8].

Wound-edge characteristics reflect healing progression and constitute an important component of postoperative wound assessment [15]. In our study, the proportion of well-approximated wound edges more than doubled, from 26.8% to 68.8% ($p < 0.001$), consistent with domestic studies [7, 8]. However, among the 143 wounds classified as "approximated, under tension" at Assessment 1, 4 cases (2.8%) deteriorated to "not approximated, under tension" by Assessment 2; these patients shared common characteristics, such as having undergone lower-limb surgery and initiating mobilization after 24 hours.

Specific characteristics of the wound bed also play an important role in the continuum of wound healing [15]. Although the wound bed showed improvement (46.3% transitioned to epithelializing), this change did not reach statistical significance (p = 0.059), consistent with the Scar Formation indicator in the study by Menna Barreto et al., attributed to the relatively small volume of tissue requiring regeneration during early-phase healing [16]. At the case level, 2 of 7 "granulating" wounds at Assessment 1 progressed to "sloughy" tissue at Assessment 2; both cases had open fracture, mobilization after 24 hours, and diabetes mellitus.

Inflammatory signs (edema, erythema) and exudate characteristics (color, volume) also improved significantly ($p < 0.001$), consistent with the expected physiological trajectory of early-phase wound healing and with previous studies [7, 8, 10, 16]. Wound odor is not typical of normal healing and more commonly suggests infection or the presence of necrotic tissue [17]. Only a very small proportion of wounds in our study exhibited odor (1.0% at Assessment 1 and 2.0% at Assessment 2), a non-significant difference (p = 0.500), consistent with domestic studies using the same SWAT instrument [7, 8].

Beyond wound characteristics per se, postoperative pain is a critical clinical parameter that

affects not only patients' quality of life but also their capacity for early mobilization, length of hospital stay, and risk of complications [3]. Pain showed the most pronounced improvement among all characteristics examined, with severe pain decreasing from 22.9% to 1.5% ($p < 0.001$), consistent with other studies [7, 8]. This improvement is consistent with the expected trajectory of acute postoperative pain, which typically diminishes progressively as recovery proceeds [18].

Postoperative hematoma can impair and delay wound healing, underscoring the clinical importance of hematoma assessment in wound care [19]. Notably, the prevalence of wounds with hematoma increased between the two assessment points, from 16.1% to 19.5% ($p = 0.016$), contrary to the improving trend observed for all other characteristics. This finding also contrasts with the declining trend reported at two domestic hospitals [7, 8]. Case-level analysis revealed that all 33 cases presenting with hematoma at the first assessment retained this condition at the second assessment, consistent with the slow physiological nature of hematoma resolution, while 7 newly detected cases likely reflect the tendency for hematomas or bruising to manifest clinically several days post-operatively rather than appearing fully at the outset [20]. These cases were predominantly found among patients who mobilized after 24 hours, those undergoing lower-limb surgery, and patients with diabetes.

4.2. Factors associated with surgical wound characteristics after surgery

In this study, the second total SWAT score was used as a comprehensive quantitative indicator to assess incision characteristics during the early postoperative period, with higher scores reflecting less favorable incision characteristics at the time of assessment.

In our study of 205 patients, the rate of open fractures was 13.2%, consistent with findings by Taghiloo et al. in a study of 106 patients with extremity trauma in Iran (13.0%) [21]. A 2025 meta-analysis of 16 studies demonstrated that open fractures are a risk factor significantly increasing the rate of surgical site infections following orthopedic trauma surgery [2]. In our study, the mean SWAT score of patients with closed fractures was 0.68 times that of patients with open fractures ($p < 0.001$), indicating that open fractures are an independent factor associated with higher total SWAT scores on postoperative day 5. This result aligns with the underlying pathophysiology: open fractures are typically accompanied by extensive soft-tissue injury and initial contamination; furthermore, soft-tissue crushing and local vascular damage impair perfusion, thereby adversely affecting the wound healing process [22].

