PREDICTOR OF BURN WOUND CONVERSION AS A REFERENCE FOR CONSERVATIVE AND OPERATIVE MANAGEMENT: REVIEW OF IMAGEJ, FLIR ONE® AND DEVELOPMENT OF A RISK FACTOR SCORE MODEL

PRÉVISION DE L'APPROFONDISSEMENT DES BRÛLURES AFIN DE DÉFINIR UNE STRATÉGIE CONSERVATRICE OU CHIRURGICALE. ÉVALUATION DE IMAGEJ ET FLIR ONE®, DESCRIPTION D'UN SCORE PRÉDICTIF DE RISQUE

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SUMMARY. Burn wound conversion describes the process by which superficial-partial thickness burns convert into deeper burns within 3-7 days after burn. Autophagy, inflammation, ischemia, infection and reactive oxygen species are thought to have a role in pathogenesis of burn wound conversion. This study aims to assess risk factors for burn conversion and develop a scoring system to predict it. The study was conducted using nested case control method, in burn patients treated in Dr. Cipto Mangunkusumo Hospital and Jakarta Islamic Hospital Cempaka Putih. Subjects were recruited by consecutive sampling in February 2019-August 2020. The role of clinical characteristics, local and systemic examination as predictors of burn wound conversion were assessed. Risk factors were analysed using bivariate and multivariate analysis. There were 40 subjects in the case group and 20 subjects in the control group. Involvement of trunk, limbs, burn extent measured using ImageJ, ≥ 9.49%TBSA, wound surface temperature measured using Flir one® thermography ≤ -1.55ºC, procalcitonin level ≥ 0.075 ng/mL, and blood lactate level ≥ 1.75 mmol/L had a significant relationship with burn wound conversion. Three scoring models were developed: model 1 to be applied in tertiary health facilities, and model 2 and 3 to be applied in primary and secondary health facilities with sensitivity and specificity of 92.5% and 85%, 95% and 70% and 92.5% and 85%, respectively. The scoring models can be used in daily practice, especially as a reference for conservative and operative management.

Keywords: lactate, procalcitonin, burns, burn wound conversion, Flir one®, ImageJ, limb, trunk

RÉSUMÉ. *L'approfondissement représente l'évolution en quelques jours d'une brûlure supposée superficielle vers une atteinte profonde. L'inflammation, l'ischémie, l'infection, les radicaux oxygénés actifs et l'apoptose sont supposés y jouer un rôle. Cette étude a pour but d'évaluer les facteurs de risque d'approfondissement et de développer un score de risque. Elle consiste en une étude cas (40), témoins (20) réalisée auprès de patients des hôpitaux Dr Cipto Mangunkusumo et Cempaka Putih de Djakarta, entre février 2019 et août 2020. Les paramètres cliniques locaux comme généraux ainsi que les données de surface (objectivées par ImageJ) et de température des zones atteintes (mesurées par Flir One®) ont été étudiées. L'atteinte du tronc ou des membres, une atteinte ≥ 9,49%, une baisse de température locale ≤ -1.55ºC, une PCT ≥ 0,075 ng/mL et des lactates sanguins ≥ 1,75 mmol/L sont significativement associés à l'approfondissement. Nous avons développé 3 scores. Le premier s'adresse aux centres spécialisés, les 2ème et 3ème au pré-hospitalier et aux hôpitaux généraux respectivement, avec des sensibilités/spécificités de 92,5/85% ; 95/70% et 92,5/85%. Ces scores peuvent être utilisés en pratique courante, en particulier pour choisir une approche conservatrice ou chirurgicale.*

Mots-clés : *lactate, procalcitonine, brûlure, approfondissement, Flir one®, ImageJ, membre, tronc*

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Introduction

Burns are skin to soft tissue injuries caused by trauma from heat, hot liquids, electricity, chemical, radiation or cold trauma, and they have become a global health problem due to high morbidity and mortality.[1] The causes of most of burns' mortality are multiple organ failure and sepsis.[2] There are 11 million burn patients with 320.000 deaths per year and half of them are in Southeast Asia.[3,4] The depth of the burn has a dynamic nature and changes over time. The burn area can either heal (epithelialization) or progress into a deeper burn wound (burn conversion).[5] There are three zones of burn wound, the coagulation zone, the stasis zone, and the hyperaemic zone.[6] Burn wound conversion describes the process by which superficial-partial thickness burns convert into deeper burns within 3-7 days after the burn.[7] Currently, autophagy processes, inflammation, ischemia, infection and reactive oxygen species are thought to play a role in the pathogenesis of burn conversion.[5,7,8]

