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A simple algebraic model to predict burn depth and injury[☆]

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ABSTRACT

A numerical model has been used to predict the depth of burns which result when human skin is exposed to high-temperature water. The model included a multi-layer facsimile of skin tissue (epidermal, dermal, subcutaneous fat, and muscle). The investigation covered a wide range of temperatures and exposure times. For lower temperatures and shorter exposure times, the model correctly predicts minimal burn injury while for higher temperatures and longer exposure durations, the burn extent is found to extend throughout the epidermal and dermal layers. Based on the results from the simulations, a simple approximating function was developed that allows medical practitioners to quickly and accurately determine the depth of injury. This tool will improve prognosis and enable more appropriate care to be delivered to patients. The approximating function was compared with data from the literature and was found to be in good agreement.

1. Introduction

Skin burns are a very common type of injury that affects large and diverse populations; the injury sustained from a burn can vary from minor to life threatening. For severe burns, accurate identification of the injury extent is important for the selection of appropriate care. One major difficulty is that most commonly, burns are characterized by visual observation which is subject to a high degree of uncertainty [1–5].

This work presents a very simple model which can be used by clinicians to predict the depth of burn injury without relying solely upon visual observation. The model is based on a set of results which were obtained from a detailed simulation of heat transfer through a four-layer tissue model [6,7]. This approach was shown to provide highly accurate results that were compared with clinical data and shown to be in excellent agreement. On the other hand, the technique presented in [6,7] and similar efforts [8] require computational resources beyond that found in a care setting.

Despite this limitation, it is possible to provide a simplified approximation of the results of [6,7] in a form that is simple to use and sufficiently accurate to advance the standard of care. The purpose of this presentation is to present such a simplified model and to compare its results with results obtained from clinical situations.

2. The simplified model

The basis for the simplified model is a set of calculated burn depths which resulted when a four-layer human skin model was subjected to scalding temperatures that ranged from 60–90 °C. The thicknesses of the tissue layers are noted in Table 1.

The durations of exposure varied from 7.5 s to 110 s. It was found that, as expected, the depth of burn injury depended strongly on both the exposure temperature and the duration [6,7]. A summary of the key results is shown in Table 2. There, 16 individual cases are presented which show the wide range of exposure temperatures and durations and their associated injury depths.

Burns were classified into one of four categories: (1) *Superficial* (S) burns which are burns confined to the epidermal layer and are characterized by slight edema with quick healing; (2) *Superficial partial-thickness* (SP) burns extend into the outer region of the dermal layer and result in moderate edema but little, if any, scarring (less than 1 mm burn depth); (3) *Deep partial-thickness* (DP) burns extend well into the dermal layer and are slow to heal (1 mm or greater burn depth), leading to hypertrophic scarring; and (4) *full-thickness* (FT) burns which extend through the entire dermis and require skin grafting as treatment (burn depths greater than 2 mm) [1,11,12]. A summary of the resulting burn classifications for the 16 cases are displayed in Table 3. From the table, it is seen that none of the 16 cases resulted in superficial burns that are confined to the epidermal layer.

The numerical model was a finite-difference expression of the Pennes bioheat equation [13] and injuries values were taken from Henriques and Moritz [14]. Details of the numerical calculations and tissue properties are provided in [6,7].

If the effort presented here is to be useful for practicing clinicians, it must be presented in a manner that can allow for quick and accurate

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