In our study, 80.5% of patients underwent early mobilization within 24 hours of surgery, reflecting strong adherence to current clinical guidelines regarding early rehabilitation [23]. A large-scale study by Hjelholt et al. involving 36,229 fracture patients found that delaying mobilization beyond 24 hours increased the risk of surgical site infection [14]. Similarly, our results showed that the mean SWAT score of patients mobilized within 24 hours after surgery was 0.73 times that of patients mobilized after 24 hours ($p < 0.001$). This can be attributed to the role of early mobilization in stimulating muscle contractions and promoting venous and lymphatic return, thereby reducing tissue fluid stasis and mitigating complications associated with prolonged immobilization [23].

The surgical sites in the study were distributed relatively evenly between the upper limbs (51.2%) and lower limbs (48.8%), consistent with the findings of Taghiloo et al. (51% upper limb and 49% lower limb) [21]. Regarding the relationship with incision characteristics, Onyekwelu et al. demonstrated that lower-limb surgery carries a higher risk of surgical site infection compared to upper-limb surgery [24]. In our study, multivariate analysis revealed that the mean SWAT score of patients who underwent lower-limb surgery was 1.12 times that of patients who underwent upper-limb surgery ($p = 0.028$), indicating that lower-limb surgery is a factor associated with higher total SWAT scores during the early postoperative period. The mechanism underlying this difference is closely linked to hemodynamic characteristics: the lower limbs are subject to greater adverse gravitational effects on venous return, leading to a higher susceptibility to congestion, tissue fluid stasis, and prolonged edema compared to the upper limbs [25].

However, this study has several limitations. First, participants were recruited via convenience sampling from a single department at Hue University of Medicine and Pharmacy Hospital; this may lead to selection bias and limit the generalizability of the results to other settings. Second, wound monitoring focused primarily on the early postoperative period (up to postoperative day 5); therefore, the study did not fully document long-term wound healing or late-onset complications. Third, inter-rater reliability was

not assessed; thus, the consistency of SWAT scores among data collectors could not be quantified.

5. CONCLUSION

Wound status improved significantly between the first dressing change and postoperative day 5. In the multivariate model, factors such as open fracture, mobilization delayed beyond 24 hours post-surgery, and lower-limb surgical sites were statistically associated with higher SWAT scores at the second assessment. These findings confirm the value of longitudinal assessment of surgical wounds to monitor changes in wound status and underscore the need for close monitoring of patients presenting with characteristics linked to high SWAT scores.

Conflict of interest

The authors declare no conflicts of interest.

REFERENCES

1. World Health Organization. Musculoskeletal health. [Online]. 2022 [cited 2026 Aug 15]. Available from: URL: https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions.

2. Liu H, Wang Y, Xing H, Chang Z, Pan J. Risk factors for deep surgical site infections following orthopedic trauma surgery: a meta-analysis and systematic review. J Orthop Surg Res 2024; 19(1):811.

3. Morrison SR, Magaziner J, McLaughlin MA, Orosz G, Silberzweig SB, Koval KJ, et al. The impact of post-operative pain on outcomes following hip fracture. Pain 2003; 103(3):303-11.

4. Emori TG, Culver DH, Horan TC, Jarvis WR, White JW, Olson DR, et al. National nosocomial infections surveillance system (NNIS): description of surveillance methods. Am J Infect Control 1991 Feb; 19(1):19-35.

5. Campwala I, Unsell K, Gupta S. A Comparative Analysis of Surgical Wound Infection Methods: Predictive Values of the CDC, ASEPSIS, and Southampton Scoring Systems in Evaluating Breast Reconstruction Surgical Site Infections. Plast Surg (Oakv) 2019 May; 27(2):93-99.

6. Copanitsanou P, Kechagias VA, Grivas TB, Wilson P. Use of ASEPSIS scoring method for the assessment of surgical wound infections in a Greek orthopaedic department. Int J Orthop Trauma Nurs 2018 Aug; 30:3-7.

7. Do TTH. Development and validation of a surgical wound assessment tool for use in Vietnam [PhD thesis]. Brisbane, Australia: Queensland University of Technology; 2019.