Diagnosis of the depth and extent of burns can be done by clinical examination and investigation. Diagnosis in burn patients remains a difficult clinical challenge. Therefore, a burn conversion predictor model is needed to assist the management of burns by doctors and paramedics. The scoring model aims to guide the clinician in diagnosing the depth and extent of burns with limited tools and can be used as a reference to determine whether management should be conservative or operative. Management decision making is very important because it relates to early tangential excision to prevent sepsis, which is the most common cause of death in burn patients.

This study aims to (1) analyze the clinical characteristics (gender, cause, and burn region) with burn conversion; (2) analyze the relationship between local clinical assessment (burn extent measured using the ImageJ application and wound surface temperature measured by Flir one® thermography) with burn conversion; (3) analyze the relationship between systemic clinical assessment (mean arterial pressure, urine output, blood procalcitonin level, blood lactate level) with burn conversion; (4) develop a predictor score model as a reference for conservative and operative management using local and systemic clinical assessment.

Materials and methods

This is a nested case control study to identify the relationship between predictor factors with the case group (confirmed conversion from histopathological examination) and the control group (confirmed no conversion from histopathological examination or observation for 7 days). The variables that had the most significant correlation with burn conversion were analyzed using logistic regression, and a burn conversion predictor score model was made.

The subjects were burn patients who had just arrived at the ER and Burn Unit at Dr. Cipto Mangunkusumo Hospital and Jakarta Cempaka Putih Islamic Hospital from February 2019 to August 2020 and were selected by consecutive sampling method. The inclusion criteria of this study were burn patients aged 16-70 years, who had second-degree burn with an area of < 40% TBSA, were admitted less than 48-hour post burn, and agreed to informed consent. Meanwhile, the exclusion criteria in this study were burn patients who had burns due to electricity, chemicals and radiation; systemic vascular diseases such as atherosclerosis, coagulopathy, peripheral vascular disease, diabetes mellitus, and immunosuppression; and patients with inhalation trauma.

The variables used were primary data from subject characteristics (age, origin of referral hospital, region of origin of referral hospital, patient financing, gender, cause, burn region), local clinical examination (the assessment of the burn depth using the ImageJ application and examination of the skin surface temperature of the burn area (thermography) using Flir one®) and systemic examination (mean arterial pressure, urine output, laboratory tests of blood procalcitonin levels, and blood lactate levels).

Descriptive, bivariate and multivariate analysis were performed. The normality test was performed using the lilliefors test. Hypothesis testing for 2 groups of nominal data variables used chi-square test or fisher exact. Hypothesis testing for 2 groups of numerical data variables used the unpaired t test or Mann-Whitney. ROC curve analysis was performed to determine the cutoff point for numerical variables and continued with bivariate analysis using the chi-square test to assess the relationship between various predictor factors and the occurrence of burn conversion.

The multivariate analysis used was logistic regression with the backward selection method. The data were analyzed using SPSS 22.0 and StataSE 15.1.

This study received ethical approval and passed ethical review from the Health Research Ethics Committee of the Faculty of Medicine, University of Indonesia, Dr. Cipto Mangunkusumo Hospital, number: 56/UN2.FI/ETIK/2019, January 21, 2019.

Results

From February 2019 to August 2020, there were 237 burn patients treated in Dr. Cipto Mangunkusumo Hospital and 37 patients in Jakarta Cempaka Putih Islamic Hospital. Based on the inclusion and exclusion criteria, 62 patients with second degree burns were enrolled in this study. There were 2 drop out samples, the first sample was operated on the second day of hospitalization thus the data collection could not be continued, and the second sample was self-discharged before completing the data collection process. Sixty samples were obtained, which were then proven whether to have burn conversion based on changes in burn depth as assessed by ImageJ and histopathological examination by the Department of Pathology Anatomy, Faculty of Medicine, University of Indonesia, Dr. Cipto Mangunkusumo Hospital, or by clinical observation for 7 days. In this study, the sample consisted of 40 cases and 20 controls.

