Original Article

Grabcut Algorithm: A New Assessment of Burn Wound Area from Digital Images

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Background: As far as high technology is concerned, digital images of burn patients are widely used for wound documentation and specialist consultation. Wound area can be approximated from the photographs to aid further treatment for the patients. However, objective estimation of the wound areas in the digital images is still problematic.

Objective: To calculate sizes of burn wounds from digital images.

Materials and Methods: A computer application, Burn Percentage Calculation (BPC), was developed based on image segmentation algorithm called Grabcut. This image processing tool extracted an object of interest out of the background by using differences of pixel color and contrast in the image. The probabilistic models of being foreground and background were created to distinguish object pixels from the rest of the input image. The BPC application effectively extracted patient's body parts and burn wounds from the background. By mapping to Lund and Browder chart in the application, the wound area in a unit of percent total body surface area (%TBSA) was obtained. To validate the application, 10 plastic surgery residents were assigned to assess burn wound areas from 5 digital photographs using BPC application compared to conventional Lund and Browder chart.

Results: Forty-one digital images of burn patients were processed by BPC application. The application clearly separated the burn wounds from the background, and calculated wound areas in a unit of %TBSA. Burn sizes calculated by BPC application were not significantly different from those using conventional Lund and Browder diagram.

Conclusion: Grabcut algorithm is a powerful image segmentation tool which can sufficiently extract burn wounds from a 2D photograph. Our study demonstrated that sizes of burn wounds in the photographs were accurately calculated using an image segmentation-aided computer application. The resulting burn areas can guide individualized treatment for burned patients.

Keywords: Burn wound area; Digital image; Grabcut algorithm; Image segmentation; TBSA

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An assessment of total body surface area (TBSA) of burns is critical in the initial step of burn resuscitation[1,2]. It is imperative and also crucial for nutritional management to overcome the hypermetabolic burden[3,4]. Moreover, the area of burn is related to the prognosis during hospitalization and long-term complications[5,6]. However, accuracy of the burn area assessment still depends largely on the physician's experience and requires a time-consuming process. In the setting of emergency, this could lead to unreliable estimation as highlighted by inaccurate burn area assessment in the emergency department and referred cases[7-10]. Overestimation of the burn area contributes to excessive fluid intake causing complications such as pulmonary edema and compartment syndrome, while underestimation of the burn area provokes circulatory collapse and further end-organ failure[11-13].

Classical 2D diagrams have been used to assess the proportion of TBSA of burns, including the Rule of Nines[14,15] and Lund and Browder chart[16]. According to the Rule of Nines, the body is divided into parts depicting 9% TBSA for head and neck, 9% TBSA for each upper extremity, 18% TBSA for anterior trunk, 18% TBSA for posterior trunk, 18% TBSA for each lower extremity, and 1% for genitalia. It is inaccurate for children, and should be used in adults only. Although this method simplifies the assessment of the burn wounds, variation in the estimates and overestimation are frequently encountered, which fundamentally leads to over-resuscitation[15,17,18]. Lund and Browder diagram, on the other hand, gives more details on surface areas of each body part, and is applicable to adults and children. This method has been widely used as a standard calculation of %TBSA in burn units worldwide[19]. However, estimation of burn size by exploiting 2D diagrams is at risk of miscalculation in the process of transferring observation to the diagram. This human error is further emphasized in large and scattered burn

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wounds, and thus leads to improper resuscitation[18,20,21]. Software systems have been developed to aid %TBSA calculation including 2D[22,23] and 3D designs[24-26]. Since these approaches still rely on physician's observation, human error may occur during burn area assessment.

Recently, digital images have been used as a part of medical record and specialist consultation. Although burn wound areas can be roughly estimated from the photographs[23,27,28], effective and user-friendly software products are still underdeveloped. A computer program which utilizes 3D mapping from photographs of burned patients was invented to avoid subjective assessment of wound areas[29]. Nevertheless, this still employs complicated software and requires user's experience to achieve accurate and precise results.

2D digital photographs can be efficiently processed by using image editing tools. Grabcut is an image-editing algorithm which separates an object of interest from its respective background in the image[30]. This function is called image segmentation. To develop a computer application which provides %TBSA calculation from the digital photographs, we incorporated the Grabcut algorithm into the application called Burn Percentage Calculation (BPC). This function extracted burn wounds from the patient's image, and aided calculation of the wound area. This software serves as an innovative and convenient tool for burn area assessment and facilitates subsequent treatments.

This study aimed to 1) develop application software based on Grabcut algorithm to assess the burn wound area, and 2) compare burn wound areas calculated from the computer application to those calculated from traditional Lund and Browder chart.

Materials and Methods

Burned patients

Analysis of burn wound area was performed on 41 patients admitted to the Burn Unit, Ramathibodi Hospital, Mahidol University, Thailand, during January 2012 to May 2019. All subjects with documented digital images were included to the study. Ethical approval for this study was obtained from Human Research Ethics Unit, Faculty of Medicine, Ramathibodi Hospital, Thailand (MURA2018/174).

