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Characterization of burns using hyperspectral imaging technique – A preliminary study

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ABSTRACT

Surgical burn treatment depends on accurate estimation of burn depth. Many methods have been used to asses burns, but none has gained wide acceptance. Hyperspectral imaging technique has recently entered the medical research field with encouraging results. In this paper we present a preliminary study (case presentation) that aims to point out the value of this optical method in burn wound characterization and to set up future lines of investigation. A hyperspectral image of a leg and foot with partial thickness burns was obtained in the fifth postburn day. The image was analyzed using linear spectral unmixing model as a tool for mapping the investigated areas. The article gives details on the mathematical bases of the interpretation model and correlations with clinical examination pointing out the advantages of hyperspectral imaging technique. While the results were encouraging, further more extended and better founded studies are being prepared before recognizing hyperspectral imaging technique as an applicable method of burn wound assessment.

1. Introduction

Burn is one of the most important and complex trauma and affects a large percentage of the general population. One of the main goals in assessing a burn is to determine if it will heal spontaneously within 3–4 weeks or it will need skin grafting. Many methods have been tested (laser Doppler imaging [1], indocyanine green video angiography [2], near infrared spectroscopy [3], microscopic imaging techniques including capillary microscopy [4], orthogonal polarization spectral imaging [5] and reflectance-mode confocal microscopy [6], thermography [7], etc.), but pathological examination is still considered the golden standard. Unfortunately, even pathology has its downfalls, starting with being an invasive method and ending with interpretation issues [8].

A possible new tool in the area of skin injuries could be the hyperspectral imaging technique (HSI) based on its ability to simultaneously provide both spectral and spatial information with high resolution. The spectral information contained in a hyperspectral image allows the characterization of different

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types of biological tissue and the spatial information provides the morphological information of tissues.

Hyperspectral imaging technique (HSI) consists in recording a series of images of biological tissue in many adjacent narrow spectral bands and reconstruction of reflectance spectrum for every pixel of the image [9]. The set of images thus obtained (typically tens or hundreds of images) is called the hypercube. The advantage of this technique is that the acquisition of the spectrum for each image pixel over a selected wavelength interval makes possible remote identification of biological tissues or tissue constituents through their characteristic reflectance spectrum (spectral signature). In addition, the relative concentration of these constitutive elements may be also determined by statistical techniques to the problem of unmixing pixel spectra.

The HSI has been widely applied until now in various fields such as earth observation, geology, vegetation sciences, soil sciences, hydrology, food processing, environment, forensic science, etc. In the medical field HSI is a rather new optical method that is beginning to gain medical applications in fields like peripheral vascular disease evaluation, diabetic foot ulcer prognosis, tumor extent, etc. [10]. Some researchers have reported encouraging results. Chin et al. [11] and Johnson et al. [12] showed that HSI technique can be a reliable tool in assessing and classifying peripheral vascular disease or even monitoring revascularized limbs. Eisenbeiss et al. [13] reported also that the multispectral imaging can be considered as an objective method for the determination of burn depth. The authors revealed that this method provides useful information for treatment guidelines. Khaodhiar et al. [14] have highlighted the ability of HSI technique to quantify tissue oxygenation (hemoglobin and deoxyhemoglobin) and predict ulcer formation and healing diabetic foot. Some studies, published in the last decade, reported promising results in detecting gastric cancer [15,16], tongue cancer [17], and melanoma [18] using HSI technique.

The aim of this paper was to explore the applicability of HSI technique and a linear unmixing model as tools for mapping injured tissue in burned skin. The main issues addressed are as follows: (a) selecting types of tissue present in the burned skin (called endmembers) using principal component analysis (PCA); (b) exploring the spectral feature of these endmembers; (c) performing spectral unmixing for mapping bad tissues abundances in a pixel; (d) testing the applicability of the HSI technique for characterization of burns; (e) hyperspectral image analysis aiming at supporting quantitative diagnosis; (f) establishing future lines of investigation.

2. Patients and methods

2.1. Patients

A 60 year old woman with burns on 8% total body surface area (TBSA), admitted in the hospital 5 days before, was selected for this preliminary study. Approval for the investigations had been obtained from the Ethics Committee. We have chosen this subject because she had a 3% burn on the leg that had the clinical appearance of an intermediate burn, the location making the examination easy and we could test at the same time a large portion of healthy skin around the burn. The moment was chosen so that the wound had already passed through changes in depth in the first days, and any infection could be out ruled. The wound healed spontaneously in three and a half weeks, proving that it was indeed an intermediate burn. On the dorsum of the foot, the patient shows a more superficial burn (superficial partial thickness).

The examination took place in the room where the patient had her dressings changed daily. Local treatment consisted in debridement on admission, followed by application of silver sulphadiazine 1% (Dermazin®) under sterile dressings. After removing the cream and the wound exudates with saline, povidone–iodine 10% was applied on the healthy skin around the wounds and a digital picture was taken followed by the examination with HSI technique. On clinical examination, the wound showed both white and red areas intermingled on the whole examined surface, giving a rather uniform appearance. On light touch, the wound showed normal sensibility. There were no signs of inflammation in the surrounding unburned skin. Moderate edema was present in the ankle area close to the wound. The dorsum pedis burn showed pinkish dermis sensitive to light touch suggestive of a superficial dermal burn.

2.2. Hyperspectral imaging system

The line-scan hyperspectral imaging system used to acquire hyperspectral images of burns consists of an imaging spectrograph (ImSpector V8E, Specim, Oulu, Finland), a DX4 CCD camera (Kappa, Gleichen, Germany), an illumination unit containing two 300 W halogen display optic lamps (OSRAM, Germany) equipped with diffusion filters (Kaiser Fototechnik GmbH & Co.KG, Buchen, Germany) so that the illumination to be uniformly on the investigated area, a tripod and, a computer running specific softwares (SpectralDAQ, Specim, Oulu, Finland; ENVI software, Exelis Visual Information Solutions, Italy, time limited key) for acquisition, processing and analysis of the resulting image data (Fig. 1). The hyperspectral camera acquires 346 spectral bands from 400 to 1000 nm at 1.73 nm intervals at a speed of 11 lines per

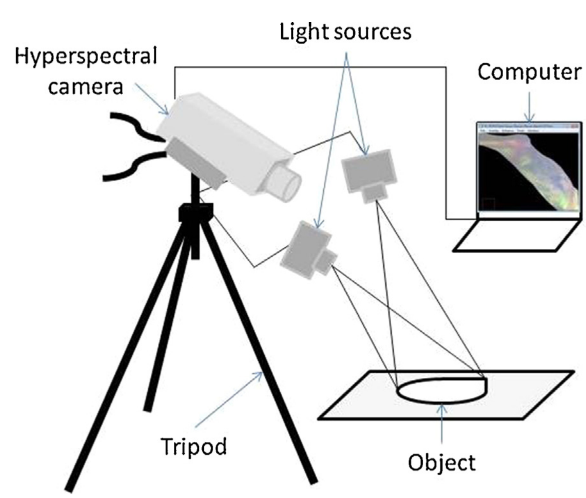

Fig. 1 – The experimental setup for hyperspectral imaging of the burn wounds.