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Thermal imaging and modelling of burned skin

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1. Introduction

Proper evaluation of the surface and the depth of a burn wound, especially in the case of a severe burn, enables an appropriate choice of treatment to be made. This choice decides subsequently about the success of the entire medical treatment. Clinical assessment is currently the most frequently applied method in burn depth evaluation. Unfortunately the use of this method results in a high number of false diagnoses. Numerous other methods have therefore been introduced but none has been fully accepted by clinicians treating burns. The aim of this paper is to discuss properties of normal and burned skin from the point of view of active dynamic thermal imaging (ADT) applications in burn depth diagnostics. In the following paragraph we discuss physiology of normal and burned skin in terms of possible reaction on thermal phenomena, both – heating and cooling. In the experimental part reactions of normal and burn tissues to the cold stress are shown.

2. Material and method

We performed ADT experiments using the procedure and configuration of instrumentation described in our former publications [1, 2, 3, 4, 5, 6, 7], based on IR imaging of thermal transient processes after external pulse excitation. Using equipment: a high quality IR camera Flir SC 3000, quantum well FPA LW of 25 mK resolution and 60 Hz acquisition rate for capturing of series of thermal images during and after cooling and a cryotherapy device using CO_2 vapour, with specially designed applicator to get uniform cooling of tested skin of animals were applied – Fig.1.

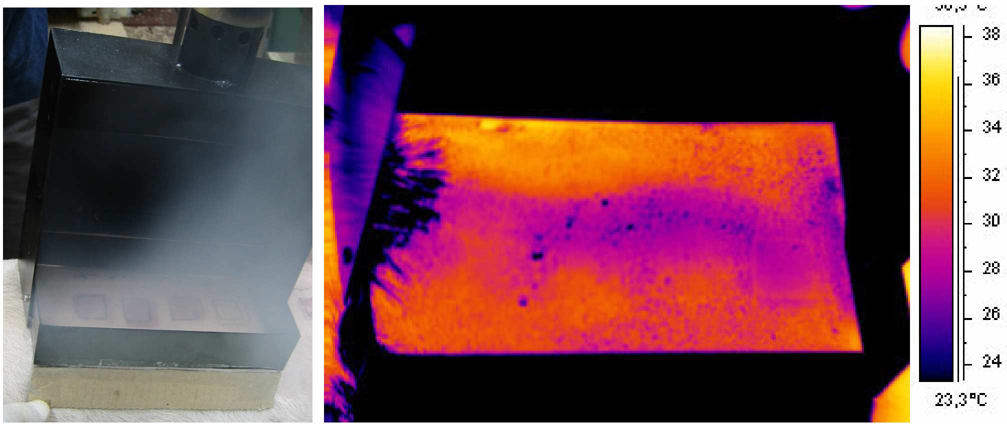

***Fig. 1.** a) Applicator used for CO_2 cooling procedure, b) thermal image taken at the end of the cooling phase*

Interpretation of IR investigations on living tissue requires formation of stable and repeatable thermal images representing specific type of tissue damage – in our case burns of different depths. This is even more important when we try to calculate some model based quantitative parameters. In order to produce a uniform contact burn, it is important to choose a large enough animal whose flat surfaces, e.g., the paravertebral area or the ribs, permit creation of uniform burns with a flat bar. This ensures application of a constant and uniform pressure to all areas of the burn. Therefore, we used pigs for experiments as those animals are not only big enough but also additionally are of the closest to human skin.

The thermal investigation was performed as follows: static thermography measurements for indicating differences in temperature distribution for burn wounds of different depths; active cooling phase by cryotherapy CO_2 device lasting several seconds, recording thermal sequence of the thermal transient processes during cooling and recovery phase. Basing on recorded thermal sequences the parametric images of thermal time constants were calculated.

3. Results

It is clearly seen that increasing the time of cooling results in stronger decrease of temperature drop ΔT at the surface of the tested skin and in widening the layer of colder temperature along the depth of the skin, finally resulting in significant increase of the thermal time constant.

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Analyzing thermal response in ROI's (see Fig. 2a): AR01 – 80°C, 5 sec.; AR02 – 80°C, 15 sec.; AR03 – 80°C, 25 sec.- burn wounds healing within 3 weeks and AR04 – 100°C, 60 sec. – the burn not healing within 3 weeks, AR05, AR06 – are the reference fields of healthy (not burned) skin; the temperature curves are classified on 3 groups of different behaviour. The reference healthy skin secures all mechanisms characteristic for reaction to cooling by CO_2 vapour. This is fast vasoconstriction to the cold stress (narrowing of the lumena of blood vessels), followed by vasodilation - the opening of blood vessels – typical reaction after cooling, existing also in deeper layer of the tissue for longer periods of cooling. In effect the thermal response of the healthy skin is characterized by relatively long time constant for the short cooling and then due to increased vascularisation in deeper layers of the tissue, in response to longer cooling, it is keeping the time constant almost unchanged for increased periods of cooling. Burns which will healing within 3 weeks are lacking the effect of vasoconstriction and due to strong vascularization at the superficial layer of the tissue the thermal response is fast. In contrast in the deep burn the perfusion of the tissue is poor and thermal response is much slower.

a) b)

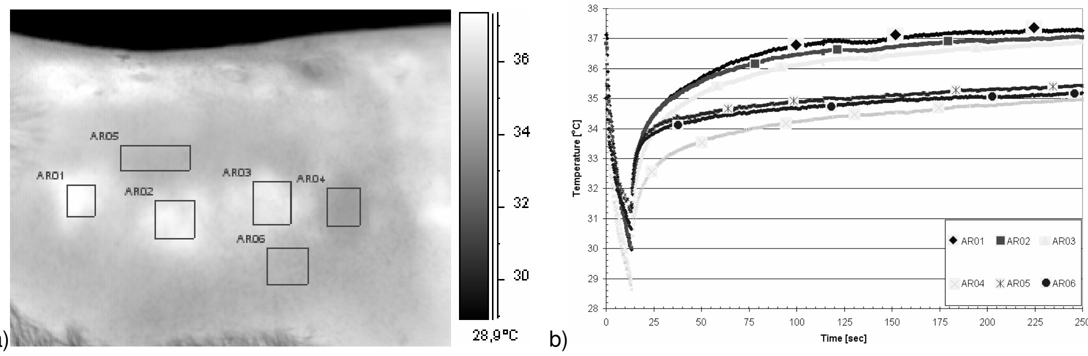

Fig. 2. *Distribution of temperature after burn: a) AR01 – 80°C, 5 sec.; AR02 – 80°C, 15 sec.; AR03 – 80°C, 25 sec.; AR04 – 100°C, 60 sec. – the burn not healing within 3 weeks! AR05, AR06 – are the reference fields of healthy (not burned) skin; b) thermal response of the ROI AR0x of skin for stimulus of CO_2 lasting 10 sec.*

Collected experimental results were compared with data obtained from numerical thermal model of skin [6]. Correlation between thermal model simulations and experiment results is very high what confirms that the main mechanisms responsible for heat exchange in the investigated tissues are properly recognized.

4. Conclusions

The problem was to define proper methodology of experiments for ADT in burn diagnostics and choice of equipment and experimental conditions, eg. time of excitation phase, etc. The recent paper is reporting results of experiments, which are already standardized in secure established measurement conditions. Therefore we are fully convinced that the examples we show are of proper diagnostic importance (high diagnostic quality) even the number of discussed cases is small. The results of cooling clearly show very high importance of this procedure in comparison to heating by optical excitation.

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