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Proposed Wound Healing Assessment using Digital Image Analysis

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ABSTRACT

Background: Wound healing is an important, yet complicated process in dermatology. Periodic assessment of wound healing is sometime neglected by the patients due to several factors such as time consuming, high treatment cost and inconvenience. Therefore, improper management on treatment of chronic wounds has always been a significant healthcare issue. **Objective:** The assessment of wound closure can be performed either by subjective clinical inspection or with a variety of methodologies anticipated to provide more objective data. The aim of this study is to design a convenient and affordable wound scanning system which provides objective and quantitative method to access the degree of wound healing. **Results:** This system is based on digital image analysis which can measure the shift from black or yellow necrosis to red granulation tissue and also the reduction in wound size. The data on progress of wound healing is clearly presented in both graph and pie chart while all the wound data would be stored automatically for future reference. **Conclusion:** This system provides a simple solution for monitoring wound healing process which can be used to access the healing trajectory and recommend continued or modified treatment. It also helps to enhance the communication between the patient and clinician on the assessment of wound healing process.

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INTRODUCTION

Wound healing can be divided into four phases (Mercandetti & Cohen, 2012; Gosain & DiPietro, 2004). In the haemostasis phase, the blood changes from a liquid into a gel (Yakhno *et al*., 2003). For our skin, both epidermis (outermost layer) and dermis (inner layer) are in equilibrium. These layers will form a protection barrier with the help of platelets which can avoid continuous bleeding or more precisely known as coagulation factor. Hence, it can protect the epidermis and dermis from external environment. In the inflammation phase, the platelets are accumulated to form a clot of fibrin which can block the bleeding blood vessels (Diegelmann & Evans, 2004). After that, the platelets will release cytokines to activate the stage of inflammation. The migration of white blood cells helps to remove the dead and dying cell. Once bleeding has stopped, the process of proliferation has been activated. The creation of new blood vessels (Angiogenesis) and the formation of granulation tissue occurred. For the final remodelling phase, the collagen is remodelled and rearranged more parallel to the wound (Orgill & Blanco, 2009).

Any skin injury is at risk of becoming infected. If a wound does not get a correct treatment, it may have the chance to get wound infection. Wound infection occurs when bacteria from the environment enters an open wound, for instance cut, scrape, bruise or puncture wound. If left untreated, the infection may spread to other parts of the body. This may result in the loss of function or amputation, and can be dangerous. Many factors can affect the rate of wound healing and this can be categorized into local factors and systemic factors (Guo & DiPietro, 2010). Local factors for example oxygenation and inflection are those directly affect the feature of the wound itself. Systemic factors, however, are the overall health or disease state of the individual that affecting the recovery speed of the patient. These include age, immunosuppression, sex hormones, stress, health habit, chronic disease, nutritional status, radiation therapy, and vascular insufficiencies (Guo & DiPietro, 2010; Edwards & Harding, 2004; Hess, 2011).

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Patient care technology has become more complicated without the extensive application of technology. Nurses found it difficult on their senses of sight, touch, smell, and hearing to monitor or control patients' wound status and to detect the changes (Barton, 2009; Hughes *et al*., 2008). Over time, it was replaced with technology designed to detect physical changes in patient conditions such as Fotoscan 3D. This development in advanced wound care was concentrated on wound treatments and therapies. An enormous amount of instruments to assess wound healing had also been introduced on the market to enhance communication among clinicians by defining a common language and standardizing assessment of wound characteristics (Pillen *et al*., 2009).

A wound scanner is proven necessary by the clinicians in the wound healing. However, this technology might have not benefited the patients in wound caring due to several factors such as time consuming, high treatment cost and inconvenience. Some of the patients might have wrong perception in accessing their wound healing and causes a delay in treatment. Moreover, there was no literature review which shows the invention of two-dimensional (2D) wound scanner that can function easily as portable household wound scanner. This motivates the research to design a digital image analysis system which can measure the shift from black or yellow necrosis to red granulation tissue and also the reduction in wound size. This system would provide objective evaluation data which is crucial in the epithelialization phase that the time required for complete wound healing, or the reduction in wound size within a certain time limit are the primary concerns.

Reseacrh Methodology:

A wound image is obtained by positioning a webcam and a light source. All variables such as height, distance, angle and light intensity are recorded for calibration purpose. The software is developed using MATLAB Graphical User Interface (GUI) and the flow of the algorithm is as shown in Figure 1.

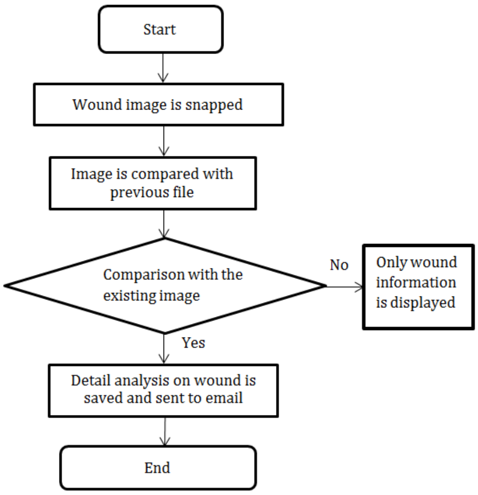

Fig. 1: Flow Chart of the developed Software.

