Computers in Biology and Medicine 76 (2016) 80–93

Contents lists available at ScienceDirect

Computers in Biology and Medicine

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

Tumor parameter estimation considering the body geometry by thermography

Shazzat Hossain, Farah A. Mohammadi *

Department of Electrical and Computer Engineering, Ryerson University, Toronto, Canada M5B 2K3

ARTICLE INFO

Article history:
Received 14 July 2015
Received in revised form
22 June 2016
Accepted 23 June 2016

Keywords:
Bio-heat transfer
Genetic algorithm
Non-invasive diagnostics
Thermogram
Tumor
Numerical simulation

ABSTRACT

Implementation of non-invasive, non-contact, radiation-free thermal diagnostic tools requires an accurate correlation between surface temperature and interior physiology derived from living bio-heat phenomena. Such associations in the chest, forearm, and natural and deformed breasts have been investigated using finite element analysis (FEA), where the geometry and heterogeneity of an organ are accounted for by creating anatomically-accurate FEA models. The quantitative links are involved in the proposed evolutionary methodology for forecasting unknown Physio-thermo-biological parameters, including the depth, size and metabolic rate of the underlying nodule. A Custom Genetic Algorithm (GA) is tailored to parameterize a tumor by minimizing a fitness function. The study has employed the finite element method to develop simulated data sets and gradient matrix. Furthermore, simulated thermograms are obtained by enveloping the data sets with $\pm$10% random noise.

1. Background

At present, many imaging techniques such as X-rays, MRI (Magnetic Resonance Imaging), Ultrasound, CT (Computed Tomography), SPECT (Single Photon Emission Tomography), PET (Positron Emission Tomography) and others are used for medical diagnosis. Among them, some are invasive and ionizing and others are noninvasive and nonionising. Unlike X-rays, MRI, and Mammography, the Infrared (IR) technique are non-contract, comfortable, safe, has no radiation dose, and can be applied repeatedly to the human body without known risk of morbidity [1]. It relies on human body's inherent electromagnetic (EM) radiation quality, since the living body emits infrared energy as a function of skin temperature. Abnormalities in skin temperature distribution have been recognized as a sign of disease for centuries, well before humans knew about the cause of ailments or of pain. Today's sensitive temperature measuring devices invite medical doctors to identify subtle thermal abnormalities and find an association between thermal image and a certain disorder [2,3].

Generally, body surface temperature is controlled by the local metabolism, blood circulation, and the heat exchange between the skin and ambient surroundings [4–6]. Change in any of these parameters could influence the temperature distribution and radiating heat flux, consequently reflecting the physiological state. Inflammation, metabolic rate, interstitial hypertension, abnormal vessel morphology and lack of response to homeostatic signals are some of the particular features that make tumors behave differently to normal tissues in terms of heat production and dissipation [7–9]. Therefore, abnormal skin temperature profiles can be used to predict the location, size and thermal parameters of the hyperactive region as well as to follow up the treatment procedure.

The correlation between the interior temperature distribution and bio-thermal parameters were developed by direct solving the steady-state Pennes' bio-heat equation analytically with different boundary conditions [10] and the influence of thermal conductivity, metabolism, blood perfusion and heat exchange rate was studied for homogeneous and isotropic tissues [11–13]. Establishing this relationship while considering the geometrical and behavioral variation of biological tissues, common phenomena observed intumours or cancer, numerical methods such as the finite difference method (FDM) [11], the finite element method (FEM) [12,14], and the boundary element method (BEM) [13] have been developed. Earlier research has shown the correlation between bio-thermal parameters and temperature profiles.

However, the medical application of IR thermography invokes an indirect solution, being limited in past years, mainly due to the complexity, high cost and poor sensitivity of output data generated from IR cameras available at the time. Nowadays, advances in the IR technology have again promoted its medical application as a promising non-invasive tool for imaging the thermal pattern on the surface and for discovering the influence of vascular,

* Corresponding author.
E-mail address: fmohamma@ee.ryerson.ca (F.A. Mohammadi).

http://dx.doi.org/10.1016/j.compbiomed.2016.06.023
0010-4825/

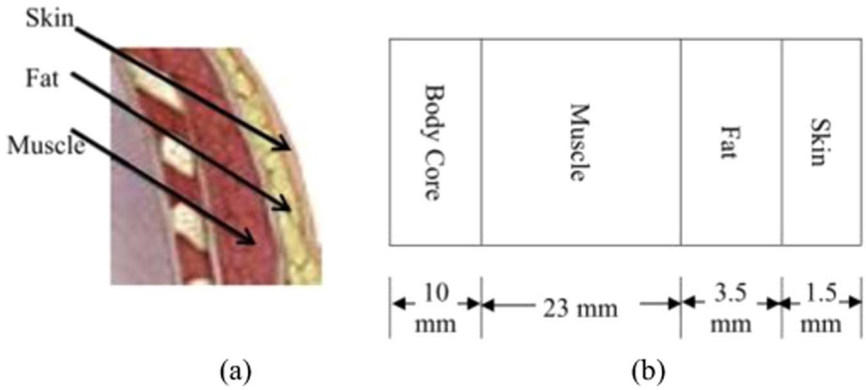

Fig. 1. Male chest – (a) Cross-section, and (b) 2-D model.

