Original Article

The Correlation between the Color Changes of Contusions and the Time Period after Injuries in Thai Populations

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Abstract

Introduction: The color changes of contusions is related to the aging of injuries, which is important in medico-legal aspects. The purpose of this study is to determine the correlation between the color changes of contusions and the time period after injuries in Thai populations.

Method: A cross-sectional study of 400 contusions from 199 Thai healthy patients who had blunt injuries and knew the certain time of injuries was conducted. The colors of contusions were evaluated by visual assessment. The patients' data including age, sex, size, body area of contusions, type of weapons used, and the time period after injuries were recorded. The data were analyzed by descriptive statistics, Kruskal-Wallis H Test, Mann-Whitney U test with Bonferroni correction for multiple comparisons, and logistic regression analysis.

Results: The correlation between the color changes of contusion and the time period after injuries was statistically significant ($p < 0.001$). The average times for each color in contusions presented at the visiting time were 24, 48, 60, and 84 hours for red, purple, green, and yellow color, respectively. The minimum time that yellow color could be noticeable was 18 hours.

Discussion and Conclusion: Yellow color was the key finding for the dating of contusions and should be determined in the examination of contusions.

Key words: color changes of contusions, aging of contusions, time of injuries, visual assessment

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Introduction

The aging of injuries plays an important role in forensic medicine because it has an effect on medico-legal consequence in the aspect of the causation between the assault and the outcome of injuries. Contusion wounds are the most common traumatic findings found in blunt force injuries resulting from a blow or squeeze to the tissue and subsequent ruptures of blood vessels, without breaking of the skin[1]. There are many previous studies supporting that the changing of the color of contusions is related to the aging of injuries. Most of these studies are conducted in White populations. However, the data of the dating of contusions by color changes over the time period in Thai populations who have darker skins have never been studied before.

In previous study, there was a general agreement that red, blue and purple colors appeared in the early stage[2]. Then, green and yellow color appeared in the later period after 4 - 7 days and not less than the seventh days, respectively[2]. The study of contusion in animal models revealed that yellows appeared in the contusion by 48 hours[3]. However, the study of the aging of bruises in human subjects by Langlois NE and Gresham GA had made a crucial remark that a contusion with yellow discoloration was more than 18 hours old but absence of a yellow color did not mean that the contusion was less than 18 hours old[2]. This conclusion is still acceptable and currently published in standard forensic textbook[1].

The author conducts this study to determine the relationship between the color change of contusions and the timing of injuries in Thai populations. This information will be useful for interpretation of the color of contusion in Thai patients because forensic physicians and even general practitioners can be asked to give medical opinions about the dating of injuries.

Method

A cross-sectional study of the color of contusions during the time period after injuries was conducted in 400 contusions from 199 Thai healthy patients who were sent for physical examination at Clinical Forensic Medicine Clinic, Department of Forensic Medicine, Phrachomklao Hospital, Phetchaburi Province. All of the patients were injured by blunt force trauma and the certain time of injuries was confidently identified. The data from patients including patient identification, age, sex, and the timing of injuries were recorded by the assistant officer. Patients' histories of injuries and the weapons used in body assault were obtained by the author (forensic physician). The characteristics of contusions including color, size, and area of contusions were examined by the author with visual assessment using standard color chart with a centimeter scale at the time of visiting. Then, photographs were taken in the same ambient lighting condition at 1.00 - 3.00 pm in the clinical forensic medicine room for every subject by using digital camera Canon Powershot G1X with a 15.1 - 60.4 mm lens (1:2.8 - 5.8). Because one contusion site could produce more than one color, the declaration of the specific color in each wound should be defined. The declaration of the specific color in contusion was defined by the recognition of specific color in an area of greater than 1 x 1 square centimeters (cm^2) inside that contusion wound and that contusion would be declared as that color. The color declaration was mainly based on the older color if there were at least two colors in the same contusion site. According to the general agreement in color changes of contusion wounds, red and purple colors occurred in the early stage of contusions, followed by green and yellow colors in the later period[2]. Thus, if green and yellow colors appeared in contusions, those contusions would be declared as green and yellow color contusions, respectively.

The inclusion criteria of this study were Thai patients who had the histories of blunt force injuries with the time period after injuries not greater than 14 days. The exclusion criteria of this study were patients who were over 50 years old, patients who had the histories of loss of consciousness and could not provide accurate time of injuries, patients with underlying cirrhosis or other chronic liver diseases, patients who had bleeding disorders, patients using anticoagulant drugs, patient who had skin type V-VI in classification for human skin color by the six categories of the Fitzpatrick scale and patients who had severe injuries with their contusions, for example, bone fractures and ruptured major blood vessels.