8. Trinh TT, Le THN, Le NH, Nguyen TTN, Nguyen TP, Nguyen THT, et al. [Monitoring surgical wound characteristics of lower limb orthopedic surgery using the SWAT wound assessment tool at Military Hospital 175]. Ho Chi Minh City Med J 2025; 28(2):74-83. [Vietnamese].

9. Hoang VM, Khuong QL, Ong PT, Vo VT, Kim BG, Nguyen TD. Sample size determination in research. In: Hoang VM, Luu NH, editors. Sampling methods and sample size calculation in health science research. Hanoi: Hanoi University of Public Health; 2020. p. 22-68.

10. Cañedo-Dorantes L, Cañedo-Ayala M. Skin Acute Wound Healing: A Comprehensive Review. Int J Inflam 2019; 2019:3706315.

11. Seidelman JL, Mantyh CR, Anderson DJ. Surgical Site Infection Prevention: A Review. JAMA 2023 Jan 17; 329(3):244-252.

12. Dennison DG, Blanchard CL, Elhassan B, Moran SL, Shin AY. Early Versus Late Motion Following Volar Plating of Distal Radius Fractures. Hand (N Y) 2020 Jan; 15(1):125-130.

13. Nakamura K, Sasaki T, Kitagawa T, Shimizu M, Aoki K. Effect of Early Mobilization on Gait Recovery One Year After Hip Fracture Surgery: A Single-Center Cohort Study. Cureus 2025; 17(2):e79133.

14. Hjelholt TJ, Andersen IT, Kristensen MT, Pedersen AB. Early mobilisation after hip fracture surgery reduces the risk of infection: an inverse probability of treatment weighted analysis. Age Ageing 2025; 54(1):afaf007.

15. World Union of Wound Healing Societies. Advances in wound care: the Triangle of Wound Assessment. London: Wounds International; 2016.

16. Menna Barreto LN, Silva MBD, Engelman B, Figueiredo MS, Rodríguez-Acelas AL, Cañon-Montañez W, et al. Evaluation of Surgical Wound Healing in Orthopedic Patients with Impaired Tissue Integrity According to Nursing Outcomes Classification. Int J Nurs Knowl 2019; 30(4):228-33.

17. Ousey K, Roberts D, Gefen A. Early identification of wound infection: understanding wound odour. J Wound Care 2017; 26(10):577-82.

18. Dray A, Perkins M. Bradykinin and inflammatory pain. Trends Neurosci 1993; 16(3):99-104.

19. Mortazavi SM, Hansen P, Zmistowski B, Kane PW, Restrepo C, Parvizi J. Hematoma following primary total hip arthroplasty: a grave complication. J Arthroplasty 2013; 28(3):498-503.

20. Luo X, Wang D, Xu W, Zou J, Kang R, Zhang T, et al. Personalized delayed anticoagulation therapy alleviates postoperative bleeding in total knee arthroplasty (TKA) patients. J Exp Orthop 2024; 11(4):e70074.

21. Taghiloo D, Ganjkhanloo A, Salehi M, Perseh L, Soltani M, Mohammadi F, et al. Comparison of the diagnostic value of clinical examination versus results of radiography in the upper and lower limb fractures. Journal of Medicinal and Pharmaceutical Chemistry Research 2025; 7(2):275-81.

22. Sen RK, Murthy N, Gill SS, Nagi ON. Bacterial load in tissues and its predictive value for infection in open fractures. J Orthop Surg (Hong Kong) 2000; 8(2):1-5.

23. Rhamelani P, Mahdhiya NZ, Yoviana I, Jessica J, Komariah M. Early Mobilization in Post-Orthopedic Surgery Patients: A Scoping Review. J Multidiscip Healthc 2025; 18:305-17.

24. Onyekwelu I, Yakkanti R, Protzer L, Pinkston CM, Tucker C, Seligson D. Surgical Wound Classification and Surgical Site Infections in the Orthopaedic Patient. J Am

Acad Orthop Surg Glob Res Rev 2017; 1(3):e022.

25. Baish JW, Padera TP, Munn LL. The effects of gravity and compression on interstitial fluid transport in the lower limb. Sci Rep 2022; 12(1):4890.