Burn area calculation from digital images

A computer application, Burn Percentage Calculation (BPC), for burn area assessment was developed based on an image segmentation algorithm called Grabcut (Figure 1). By drawing a box around the object of interest, this algorithm principally constructed 2 color distributions. The drawn box was used to construct the distribution of being foreground, while the rest of the input image was used to construct the distribution of being background. Then, they were refined in each iteration of the Grabcut till being converged. Therefore, a sharp separation between those parts could be achieved, and the target object was extracted. The BPC application was applied to extract a patient's body part and burn wounds in that body part from a digital image (Figure 2). The body part was extracted from its background as a result of pixel color difference. The extracted body part was registered to the application by the user according to Lund and Browder chart (Figure 1B). Thus, the area of the body in the digital image could be determined in a unit of %TBSA. The burn wounds in the body part were extracted in the same manner based on pixel color difference. A number

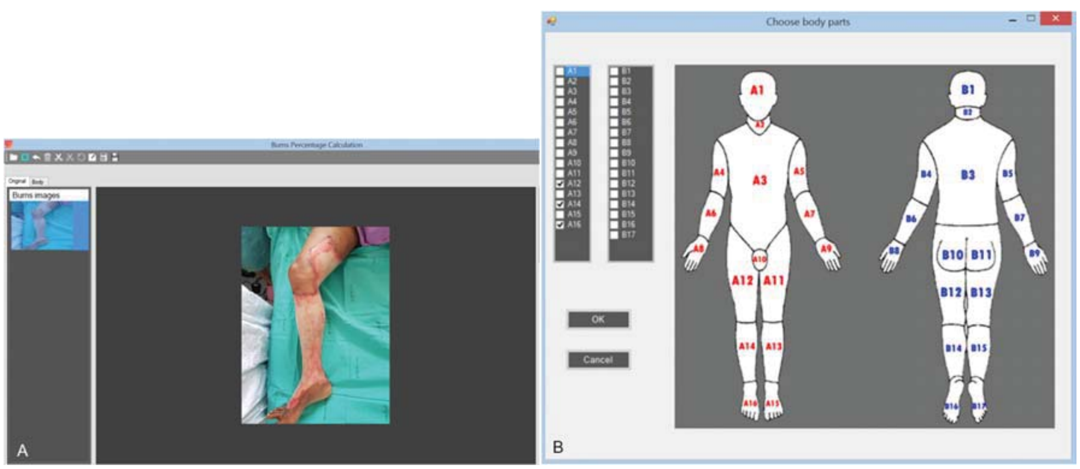

Figure 1. Software interface of Burn Percentage Calculation (BPC). A) A photograph of the patient's wound was imported. The image segmentation tools based on a Grabcut algorithm was shown in the upper panel. B) The body part in the image was mapped to a Lund and Browder diagram by the user to calculate the wound area in a unit of percent of total body surface area (%TBSA).

Figure 2. Image segmentation using Grabcut. A) An image of burn wounds at the right lower extremity was imported to the computer application. B) The lower extremity and the background were separated by means of color and contrast differences. Optimal results were obtained as demonstrated by sharp borders along the lower extremity. C) The burn wounds were extracted from the lower extremity by using the same software function.

of pixels in the body part and the burn wounds were calculated and presented as a ratio. Consequently, the area of the burn wounds, in a unit of %TBSA, was obtained from this ratio and the known %TBSA of the body part. All documented photographs of the burned patients were imported to the BPC application to analyze their respective %TBSA.

Study design

By using BPC application, 5 digital images of burned patients were calculated for %TBSA by 10 plastic surgery residents who had no computer background of this software. The residents were then assigned to estimate %TBSA separately using conventional Lund and Browder chart. Each of photographs of burn wounds was assessed by both methods and compared.

Statistical analysis

The difference of burn wound areas calculated from BPC application and conventional Lund and Browder chart was determined using two-tailed paired-sample student's t-test. The difference was considered significant when p-value <0.05. The statistical analyses were carried out by GraphPad Prism 8.0.2 (GraphPad Software, San Diego, CA).

Results

Based on image segmentation algorithm, a developed BPC program clearly extracted a body part and burn wounds from the background (Figure 2). The burn area calculated from the BPC program was 5.82%TBSA. All other digital images recruited in this study could also be

Table 1. Comparison of burn wound areas calculated by Burn Percentage Calculation (BPC) program and conventional Lund and Browder chart

Wound number	BPC (%TBSA)	Lund and Browder (%TBSA)	p-value
1	17.11±2.82	15.28±1.58	0.06
2	6.22±2.06	5.90±1.07	0.62
3	7.47±2.06	6.80±0.71	0.43
4	0.47±0.08	0.61±0.17	0.16
5	4.31±0.35	4.23±0.89	0.77

Data presented as mean±SD

calculated for burn area in a unit of %TBSA in the same manner.

Estimation of burn areas using the BPC application was compared to calculation via a conventional Lund and Browder chart. There was no significant difference between those 2 methods for burn area assessment (Table 1).

