Foot and Ankle Surgery 25 (2019) 47–50

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Non-contact ulcer area calculation system for neuropathic foot ulcer

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ARTICLE INFO

Article history:
Received 13 September 2016
Received in revised form 26 June 2017
Accepted 28 July 2017

Keywords:
Neuropathic foot ulcer
Leprosy
MATLAB
Graphical user interface (GUI)

ABSTRACT

Background: Around 125,785 new cases in year 2013–14 of leprosy were detected in India as per WHO report on leprosy in September 2015 which accounts to approximately 62% of the total new cases. Anaesthetic foot caused by leprosy leads to uneven loading of foot leading to ulcer in approximately 20% of the cases. Much efforts have gone in identifying newer techniques to efficiently monitor the progress of ulcer healing. Current techniques followed in measuring the size of ulcers, have not been found to be so accurate but are still is followed by clinicians across the globe. Quantification of prognosis of the condition would be required to understand the efficacy of current treatment methods and plan for further treatment. This study aims at developing a non contact technique to precisely measure the size of ulcer in patients affected by leprosy.
Methods: Using MATLAB software, GUI was designed to process the acquired ulcer image by segmenting and calculating the pixel area of the image. The image was further converted to a standard measurement using a reference object. The developed technique was tested on 16 ulcer images acquired from 10 leprosy patients with plantar ulcers. Statistical analysis was done using MedCalc analysis software to find the reliability of the system.
Results: The analysis showed a very high correlation coefficient ($r = 0.9882$) between the ulcer area measurements done using traditional technique and the newly developed technique, The reliability of the newly developed technique was significant with a significance level of 99.9%.
Conclusions: The designed non-contact ulcer area calculating system using MATLAB is found to be a reliable system in calculating the size of ulcers. The technique would help clinicians have a reliable tool to monitor the progress of ulcer healing and help modify the treatment protocol if needed.

1. Introduction

A large number of new cases of leprosy are detected across the globe every, of which India alone contributed to about 62% [1]; of which many are diagnosed with grade II impairments. One of the key goals of the global leprosy strategy for 2016–2020 is to bring down the grade "2" WHO disability in newly diagnosed leprosy affected patients [2]. WHO Grade "2" disability in leprosy occurs primarily due to the neglect of the early impairments. The neglect of anaesthesia in the palm and sole which are the primary impairments in leprosy, leads to secondary impairments like the palmar and plantar ulcers in the palm and the soles. The ulcers which are caused due to the neglect of plantar anaesthesia leads to further dehabilitation and exclusion of the patient from the family and community. Approximately about 20% of people affected by leprosy develop plantar ulcers either due to neglect or lack of self-care [3]. Due to lack of healthcare facilities in rural areas, the patients need to travel long distances to get the regular treatment courses. For patients with foot ulcers it is very difficult to travel long distances. Also the need to heal the ulcer becomes a least priority for a patient from a low socio economic status when their other daily needs are not met. These reason lead to a lack of motivation for the patients to visit clinics for continuous treatment and care.

Several techniques had been tried and proposed for healing and the management of plantar ulcers in leprosy affected patients. Some of the most common interventions that are carried out to heal ulcers are through [3], surgical intervention, plaster casts [4], use of offloading foot insoles [5], and provision of appropriate footwear [6]. Periodic monitoring and follow up are essential to check the efficacy of treatment [7]. The challenge becomes enormous for clinicians and health workers working in developing

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http://dx.doi.org/10.1016/j.fas.2017.07.1125
1268-7731/

countries with the lack of motivation among the leprosy affected patients from low socio economic status to heal their plantar ulcers.

The most commonly used technique for ulcer area is to measure length and width of an ulcer and multiplying it with a factor of 0.785 [8]. The other techniques that are used include wound tracing on transparent material and calculating the area [9], Kundin gauge [10], and scaled photographs [11]. The reliability of these techniques often depends and varies on the expertise of the technicians and so is not commonly used in leprosy affected patients. The technique often requires contact with the ulcer area and so it has not been recommended by clinician's and health workers. Digital measurement techniques Visitrak [12] Digital Planimetry [13] various segmentation techniques [14–16] have been developed to overcome the challenges. These techniques often need image processing techniques which many times becomes a challenge in remote areas in many developing countries. The paper presents a unique non-contact ulcer area measurement system which can help the clinicians in tracking the changes in ulcer size and to decide further course of treatment. The paper focuses on developing a new non-contact ulcer area measurement system using image processing technique which can help in acquiring of ulcer area data accurately.

2. Non contact ulcer area measurement system

The Non-contact ulcer area measurement system consists of a MATLAB based graphical user interface (GUI) which has been developed to calculate the ulcer size from an image. The technique involves two processes, acquiring the foot contour, and acquiring the ulcer area in the foot. The process of measuring foot contours using MATLAB has been dealt by Shah et. al. [17]. The measurement of ulcer area is based on a MATLAB program with a GUI which has visualization features like zoom, contrast change, ulcer segmentation and area calculation functionalities.