The median age in the case group was 44.5 years while in the control group it was 44 years. In the case group most patients were referrals from Type B (Regional Referral) Hospitals, while in the control group most patients came directly to the emergency unit of Dr. Cipto Mangunkusumo Hospital. The origin of the hospital that refers most of the cases was Central Jakarta. Most of the patient funding was from National Health Insurance. There were more male subjects than female in both groups, but there was no significant relationship with the incidence of burn conversion. The most common cause of burns in the case and control group was gas explosion. Most commonly involved area of the burns in both the case and control group were the upper extremities. There was a significant relationship between the wound region in the trunk ($p = 0.028$) and limbs ($p = 0.001$) with burn conversion. As the most common cause of burns in this study was gas explosion, household accidents were probably the most common burns accident so that the upper extremity was more at risk of experiencing burns (*Tables I & II*).

Table I - Subjects' demographic characteristics

Characteristics	Cases (n = 40)	Controls (n = 20)
Age (years)	44.5	44
Patient admission		
Not referral:	6 (15)	12 (60)
Type of health facility referring:		
National referral (type A) hospital	3 (7.5)	2 (10)
Regional referral (type B) hospital	17 (42.5)	4 (20)
District referral (type C) hospital	5 (12.5)	1 (5)
Local referral (type D) hospital	8 (19.5)	0 (0)
Primary Health Care	1 (2.5)	1 (5)
Areas of referring health care		
North Jakarta	2 (5)	3 (15)
West Jakarta	5 (12.5)	0 (0)
East Jakarta	4 (10)	2 (10)
South Jakarta	8 (20)	0 (0)
Central Jakarta	16 (40)	15 (75)
Outside Jakarta	5 (12.5)	0 (0)
Funding		
National Health Insurance	34 (85)	17 (85)
Out-of-pocket	6 (15)	3 (15)

Table II - Subjects' clinical characteristics

Clinical Characteristics	Cases (n = 40)	Controls (n = 20)	p	OR	CI 95%
Sex					
Male	23 (57.5)	13 (65)	0.576[c]	1.37	0.451–4.175
Female	17 (42.5)	7 (35)			
Cause of burns					
Flame	14 (35)	6 (30)			
Scald	5 (12.5)	5 (25)	0.539[FE]		
Hot oil	3 (7.5)	0 (0)			
Gas explosion	18 (45)	9 (45)			
Area of burns involved					
Head and neck					
Yes	22 (55)	8 (40)	0.273[c]	1.83	0.616–5.453
No	18 (45)	12 (60)			
Trunk					
Yes	22 (55)	5 (25)	**0.028[c]**	3.67	1.117–12.035
No	18 (45)	15 (75)			
Upper extremities					
Yes	39 (97.5)	18 (90)	0.255[FE]	4.33	0.369–50.953
No	1 (2.5)	2 (10)			
Limb					
Yes	34 (85)	9 (45)	**0.001[c]**	6.93	2.011–23.853
No	6 (15)	11 (55)			

Note: [c] chi-square test; [FE] Fisher Exact test

In this study, there were two methods of histopathological examination, punch biopsy and histopathological examination of the burns tissue obtained from tangential excision. All of the study subjects refused punch biopsy. Therefore, patients without burn conversion from the clinical examination were

then monitored for 7 days, while patients with conversion were then further evaluated with histopathological examination using the burned tissue taken from surgery. To confirm whether early excisional debridement was needed, we did an evaluation on day-3 post-burn using Flir one®. If the area became deeper, we proceeded to excisional debridement. We sent burn tissue from the procedure for histopathological examination. If there was no change in the Flir one® evaluation on day-3 post-burn, we would observe it until day-7 post-burn. If the area became deeper based on Flir one® examination, we concluded burn conversion. We believe that after day-7 post-burn, the burn conversion would not occur anymore.