This study was carried out under an ethical approval from the Institutional Review Board (IRB) in Phrachomklao Hospital, Phetchaburi Province. (Document Number 12/2559).

Statistical Analysis

The statistical analysis was performed by program SPSS Statistics® for Windows Version 18.0. The fundamental data including age, sex, color of contusions, size of contusions, site of contusions, and type of weapons were analyzed by descriptive statistics.

The correlation between the color of contusions and the time period (hours) was analyzed by using Kruskal-Wallis H Test. In addition, the interaction between color changes of contusions and other factors including age, sex, size and site of contusions and type of weapons on the time period (hours) was analyzed by Mann-Whitney U test with Bonferroni correction for multiple comparisons.

Finally, the prediction of the time period of injuries from color changes of contusion was analyzed by logistic regression analysis.

Results

There were 400 contusions from 199 Thai healthy subjects recruited in this study. There were 106 males (53.3%) and 93 females (46.7%). The age of patients ranged from 8 years to 50 years and the average age of all subjects was 24 years old. The average ages of male and female subjects were 19.5 and 28 years old, respectively. Some subjects had more than one contusion either in the same area or difference areas. The time period after injuries in this study ranged from 1 hour to 14 days (336 hours). The colors developed in these 400 contusions were described as 72 red (18%), 98 purple (24.5%), 109 green (27.2%) and 121 yellow (30.2%). The appearance time of these four colors in contusions at the time of visiting was demonstrated in (Figure 1)

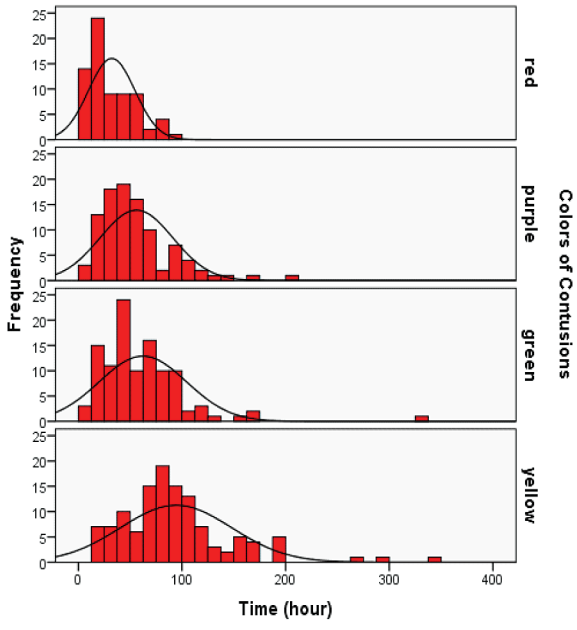
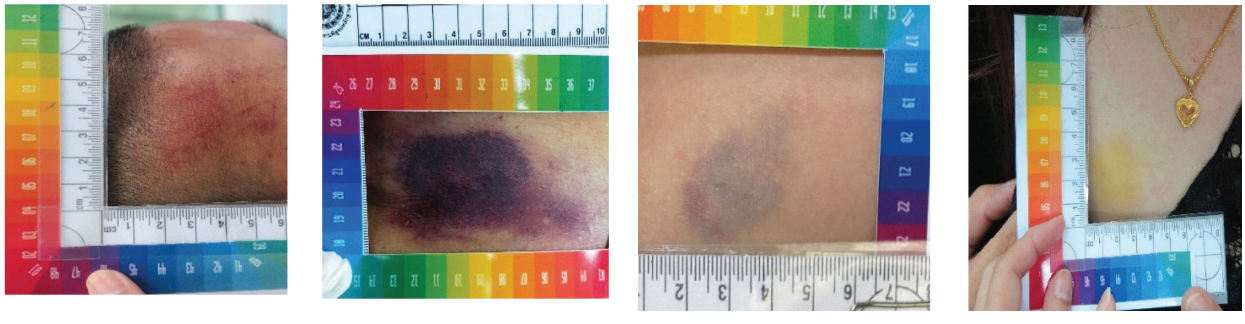


Figure 1 the appearance time of four colors in contusions at the time of visiting

Red and purple colors were presented first after injuries and could be presented at 1 hour after injuries. The average time (median time) of red and purple colors presented at the visiting time was 24 and 48 hours after injuries, respectively.