At the beginning, the user of the wound scanner will click the start webcam button to trigger the wound scanning process. For the first time, user is required to snap an image on the wound by activating a webcam also activate of MATLAB to snapshot the image and only basic wound information (surface area and color) will be displayed to the user. For existing user, however, they will be directly prompt to the image capturing. The image can be projected on the image stored the day before to show comparisons. All the data would be displayed in graph pattern. The graph will give a clear image and illustration to the user on their percentage of healing. All these data would be saved automatically.

Digital Image Processing for Wound Scanning:

The fundamental steps in digital image processing (DIP) of the captured wound are as follow:

I.Image Acquisition:

The first step is digital data or wound image acquisition which involves pre-processing, for example scaling. The pre-processing can lead to the wound image improvement.

II.Image Enhancement:

This step is crucial to bring out the detail that is obscured or highlight certain features of interest in a wound image, for instance changing brightness and contrast of the image (Russ, 2011).

III.Color Image Processing:

This helps to improve the significance in the use of digital images which include colour modelling and processing in a digital domain.

IV.Image Restoration:

Image restoration is sometime performed to upgrade the appearance of a wound image. However, image restoration is objective while enhancement is subjective. This means that the restoration technique tends to be based on mathematical or probabilistic models of wound image degradation.

V.Image Compression:

This is to decrease the storage required to save a wound image or the bandwidth to transmit it. It is necessary to compress the data as the image file will be sent to the user via email for future reference.

VI. Image Segmentation:

The function of the segmentation is the process of portioning wound image into its constituent parts or objects (Sonka *et al*., 2014). Normally, autonomous segmentation is one of the most difficult tasks in DIP. A rugged segmentation procedure makes the process difficult to bring toward the successful solution of imaging that require objects to be identified individually.

VII.Representation Description:

This step follows the output of segmentation stage, which is raw pixel data, constituting either the boundary of a region or all the points in the region itself. Representation is the only solution for transforming the raw data into a suitable form for subsequent computer processing. Description deals with extracting attributes that results in some quantitative information of interest and is basic for differentiating one class of objects from another.

VIII.Classification Recognition:

This is the process that assigns a label, such as "vehicle" to an object based on its descriptors. Individual objects in a wound image will be classified and this relies on matching, learning or pattern recognition algorithms using appearance based or feature-based technique.

Wound Assessment:

Detail analysis of wound healing status is vital for monitoring and evaluation of progress in an individual patient. The two primary outcome parameters from this system are the assessment of wound size and wound colour.

The outline of the wound margin is traced and the surface area is calculated by the system developed. The wound healing rate is mainly quantified by the rate of change of the wound's surface area. A measurement of the wound surface area can identify if the wound is increasing or decreasing in size. Tissue damage can spread undermining the skin and the devitalized tissue being present which cannot be seen. Regular wound measurements using the program developed should be taken at predetermined dates (Toner, 2007).

Red, Green and Blue (RGB) histogram distribution of pixel values from wound color images is being used in the new tissue classification protocol. This is because almost all the colours can be reconstructed by using a combination of these three base colours. These RGB colours define a 3-dimensional colour space that can be used to describe all the colours. The colour of wound will be used to define the stage of wound healing process in this project. It is classified into four classes; class 1 is black in colour, it contains necrotic (dead) tissue; class 2 is yellow in colour, it consists necrosis and fibrin; in class 3, the red granulation tissue appeared and it is indicative of healing, and the final class is the present of pink epithelialization tissue which indicating that healing is almost complete. Healthy granulation tissue is pink in colour so it is an indicator of recovery. Unhealthy granulation is dark red in colour, often bleeds on contact, and may indicate the presence of wound infection. Excess granulation or over granulation may also be associated with infection or non-healing wounds. This often responds to simple cautery with silver nitrate or with topically applied steroid preparations. For the chronic wound, it may be covered by white or yellow shiny fibrous tissue. This tissue is avascular, and healing will continue only when it is removed.

Wound healing percentage is an important issue, in which modern imaging techniques have not yet given a definitive answer. The wound healing percentage in this system is mainly quantified by the percentage of change of the wound's surface area. In additional, it strongly depends on the colour change of the wound.

Proposed Software:

The GUI developed is as shown in Figure 2. In general, it is divided into three parts and each part consists of different function. For the first part, it is on image loading; second part is the image analysis while the last part is the display of assessment results. The webcam image will be revealed in axes1 and the image captured from webcam is showed in axes2. After the wound part is cropped out from the captured image, it will be shown in axes 4. The previous image will be loaded and shown in axes3.