The degree of burn was determined through histopathology examination, by identifying changes in epidermal cells, collagen, blood vessels, hair and fat. There were 24 subjects who were evaluated for histopathological examination, of which 9 subjects had a Medina-Meyerholz score of 3, consistent with deep-partial dermal (grade 2B) burns. There were 15 subjects with a Medina-Meyerholz score of 4, consistent with full-thickness (grade 3) burns. As for the 36 subjects who were observed for 7 days, there were 16 subjects with burn conversion and 20 subjects without burn conversion (*Table III*).

Table III - Data distribution on histopathology measurement and 7-days observation

Subject	Medina-Meyerholz Score		7-days observation
	Score 3	Score 4	
Cases (n = 40)	9	15	16
Controls (n = 20)	0	0	20

Analysis of relationship of burn region with burn conversion

Analysis between burn region with burn conversion showed a significant relationship between trunk (OR = 3.67, p = 0.028, 95%CI 1.117–12.035) and limb (OR = 6.93, p = 0.001, 95%CI 2.011–23.853) with burn conversion. These data indicated that presence of burns on the trunk and limb regions tends to change degree of burns from shallow to deep. From Tsuchida's study[9] on blood supply to body region using Xenon 133, it was stated that face and anterior trunk have good blood supply compared to the deltoid and control region (< 0,01). The dorsal of the limb area doesn't have good blood supply compared to the control region with the velocity of 11,4 ± 2,43 mL/100 gm/min (p < 0,01).[9] This is consistent with the pathophysiology of blood supply based on the body region; the limb region has lower local perfusion. Lower local perfusion leads to inadequacy of blood supply, and tissue ischemia and autophagy may occur.[7] The trunk region has a significant relationship in accordance with the large percentage in calculation of burn area so that it has a risk of becoming deeper.

Analysis of the ImageJ %TBSA on burn conversion

The ImageJ %TBSA data of burn patients in this study were not normally distributed, with p value of 0.028. From the Mann Whitney test, there were significant mean differences between the two groups [20.33 (3.82–43.04) and 2.87 (0.48–14.73), (p < 0.001)]. From the ROC curve analysis, the AUC for ImageJ %TBSA was 0.934 (95%CI 0.873–0.995), p < 0.001, with a cut-off point at ImageJ %TBSA value of 9.49%. At this value, a sensitivity of 85% and a specificity of 85% were obtained. Based on the validity test using the chi-square test, there was a significant relationship between ImageJ %TBSA value of 9.49% on burn wound conversion (OR = 32.11, p < 0.001, 95%CI 7.142–144.377). The use of ImageJ in measuring the burn area has a good level of accuracy and reliability. ImageJ measurement results are also more objective because the numbers are obtained in cm^2. From this study, we encourage measuring burn area using ImageJ. ImageJ is chosen to give an objective measurement of the burn area. ImageJ has been used for many studies on wound assessment, so we tried to use it too for burn wounds.

Analysis of the ΔT1 Flir one® on burn conversion

The temperature difference between the wound and healthy skin on the first day (ΔT1) of burn patients in this study was normally distributed, with p value of 0.20, and the data variants were homogeneous between the two groups. From the unpaired t-test, there was a significant difference between the case and control group [-2.958 ± 2.337 and -0.380 ± 1.632, (p < 0.001)]. From the ROC curve analysis, the AUC for ΔT1 was 0.842 (95%CI

0.741–0.943) p < 0.001, with a cut-off point at ΔT1 value of -1.55°C. At this value, a sensitivity of 77.5% and a specificity of 80% were obtained. Based on the validity test using the chi-square test, there was a significant relationship between ΔT1 value of -1.55°C and burn wound conversion (OR = 13.78, p < 0.001, 95%CI 3.668–51.748).

This is in accordance with the pathophysiology of the temperature relationship to the wound. Deeper burns tend to have a lower temperature than those of healthy areas. Destruction of blood vessels in deeper burns causes a decrease in local perfusion, thereby lowering body temperature in that area.[10]

Flir one® has been used in other burn studies as it is compact and easy to use in an emergency setting. Compared to laser Doppler imaging, which is relatively expensive, not practical to be used at the bed-side, and currently not available in our burn unit, we chose ImageJ and Flir one® for local clinical examination as these tools are easy to access and affordable. We expect to introduce these tools to other centers in low-middle income countries, especially Indonesia.