Green began to be noticeable at 3 hours after injuries. The average time of the green color presented at the visiting time was 60 hours after injuries.

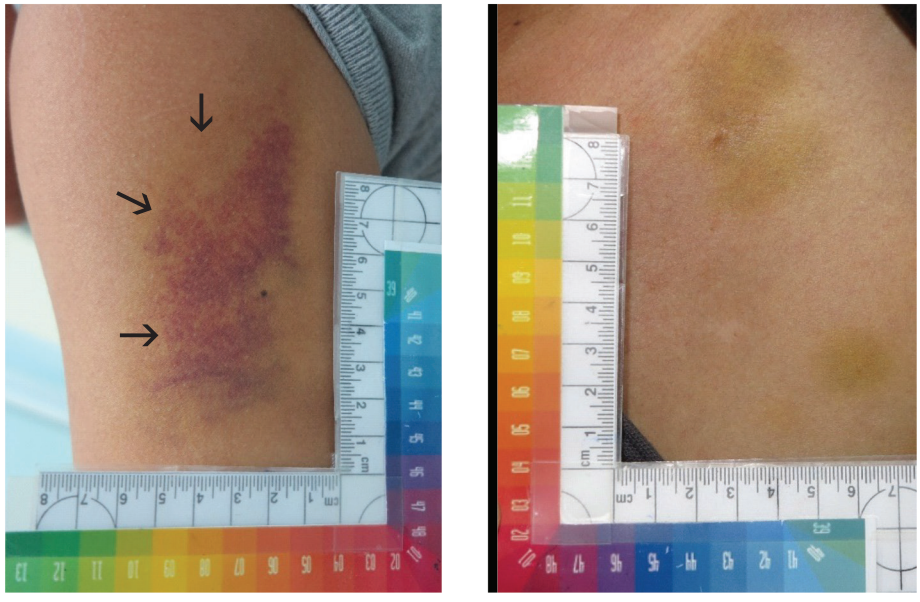
The minimum time which yellow color could be observed was 18 hours after injuries and the average time of yellow color presented at the visiting time was 84 hours after injuries (between 72 - 120 hours in most cases). These four colors in contusions were demonstrated in (Figure 2)



(red) (purple) (green) (yellow)

Figure 2 Samples of the contusion color assessment by using standard color chart with the centimeter scale

In most cases, yellow color was initially presented at the edge of wounds and yellow color was the major color found in contusion sites when patients visited the clinic at least at the day 3 - 5 after injuries as demonstrated in (Figure 3)



(a) (b)

Figure 3 (a) Yellow color was initially presented at the edge of wound (arrow), (b) Clear yellow color was presented at day 3 - 5 or more

The appearance of each color in contusion sites was correlated with the time period after injuries with high statistical significance ($p < 0.0001$) by Kruskal - Wallis H Test. However, when performing analysis with Mann-Whitney U test with Bonferroni correction for multiple comparisons, there was no statistical significance between purple and green color groups ($p > 0.05$).

By using logistic regression analysis, each color of contusion was also correlated with the time period after injuries with high statistical significance ($p < 0.0001$) and this correlation was demonstrated with predicting curve in (Figure 4)

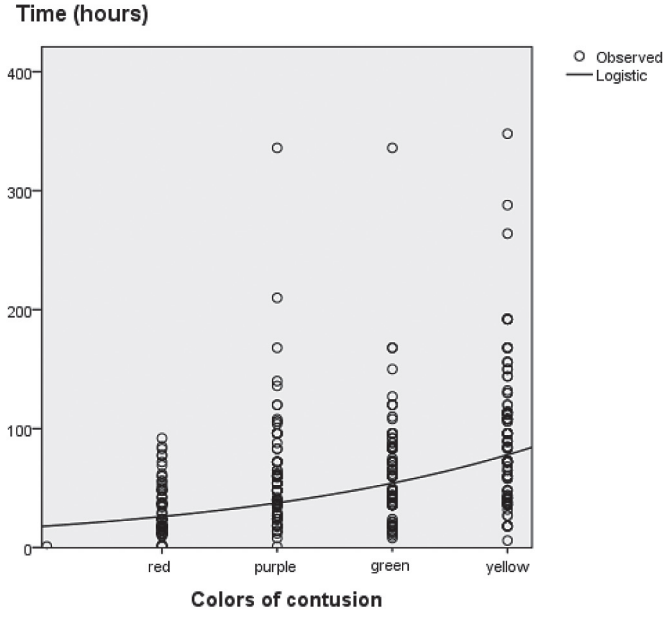


Figure 4 the correlation between each color of contusions and the time period after injuries

Other factors including sex, age, size of contusion, site of contusion and weapons used might have an influence on the correlation between the color changes of contusions and the time period after injuries. The summary of these factors in studied subjects with the statistical analysis by Mann-Whitney U test with Bonferroni correction for multiple comparisons was shown in Table 1.