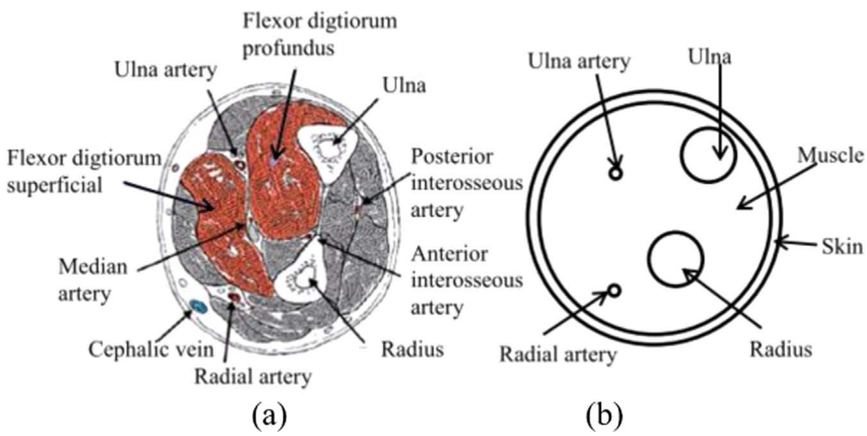

Fig. 2. Male forearm – (a) Cross-section, (b) 2-D model.

Table 1
Synopsis of adult male forearm.

Element	Diameter (mm)	Center location (mm)
Forearm	70	(0, 0)
Radius	16.47	(5, −13)
Ulna	16.47	(15, 18)
Radius artery	2.57	(−12, −18)
Ulna artery	2.57	(−10, 13)

neurogenic and metabolic process that affect them. Lawson [3] was the first to propose the use of thermography detection of breast cancer, when he observed that the local temperatures of the skin over a tumor were significantly higher (by approximately 2–3 °C) than the normal skin temperatures. Lawson and Chughtai [2] established that the regional temperature difference over an embedded tumor was due to convection effects associated with increased blood perfusion, and the increased metabolism around the tumor. A further aspect of IR imaging techniques and detection methods of breast cancer from IR images are described in detail by Diakides and Bronzino [1]. In [15] Santa Cruz et al., after making a comparative investigation between thermography and boron neutron capture therapy (BNCT), concluded that the thermography, a potential imager of tissue functionalities, can help to locate abnormally high temperature regions as well as melanoma nodules that are virtually invisible in CT images. These analyses have proved that IR images can be an important indicator for screening tumors.

Moreover, several recent investigations have utilized the correlation between the skin temperature and physiological parameters to reveal the potential of the screening tool as a useful diagnostic tool. Mital et al. [16,17] developed an in-vitro mode experimental and evolutionary method, respectively, to determine the parameters of an embedded heating source (representing a

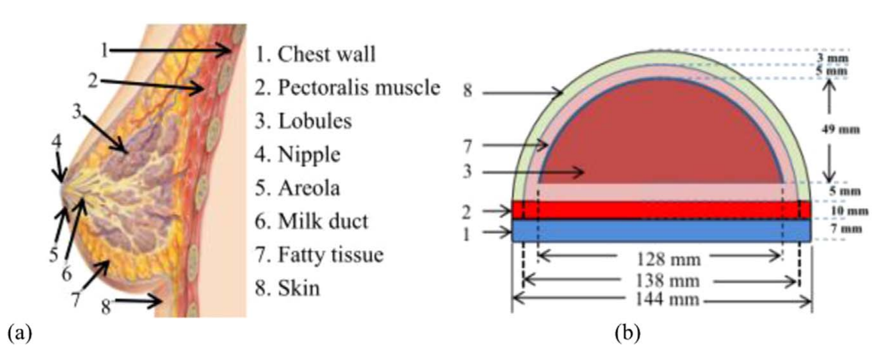

Fig. 3. Female breast–(a) Cross-section, (b) 2-D model.