Analysis of the day-1 mean arterial pressure on burn conversion

The day-1 mean arterial pressure data for burn patients in this study were not normally distributed, with p value of 0.007. From the Mann Whitney test, there was no significant mean differences between the two groups [94.41 (79.85–183.33) and 93.33 (70.66–108), (p = 0.53)] thus we did not perform ROC curve analysis. Referring to the mean arterial pressure data obtained from the sample, the minimum mean arterial pressure was 70.66 mmHg, which means that no one has experienced hypovolemic shock. Mean arterial pressure did not have a significant relationship with burn conversion. This is accordance with Sittah's study,[11] which stated that mean arterial pressure in non-survivor patients was high. Sittah's study also stated that mean arterial pressure as a resuscitation parameter did not reflect perfusion at cellular level.

Analysis of the day-1 urine output on burn conversion

The day-1 urine output data for burn patients in this study were not normally distributed (p = 0.005). From the Mann Whitney test, there was no significant mean differences between the two groups [1.02 (0.3–3.0) and 1.25 (0.2–3.13), (p = 0.962)] thus we did not perform ROC curve analysis. The median urine rate for cases and controls was within normal ranges. Urine rate is often used as a parameter for successful resuscitation, but in burn patients it can not accurately reflect perfusion at both the tissue and cellular levels. From Wilkinson's study,[12] oligury was a consequence of burn so urine volume was not recommended to be a perfusion indicator. Barton et al.[13] stated that in the shock phase, urine rate was too variable and unpredictable. Similar to mean arterial pressure, urine output cannot be used as a variable for the scoring system.

Analysis of day-1 procalcitonin level on burn conversion

The day-1 procalcitonin data for burn patients in this study were not normally distributed, with a p value of 0.001. From the Mann Whitney test, there were significant mean differences between the case and control group [0.21 (0.02–5.38) and 0.05 (0.02–0.37), (p <0.001)]. From the ROC curve analysis, the AUC for day-1 procalcitonin was 0.817 (95%CI 0.71–0.92), p < 0.001, with a cut-off point at the day-1 procalcitonin value of 0.075 ng/mL. At this value, a sensitivity of 75% and a specificity of 80% were obtained. Based on the validity test using the chi-square test, there was a significant relationship between day-1 procalcitonin of 0.075 ng/mL and burn wound conversion (OR = 12, p < 0.001, 95%CI 3.242–44.416).

The pathogenesis of burn conversion is related to several factors, most of which are closely related to the presence of multiple vasoactive and inflammatory mediators. One of the factors that contributes locally to burn conversion is bacterial infection.[5] Sawhney et al.[14] stated that application of silver sulfadiazine 1% topically on retrospective study in 342 patients with 2B degree burn with 10-50 %TBSA could lower the rate of burn conversion and lower time to wound healing.

In this study, the results showed that blood procalcitonin had a significant relationship with the incidence of burn conversion. This is related to the presence of deep burns that will increase the risk of infection, so that bacterial endotoxins will trigger

the release of procalcitonin into the blood. In our subjects, all of the patients showed bacterial growth on tissue culture.

Analysis of day-1 lactate level on burn conversion

The day-1 lactate data for burn patients in this study were not normally distributed, with a p value of 0.028. From the Mann Whitney test, there were significant mean differences between the case and control group [2.20 (0.04–6.00) and 1.25 (0.70–4.20), (p = 0.002)]. From the ROC curve analysis, the AUC of day-1 lactate was 0.747 (95%CI 0.611–0.883), p = 0.002, with a cut-off point at the day-1 lactate value of 1.75 mmol/L. At this value, a sensitivity of 70% and a specificity of 75% were obtained. Based on the validity test using the chi-square test, there was a significant relationship between day-1 lactate level of 1.75 mmol/L and burn wound conversion (OR = 7, p < 0.001, 95%CI 2.072–23.645).

In our study, we interpret that a patient with a day-1 lactate level of 1.75 mmol/L would undergo burn conversion. This is in accordance with the pathophysiology as there are several local vasodilating mediators, including leukotrienes, prostaglandins, histamine, serotonin, nitric oxide, and lactate. The presence of vasodilation contributes to progressive tissue damage in the stasis zone through edema and increased tissue pressure.[8] This condition leads to tissue ischemia/anaerobic environment.