Table 1 Summary of other factors that potentially had the influence on the color changes of contusions over the time period with p - value by Mann-Whitney U test with Bonferroni correction for multiple comparisons

Factors		Frequency (N)	Percent (%)	p-value (factors x color vs time)
Sex	Male	106	53.27	0.080
	Female	93	46.73	
Age	1 - 10	2	0.50	
	11 - 20	124	31.00	
	21 - 30	131	32.75	0.190
	31 - 40	103	25.75	
	41 - 50	40	10.00	
Body area	Scalp	33	8.25	
	Periorbital area	77	19.25	
	Face (except orbit)	90	22.50	0.051
	Trunk and back	47	11.75	
	Arms and legs	136	34.00	
	Hand and feet	17	4.25	
Size (cm^2)	1 - 9	172	43.00	
	10 - 25	167	41.75	
	26 - 49	34	8.50	0.215
	50 - 100	16	4.00	
	> 100	11	2.75	
Weapons	Body parts (hands, legs, feet)	302	75.50	
	Steel	17	4.25	
	Plastic rod/PVC	17	4.25	0.437
	Wood	35	8.75	
	Glasses/bottles	5	1.25	
	Floor/wall	15	3.75	
	Others	9	2.25	

To study the influence of other factors on the correlation between the color changes and the time period after injuries, Mann - Whitney U test with Bonferroni correction for multiple comparisons was used for this analysis. According to this analysis, it was found that sex, age, body area, size of contusions and weapons used were not statistically significant ($p = 0.080, 0.190, 0.051, 0.215$, and 0.437, respectively).

Discussion and Conclusion

The correlation between all of the color changes of contusions and the time period after injuries was statistically significant in this study. Red, purple and green colors were found in the recent periods after injuries. Red and purple color could appear within the first hour after injuries whereas green color could appear in a few hours after injuries. However, the appearance of purple and green colors were not statistically significant in this study. Therefore, to differentiate the aging period of purple and green colors may not be possible because these colors could appear in the similar period. Yellow color began to be noticeable at 18 hours or more after injuries. This finding supported the previous study by Langlois NE and Gresham GA even though the study by Scafide KR et al. showed that yellow color started to be observed at 24 hours[2, 4]. In addition, the yellow color was initially recognized at the edge of wound in the majority of wounds. Then, yellow color was the major color detected at the day 3 - 5 after injuries and could persist for 14 days. In general, the mixture of different colors was usually detected in each wound. This study revealed that the recognition of the yellow color, particularly at the edge of wound should be useful in the interpretation of the aging of contusions.

The hemoglobin in the red blood cells and its degradation products are the cause of skin discoloration seen in contusions over time[1, 5, 6]. Red color has been directly attributed to the hemoglobin color. Purple color results from blood reflecting light at different depths in the skin. Green color has been mainly attributed to biliverdin. Lastly, yellow color results from bilirubin developed as the 19 - 30 hours interval[1, 2]. Therefore, yellow color began to be detected after 18 hours[2]. However, the rate of change is variable, not only in different people but also in the same person.

In general, contusions on the same person, inflicted at same time on same body area may not necessarily exhibit the same colors. Consequently, other factors including gender, age, size of wounds, site of injuries and weapons used were analyzed by the statistical analysis. It was found that all of these factors had no influence on the color changes of contusion over the time period but these findings could be explainable. Firstly, because data in this study was not normally distributed, statistical analysis applied to all data was conducted by non - parametric methods and the power in statistics in this study would be compromised. Secondly, the different distribution in each sub - group within each factor might have the effect on this analysis as described below.

Most of the subjects recruited in this study were young people in both genders (11 - 40 years old). Skin integrity in the young people should have similar properties. Thus, when statistical analysis was performed for sex and age, they produced no statistical significance of these factors on the color changes over the time period after injuries. The previous study stated that the elderly easily had contusions because they had loose and delicate skin and less supportive subcutaneous tissue and senile purpura on the forearms may be mistaken for contusions[2]. Thus, the different age groups particularly the young adult and the elderly groups should be studied in the future research.