The workflow of the system is shown in Fig. 1. The system involves uploading the image of foot with plantar ulcer for which the area is to be calculated in the designed GUI shown in Fig. 2. For better visualization the user could zoom the sight of ulcer using "Zoom" option of the GUI. Ulcer segmentation button leads to stepwise segmentation of the image to detect the ulcer region. The system uses active contour segmentation technique to process the ulcer image that had been acquired as an image. Active contour based technique helps in achieving a better segmentation of the image. The use of post processing technique through the morphological operator reduces the error while calculating the area of ulcers. After the segmentation process the ulcer boundary is

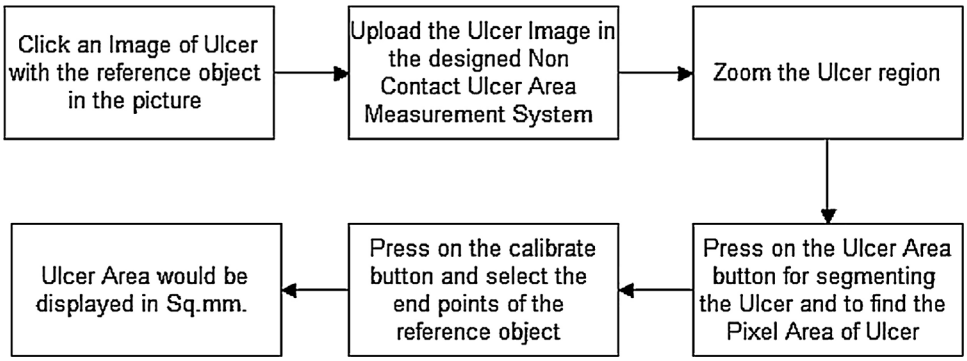

Fig. 1. Workflow of the non-contact ulcer area measurement system.

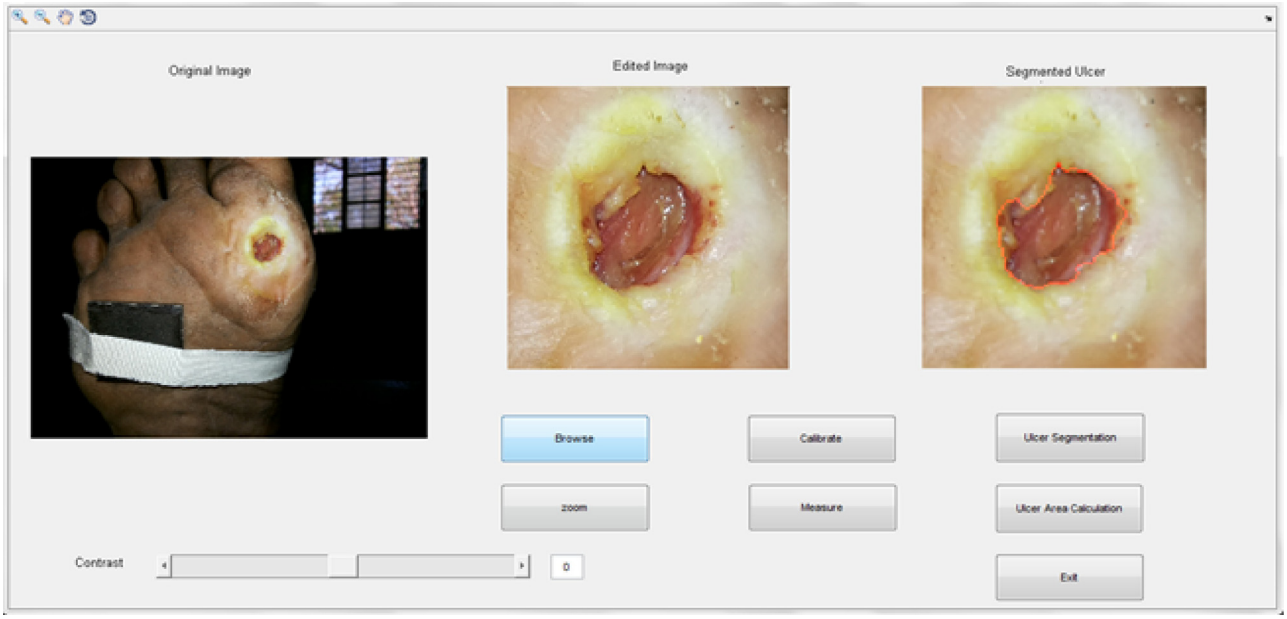

Fig. 2. Non-contact ulcer area measurement system.

bordered as shown in Fig. 2. The program then calculates the pixelarea of the ulcer and its circumference. The calibration option helps the user convert the pixels to millimetres, the user could use a known sterile object to get the conversion from. This is further used to calculate the ulcer area and circumference in standard units of square millimetres (Sq.mm) and millimetres (mm) respectively. The results acquired through this technique could help clinician in prognosis and checking the effectiveness of treatment.