Study from Wilmore et al.[15] on local and systemic response in burns also showed that lactate levels were elevated in more extensive burns. This indicates that the wound has low oxygen supply. Data from several studies indicate that lactate levels in wounds can stimulate collagen synthesis, fibroblasts and angiogenesis, thereby accelerating wound healing.[16] However, there is no evidence of an association between wound lactate levels and blood lactate levels. Checking the levels of lactate in the blood is easier to apply in daily practice. Therefore, this study used blood lactate levels because it is more practical for use in the field.

Scoring model 1: complete variables

There were 6 variables with p value < 0.25 that were included in the multivariate analysis for burn conversion, which are the trunk region, leg region, ImageJ (%TBSA), and the difference in burn temperature (ΔT1) as measured by Flir one®, blood procalcitonin levels, and blood lactate (*Table IV*). The scoring model is then tested from the aspects of calibration and discrimination. In the analysis of the Hosmer and Lemeshow test, it was found that no difference was observed between the expected and the p value <0.001, so it can be concluded that the model is well calibrated. In the discrimination analysis using the ROC curve, it was found that the AUC was 0.927 (p <0.001, 95%CI 0.835–1,000). Based on the AUC curve, the cut-off score for management with operative measures was also obtained at a score of ≥ 5.5 with a sensitivity of 92.5% and a specificity of 85%. If the patient has a total score <5.5, the prediction of the risk of experiencing burn conversion is ≤ 53.89% (probability at score 5), and if the patient has a total score of ≥ 5.5 then the prediction of the risk of experiencing burn conversion is ≥ 70.85 % (probability at score 6) (*Table V*). The scoring model 1 can be used in tertiary health facilities because it includes procalcitonin and blood lactate parameters, which are tests that are not generally available in primary and secondary health facilities.

Table IV - Eligible burn conversion predictor factors for multivariate analysis

Risk Factor	OR	P value	CI 95%
Limb region	6.93	0.001	2.011–23.853
Trunk region	3.67	0.028	1.117–12.035
ImageJ ≥ 9,49% TBSA	32.11	< 0.001	7.142–144.377
Flir one® ≤ -1,55 °C	13.78	< 0.001	3.67–51.748
Procalcitonin ≥ 0,075 ng/mL	12	< 0.001	3.242–44.416
Lactate ≥ 1,75 mmol/L	7	0.001	2.072–23.645

Table V - Weighting of burn conversion predictor variable factors for scoring model 1

Variable	B/SE	(B/SE)/0,63	Score
Limb region	1.08	1.72	2
Trunk region	1.36	2.17	2
ImageJ ≥ 9,49% TBSA	2.18	3.47	3
Flir one® ≤ -1,55 °C	1.44	2.28	2
Procalcitonin ≥ 0,075 ng/mL	0.67	1.06	1
Lactate ≥ 1,75 mmol/L	0.63	1.00	1
		Total	(0–11)

Scoring model 2: simple variables

For the scoring model 2, blood PCT and blood lactate levels were not included. The scoring model

is then tested for quality from the aspects of calibration and discrimination. In the analysis of the Hosmer and Lemeshow test, it was found that no difference was observed between the observed and the expected value of p = 0.001 so it can be concluded that the model is well calibrated. In the discrimination analysis using the ROC curve, it was found that the AUC was 0.919 (p <0.001, 95%CI 0.830–1,000). From these results it can be concluded that this scoring model has a good quality of discrimination. Based on the AUC curve, the cut-off score for management with operative measures was also obtained at a score of ≥ 1.5 with a sensitivity of 95% and a specificity of 70%. If the patient has a total score < 1.5, the prediction of the risk of experiencing burn conversion is 14.79% (probability at score 1), and if the patient has a total score of ≥ 1.5 then the prediction of the risk of experiencing burn conversion is 36.24% (probability at a score of 2) (*Table VI*). However, the determination of operative management cannot only be based on regional involvement but also needs to be supported by one of the results from ImageJ and/or ΔT1 Flir one®. If the score is ≥ 1.5 but you get ImageJ or Flir one® with a score of 0, it is necessary to do a re-examination or virtual consultation with a plastic surgeon. If the score is ≥ 1.5 with an ImageJ score and/or Flir one® ≥ 2, it is advisable to carry out operative measures according to local facilities or refer to a more complete health facility and virtual consultation with a plastic surgeon.