Size of contusions had no influence on the color changes of contusions in this study because most of the studied subjects in this study had small-sized contusions (≤ 25 cm^2) (see Table 1). In general, the color appearance of contusions resulted from the amount of hemoglobin leakage in the tissue and the depth of contusions through skin layer[6]. Size of contusions had the direct relationship to those two factors and should have an influence on the color changes of contusions. However, because most of contusions recruited in this study were small-sized contusions (≤ 25 cm^2), they may have similar amount

of hemoglobin leakage and similar depth of hemorrhage in dermal and subcutaneous layer. Thus, they produced similar changes over the time period after injuries.

The p-value for body areas of contusions was closed to 0.05 even though it was found no statistically significant. This finding reflected that different body area of contusions had the tendency to have an effect on the color changes of contusions over the time period after injuries because different body area of contusions had the different tissue properties including thickness, density of connective tissue, distribution of blood vessels and tissue reaction after injuries[6] and these factors could affect the rate of changes in hemoglobin and its degradation products. The further study should be conducted using larger sample size to determine the effect of body area of contusions.

Visual assessment was considered less reliable in the determination of the ageing of contusions[7 - 9]. Previous studies suggested that colorimetric and spectrophotometric methods should be used to measure the color changes of contusion because these methods produced objective information and gave more reliability and accuracy for the ageing of contusions[4, 10 - 14]. Colorimetry and spectrophotometry could produce the different color parameters and different patterns of reflectance wavelength between the new bruises and old bruises and these findings were useful in differentiation between the new and old bruises[4, 5, 10 - 14]. In addition, the old bruises in the longer time period came towards the reflectance wavelength pattern of normal skin[14]. Colorimetry and spectrophotometry were the reliable methods and could provide an objective information without inter-investigator bias[12, 13]. In addition, most of Thai people have darker skin color in categories II-V following the Fitzpatrick scale. Thus, the interpretation of colors of contusions may be more difficult. The previous study suggested that wound examination using colorimeter was useful for the dating of contusions in dark-skinned people[11]. However, the assessment using colorimeter and spectrophotometer requires availability of instrumentation and the applicability may be limited in Thailand. This study provided that visual assessment was still useful in evaluation of the aging of contusions in Thai population in general circumstances.

The minimum time that yellow color can be noticeable in Thai population was 18 hours after the time of injuries. The yellow started to be observed at the edge of wounds and became obviously noticeable in contusions at least at the day 3 - 5 particularly in small-sized contusions ($\leq$ 25 cm^2). Yellow color was the key finding for the dating of contusions and should be determined in the examination of contusions.

This study had some limitations. Visual assessment was performed by only the author because the author was the only one forensic physician in the hospital. Some factors which could have the influence on the color changes of contusions were not sufficiently diversified especially age groups and size of contusions. In addition, this study was the cross-sectional study that all of contusions were examined only at the visiting time and there was no follow-up of contusions.

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References

1. DiMaio VJ., DiMaio D. Forensic Pathology. 2nd ed. Boca Raton: CRC Press, 2001. Chapter 4: Blunt trauma wounds; p.91-116.
2. Langlois NE, Gresham GA. The ageing of bruises: a review and study of the colour changes with time. Forensic Sci Int. 1991;50(2):227-38.
3. McCausland IP, Dougherty R. Histological ageing of bruises in lambs and calves. Aust Vet J. 1978;54(11):525-7.
4. Scafide KR, Sheridan DJ, Campbell J, Deleon VB, Hayat MJ. Evaluating change in bruise colorimetry and the effect of subject characteristics over time. Forensic Sci Med Pathol. 2013;9(3):367-76.
5. Hughes VK, Ellis PS, Burt T, Langlois NE. The practical application of reflectance spectrophotometry for the demonstration of haemoglobin and its degradation in bruises. J Clin Pathol. 2004;57(4):355-9.
6. Langlois NE. The science behind the quest to determine the age of bruises-a review of the English language literature. Forensic Sci Med Pathol. 2007;3(4):241-51.
7. Grossman SE, Johnston A, Vanezis P, Perrett D. Can we assess the age of bruises? An attempt to develop an objective technique. Med Sci Law. 2011;51(3):170-6.
8. Hughes VK, Langlois NE. Use of reflectance spectrophotometry and colorimetry in a general linear model for the determination of the age of bruises. Forensic Sci Med Pathol. 2010;6(4): 275-81.
9. Pilling ML, Vanezis P, Perrett D, Johnston A. Visual assessment of the timing of bruising by forensic experts. J Forensic Leg Med. 2010;17(3):143-9.
10. Mimasaka S, Ohtani M, Kuroda N, Tsunenari S. Spectrophotometric evaluation of the age of bruises in children: measuring changes in bruise color as an indicator of child physical abuse. Tohoku J Exp Med. 2010;220(2):171-5.
11. Thavarajah D, Vanezis P, Perrett D. Assessment of bruise age on dark-skinned individuals using tristimulus colorimetry. Med Sci Law. 2012; 52(1):6-11.
12. Scafide KN, Sheridan DJ, Taylor LA, Hayat MJ. Reliability of tristimulus colourimetry in the assessment of cutaneous bruise colour. Injury. 2016;47(6):1258-63.
13. Trujillo O, Vanezis P, Cermignani M. Photometric assessment of skin colour and lightness using a tristimulus colorimeter: reliability of inter and intra-investigator observations in healthy adult volunteers. Forensic Sci Int. 1996;81(1):1-10.
14. Yajima Y, Funayama M. Spectrophotometric and tristimulus analysis of the colors of subcutaneous bleeding in living persons. Forensic Sci Int. 2006;156(2-3):131-7.