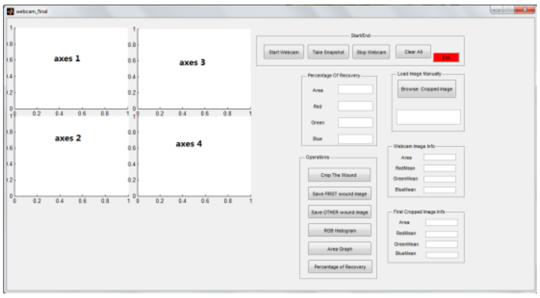

Fig. 2: GUI Interface of the developed Software.

One of the main outputs from this system is graph plotting which including bar graph and pie chart. User can check the status of the wound based on the red, green and blue (RGB) bar graph and area comparison pie chart. The RGB image was split into the three colour channels. The software can measure the intensity of RGB in the mask. Completed information is listed inside the bar graph and pie chart to clarify all the users. In additional, user can know the percentage of recovery of the wound images according to area and RGB mean intensity. A message box will be shown to notify the user whether the wound is in well condition or not.

Case Study:

This testing is performed using the webcam to capture a first day scratch image which is identified as Sample 1. The location of injured part is on the arm. The part of the wound area is cropped and it is saved as the first wound image. The information of the cropped Sample 1 which included area and mean intensity of colour is saved. The image filename is according to the saved date and time. The first image of Sample1 cannot be compared with other as there is no previous reference image. A 'no webcam' logo is showed when the webcam is turned off. The appearance of the software as seen by the user is as shown in Figure 3.

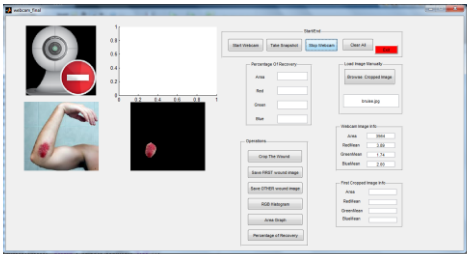

Fig. 3: Interface of Software Testing on Sample 1 on First Day.

On the fifth day, a new scratch image is captured. The information and image are saved automatically. Next, the first day wound image can be browsed and showed in the axes above. Hence, both wound images can be used to compare based on their features. At the same time, this software can calculate the percentage recovery of the wound based on the area and RGB mean intensity. All the comparison results are showed in the text boxes. The percentage change of the wound size is displayed in a message box. The appearance of the software as seen by the user is as shown in Figure 4.

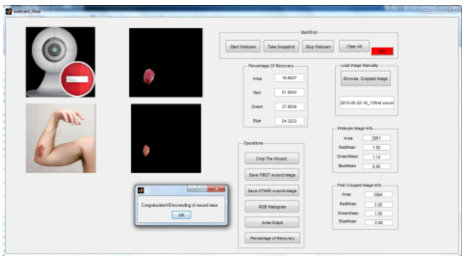

Fig. 4: Interface of Software Testing on Sample 1 on Fifth Day.

The results can be compared clearly in two graphs. RGB histogram is showed using bar chart and the area graph is displayed as pie chart. Therefore, the condition of both wound images is clearly displayed in this software. User can compare and record the wound image anytime. Figure 5 shows the output of the first case study. From the area pie chart, both areas are slightly different from each other. On the contrary, both of the red mean intensities are distinct greatly. The information as shown in Table I will be saved in the database for future reference.

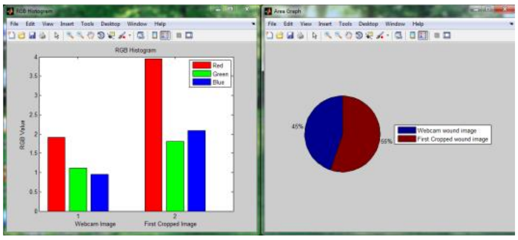

Fig. 5: Output Parameters of the Case Study.

Table I: Data of Wound Image Analysis for Sample 1

Feature	Sample1	
	First Day	Fifth Day
Area	3564.00	2901.00
Red Mean Intensity	3.95	1.92
Green Mean Intensity	1.80	1.12
Blue Mean Intensity	2.08	0.95
Percentage Recovery based on Area (%)	18.60	
Percentage Recovery based on Red Mean Intensity (%)	51.50	
Percentage Recovery based on Green Mean Intensity (%)	37.88	
Percentage Recovery based on Blue Mean Intensity (%)	54.32	

Conclusion:

In wound analysis, the wound tissue types are divided into black necrotic eschar, yellow necrosis or slough, red granulation tissue, and a fourth class that contained the undesired reflections from glossy parts of the wound which are almost entirely white. The existence of these tissues is represented in the RGB bar chart.

Human observations are subjective, imprecise and inconsistence. This digital image analysis system, therefore, offers an objective method for quantifying the wound healing trajectory.

Future Work:

The digital image analysis system developed must be evaluated with double-blind or observer blind trials and multicentre if necessary. More databases of wound data would be included as data reference. This is crucial to enhance the accuracy and precision of this system.

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