Table VI - Weighting of burn conversion predictor variable factors for scoring model 2

Variable	B/SE	(B/SE)/1,22	Score
Limb region	1.22	1	1
Trunk region	1.49	1.22	1
ImageJ ≥ 9,49% TBSA	2.55	2.09	2
Flir one® ≤ -1,55 °C	2.32	1.90	2
		Total	(0–6)

Scoring model 3: simple variables with addition of lactate

For the scoring model 3, we included all variables except blood PCT levels. The scoring model is then tested for quality from the aspects of calibration and discrimination. In the analysis of the Hosmer and Lemeshow test, it was found that no difference was observed between the observed and the expected value of p = 0.001 so it can be concluded that the model is well calibrated. In the discrimination analysis using the ROC curve, it was found that the AUC was 0.924 (p <0.001, 95%CI 0.832-1,000). From these results it can be concluded that this scoring model has a good quality of discrimination. Based on the AUC curve, the cut-off score for management with operative measures was also obtained at a score of ≥ 3.5 with a sensitivity of 92.5% and a specificity of 85%. If the patient's characteristics have a total score <3.5, the prediction of the risk of experiencing burns conversion is 10.41% (probability at score 1), and if the patient's characteristics have a total score of ≥ 3.5 then the prediction of the risk of experiencing burn conversion is 74.38% (probability at score 4) (*Table VII*). The scoring model 3 can be used in primary and secondary health facilities. If the score is ≥ 3.5, the patient is advised to undergo operative action according to local facilities or referral to a more complete health facility and virtual consultation with a plastic surgeon.

Table VII - Weighting of burn conversion predictor variable factors for scoring model 3

Variable	B/SE	(B/SE)/1	Score
Trunk region	1.37	1.37	1
Limb region	1.17	1.17	1
ImageJ ≥ 9,49% TBSA	2.18	2.18	2
Flir one ≤ -1,55 °C	2.14	2.14	2
Lactate ≥ 1,75 mmol/L	1	1	1
		Total	(0–7)

Based on the 3 ROC comparison analysis, it was found that there was no significant difference between the scoring models 1, 2, and 3 (p = 0.4427). For clinical purposes and application in the field, scoring model 1 can be used in tertiary health facilities, while scoring models 2 and 3 can be applied in primary and secondary health facilities.

Strengths and novelties

The excellence of our study is we found cut-off point values of the burn region variables, ImageJ, Flir one®, procalcitonin levels, and blood lactate on the occurrence of burn conversion. This study is

also the first study to make a scoring card for burn conversion. The scoring system currently available for burn patients is only to predict the incidence of mortality, while in this study it predicts burn progression. With the scoring system that we have developed, burn conversion can be predicted early and will affect management, which in turn affects the mortality rate in burn patients. It is our hope that this scoring card can then be developed into an application system so that it can be widely and easily used by health facilities, and can become a tool for an integrated referral system in burn cases.

Research limitations

This study has several limitations. The research was conducted at Dr. Cipto Mangunkusumo Hospital, which is a national referral hospital, and Jakarta Islamic Hospital Cempaka Putih, which is a referral center for the Islamic Hospital group and a referral center for regional, local and district hospitals, so burn cases generally have a wound area more than 40%, burn onset of more than 48 hours, and patients have additional comorbidities. Therefore the search for research subjects is difficult because they often do not match the inclusion and exclusion criteria of this study.

Conclusions and suggestions

Predictor factors for burn conversion in adult patients include involvement of limbs and trunk, local clinical examination (burn area calculated using the ImageJ application and wound surface temperature measured by Flir one® thermography), and systemic clinical examination (levels blood procalcitonin, blood lactate level). The scoring model can be recommended as a predictive model for the conversion of burns in adult patients and becomes a reference for conservative and operative management. This scoring model is recommended for application in daily practice to predict early conversion of burns so that it can reduce mortality and morbidity.

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