Discussion

Digital photography has been recently adopted for documentation of burned patients and also consultation between practitioners. Burn severity and wound area can be roughly evaluated from digital images. However, an objective method for burn wound calculation from the photographs is still limited. In this study, we applied an algorithm for image segmentation called Grabcut to create a computer application for burn area assessment. This application accurately estimated the wound areas of the burned patients, and could aid an individualized treatment plan such as fluid resuscitation, nutritional management, and wound care.

The accuracy of burn area estimation is deteriorated due to chaotic situation in the emergency room. Many studies reveal unreliable calculation of the burn size during referral and in the emergency room(7-10). Harish et al(9) demonstrated that more than half of patients were overestimated. This number is consistent with our unpublished data in which 31% of patients with major burns (>20 %TBSA) admitted to the Burn Unit in Ramathibodi Hospital was overestimated in burn sizes. Excessive resuscitation can adversely result in tissue edema which is a fundamental cause of pulmonary edema, cerebral edema, extremity and abdominal compartment syndrome(11-13). Underestimation, although occurred less frequently(7-10), leads to burn shock and organ failure. This situation hence leaves plenty of room for improvement of innovative devices specifically to aid burn size assessment.

Image segmentation is one of editing tools in digital image processing used for foreground/background splitting. The partition process is basically identification of boundaries of a target object based on difference in pixel characteristics around the object. Grabcut is a well-known algorithm which utilizes color and contrast information to differentiate an object in the image from its respective background(30). As compared to traditional image segmentation tools such as Magic Wand or Intelligent Scissors, Grabcut is far more effective to identify object-background borders. High quality results can be achieved with minimal user interaction. Therefore, we chose Grabcut as a core function to develop a computer application, which effectively extracted burn wounds out of a given digital image.

Photographic assessment of burn areas has been proven valid and reliable in the hands of experts(27,28). However, inexperienced practitioners often estimate the burn size inaccurately(28), which potentially leads to errors in further treatments. The basis of this problem involves translation of 2D wounds to a conventional diagram of Lund and Browder chart or the Rule of Nines. Moreover, the experience in the clinical evaluation of the burn wounds is also imperative. Therefore, objective measurement is required to ensure accuracy and consistent results. To date, no computer or mobile phone application has been developed based on burn size calculation of 2D digital images. BPC is the first program which employs an image segmentation tool to calculate the area of the burn wounds. Compared to other programs which depend upon transferring observation to the diagram(22-26), the BPC does not require this process since the picture of the wounds is analyzed directly by the function of image segmentation. This can increase accuracy and reduce errors between different assessors. Nonetheless, mapping of the body part to the Lund and Browder diagram is still mandatory. Accuracy is thus based on complete caption of the body part, which matches to the Lund and Browder diagram (Figure 1B).

Some limitations of BPC program have to be mentioned. Favorable results of the image segmentation necessitated a homogeneous background with a distinctive color compared to the skin. The background with colors closed to patients' skin tone resulted in contamination of the segmented body part, and subsequently an error in calculation. Similarly, burn wounds with close color to the skin also posed the same problem. An editing function, which offered addition or deletion of some pixels as shown in the program interface (Figure 1A), was hence introduced to cope with this problem. Thought requiring more time to complete the image segmentation process, accuracy of burn area calculation was accomplished.

The burn areas recruited in this study were rather small, ranging from 0.47 to 17.11 %TBSA. The underlying reason was that the digital images focused on the wounds in only particular part of the body, for example, the palmar surface of hand, the anterior trunk, the posterior leg. This was according to the image gallery of the patients. Moreover, the image of each body part facilitated mapping to the Lund and Browder diagram in the BPC program. Therefore, accurate estimation was easier achieved. To estimate the total burn size, gathering of all burn wounds in each part of the body was still required. It is also worth to mention that the burn areas calculated from 2D photographs might have a subtle difference compared to 3D models. This can occur when curvature of the body parts is analyzed as a flat surface.

Based on our study, BPC was comparable to the conventional Lund and Browder chart in estimation of burn wound areas. Even though the estimation was performed in small burn areas, summation of small areas wound be estimated close to the same in both methods.

In the present study, we developed a computer program to estimate burn sizes from digital images. Our future research aims to transfer this program to a smartphone version. Due to an already-installed camera in the smartphone, assessment of burn wound areas would be more convenient for the users.

Conclusion

Digital images are generally used during the process of patient referral and consultation. A computer program based on an image segmentation algorithm, Grabcut algorithm, was developed to calculate burn sizes from the digital photographs. As compared to a standard Lund and Browder chart, the program could accurately estimate the burn areas by an objective approach. Therefore, this program could assist physicians to calculate %TBSA for further proper resuscitation of the burned patients.

What is already known in this topic?

Accurate estimation of burn wound areas is fundamental to proper fluid resuscitation. Precise assessment of the burn sizes is still problematic for inexperience practitioners, especially in the emergency room. This problem leads to over- or under-resuscitation and subsequent complications.

What this study adds?

We developed a novel computer program for burn area calculation from digital images. This program was based on an image segmentation algorithm, called Grabcut, which effectively extracted a patient's body part and burn wounds from the background. Reliable calculation of the burn sizes in a unit of %TBSA was achieved using this computer program.

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Potential conflicts of interest

The authors declare no conflict of interest.

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