3. Methodology

3.1. Subjects

Ten leprosy affected subjects with 16 plantar ulcers were evaluated for the study. All the ulcers were located in different regions in the plantar aspect of the foot. Ethical approval was obtained from VIT University Institutional Ethical Committee for Studies on Human Subject.

3.2. Experimental procedure

All the subjects were made to sit comfortably with their ulcerated foot kept on a support. For calibration purpose an iron square sheet (30 mm × 30 mm) was placed near the site of ulcer. Care was taken that the iron piece did not touch the ulcer. A digital photograph of the foot ulcer along with the reference iron square was clicked using a 5Mega Pixel Mobile phone camera. The images were further uploaded on the MATLAB based ulcer area measurement system for further calculation of ulcer area. Manual readings of ulcers area were done by using the traditional method of measuring the length and the width of the ulcer and multiplying by a standard constant, by the clinician. The measurements were also simultaneously taken for the ulcers using the manual method that is being followed for measuring ulcers in a leprosy affected patient.

3.3. Statistical analysis

Statistical analysis was done to assess the reliability and accuracy of the proposed system. "MedCalc" software was used for statistical analysis. Correlation analysis was carried out to calculate the pearson correlation coefficient of the proposed system with the traditional system to find its reliability.

4. Result

The size of the ulcers measured through the traditional technique were compared with that of the size measured through the new image processing technique. All the 16 ulcer sites of the leprosy affected patients were compared individually. The graph in Fig. 3 shows the correlation analysis of the ulcer area calculated using manual and proposed non-contact ulcer area measurement system. The pearson's correlation coefficient value was calculated as $r = 0.9882$ with the level of significance being ($p < 0.0001$). The mean error found to be was 12.62211 sq mm.

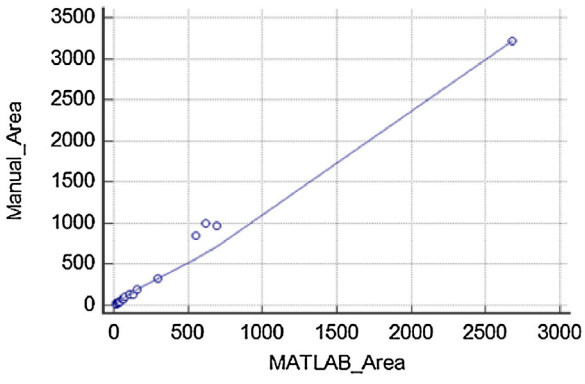

Fig. 3. Correlation analysis for ulcer area calculated using manual and proposed non-contact ulcer area measurement system.

5. Discussion

The non-healing plantar ulcers in leprosy has been a major contributing factor to the economic and social losses that the patient incur [18]. The efforts of the clinicians and the health care workers in healing ulcers become futile if the patients are not willing to visit the health care facility for periodic follow up. With the lack of follow up the clinicians fail to periodically record the progress of their treatment. In the present study the non-contact ulcer area measurement system developed was used in measuring the ulcer area on patients with neuropathic foot plantar ulcers. Accuracy of measuring the size of ulcers have been unreliable in many of the earlier techniques that has been followed. The morphological operators when effectively used during the post processing period would even help measure the depth of the ulcer. The processing of the image in the present system varies and is delayed. Single active contour based image segmentation could be the one of the key factor for the delay in the processing of the images. The proposed system of digital image processing technique increases the efficiency and accuracy in calculating the ulcer area in comparison to the other manual methods.

The study which were done on the ulcers showed a high correlation coefficient ($r = 0.9882$) establishing that the ulcer area calculation through the image processing method is similar to that of the manual calculation method that is presently used. The reliability and the accuracy of measuring the ulcers through the manual method would help clinicians in managing leprosy in a better way.

The non-contact technique of the proposed method can be effectively used in the community without compromising on the sterile techniques that is required for the management of ulcers. With the image of the ulcer being the only minimal requirement for measuring the size of the ulcers, the patient can get the maximal benefits of the experts from the comfort of their home. The technique would also help the remotely located leprosy affected patients in healing their ulcers.

The system in future would be modified to compare the ulcer images of an individual patient be taken periodically and to provide a systematic summary of the ulcer healing process.

6. Conclusion

The present study provides a unique technique to measure the ulcer area using non-contact technique, which could help the clinician in monitoring the ulcer in an efficient way. The method also helps the clinicians in following the prognosis and in studying the healing process of the ulcer. The correlation of the results suggest that the proposed system is more reliable and accurate than the existing system. The proposed ulcer area calculation system is a non-contact system using only the images of the ulcer is a cost effective method to prevent the worsening of the impairment in leprosy.

Conflict of interest

The authors have no conflict of interest.

Acknowledgements

Author would like to thank the management of VIT University and Schieffelin Institute of Health-Research and Leprosy Centre,

Karigiri for providing the required resources and supporting the work.

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