บทคัดย่อ

ความสัมพันธ์ระหว่างการเปลี่ยนแปลงสีของบาดแผลฟกช้ำกับระยะเวลาหลังได้รับบาดเจ็บในประชากรไทย

ดวงตา ดุลบุตร

กลุ่มงานนิติเวช โรงพยาบาลพระจอมเกล้า จังหวัดเพชรบุรี

บทนำ: การเปลี่ยนแปลงสีของบาดแผลฟกช้ำมีความสัมพันธ์กับระยะเวลาของการบาดเจ็บซึ่งมีความสำคัญในประเด็นทางกฎหมาย การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างการเปลี่ยนแปลงสีของบาดแผลฟกช้ำกับระยะเวลาหลังได้รับบาดเจ็บในประชากรไทย

วัสดุและวิธีการ : ศึกษาแบบภาคตัดขวางในบาดแผลฟกช้ำจำนวน ๔๐๐ บาดแผล จากผู้ป่วยไทยที่มีสุขภาพแข็งแรงจำนวน ๑๙๙ คน ที่ได้รับบาดเจ็บจากวัตถุของแข็งไม่มีคมและทราบระยะเวลาที่ได้รับบาดเจ็บที่แน่นอน สีของบาดแผลฟกช้ำได้รับการตรวจประเมินด้วยตาเปล่า ข้อมูลอื่นๆ ของผู้ป่วย ได้แก่ อายุ เพศ ขนาดบาดแผล ตำแหน่งบาดแผลบนร่างกาย อาวุธที่มากระทำ และระยะเวลาเกิดเหตุ ได้รับการบันทึก ข้อมูลทั้งหมดนำไปทำการวิเคราะห์ด้วยสถิติเชิงพรรณา, Kruskal-Wallis H Test, Mann-Whitney U test ร่วมกับ Bonferroni correction และ logistic regression

ผลการศึกษา : การเปลี่ยนแปลงสีของบาดแผลฟกช้ำมีความสัมพันธ์กับระยะเวลาหลังได้รับบาดเจ็บอย่างมีนัยสำคัญทางสถิติอย่างมาก ($p < 0.001$) ระยะเวลาเฉลี่ยที่ตรวจพบสีของบาดแผลฟกช้ำ ณ เวลาที่ผู้ป่วยมาพบแพทย์ ได้แก่ ตรวจพบบาดแผลฟกช้ำสีแดง สีม่วง สีเขียว และสีเหลือง ที่ ๒๔, ๔๘, ๖๐ และ ๘๔ ชั่วโมงตามลำดับ การตรวจพบสีเหลืองของบาดแผลฟกช้ำจะตรวจพบที่ระยะเวลาอย่างน้อย ๑๘ ชั่วโมง

วิจารณ์ และสรุปผลการศึกษา: การตรวจพบสีเหลืองเป็นปัจจัยสำคัญในการบอกระยะเวลาของการได้รับบาดเจ็บและควรได้รับการตรวจหาในการตรวจบาดแผลฟกช้ำ

คำสำคัญ: การเปลี่ยนแปลงสีของบาดแผลฟกช้ำ, อายุของบาดแผลฟกช้ำ, ระยะเวลาที่บาดเจ็บ, การตรวจประเมินด้วยตาเปล่า