Interdisciplinarity in computer-aided analysis of thermal therapies

[1]DANIELA CÂRSTEA, [1]ION CÂRSTEA, [3] IULIA MARIA CÂRSTEA
[1] Industrial High-School Group of Railways and Transport, Craiova
[2] University of Craiova, Department of computers engineering
[3] University of Medicine and Pharmacy "Carol Davila", Bucharest
ROMANIA
E_mail: danacrst@yahoo.com, ion_crst@yahoo.com, nashucel@yahoo.com

Abstract: – The interdisciplinarity in computer-aided analysis of the human body is an attitude of high education and top research and our work is an illustrative example in this area. The thermal therapies, thermal injury and thermal comfort can be understood if the temperature distribution in space and time in the living tissue can be estimated or predicted. But this objective can be fulfilled by a team of different specialists as engineers, doctors, mathematicians and programmers. The work tries to present some computational aspects in numerical simulation of the thermal model in skin tissue and the limits of the mathematical models used in this approach.

The bioheat equation is discussed in the context of some clinical applications as irradiated skin tissue by laser or a fire pulse. A thermal model based on the finite element method was used.

Keywords: - Thermal therapy; Numerical solution; Bioheat transfer equation; Interdisciplinarity.

1 Introduction

A top research and a high education in science and engineering involve an increase of the interdisciplinarity role. This concept can be used with a confuse meaning so that we examine its pivotal role in engineering and medicine with emphasis on the computer-aided analysis of the temperature distribution in the skin tissue. The concepts as multidisciplinarity, interdisciplinarity and transdisciplinarity are used in professional literature of coupled problems.

Multi-disciplinary approach involves a number of disciplines coming together but each working independently and primarily with their own frame of reference and methods. Multidisciplinary analysis is the weak link of the coupled fields. It draws on the knowledge of several disciplines, each of which provides a different perspective on a problem or issue.

Trans-disciplinary approaches involve organisation of knowledge around complex subjects, or real world problems, rather than disciplines. Such approaches are more likely to produce outcomes which are more than the sum of different parts. *Transdisciplinarity* complements disciplinary approaches and involves the recognition of the existence of different levels of reality governed by different types of logic. The transdisciplinary vision goes beyond the exact sciences and demands dialogue with the humanities and the social sciences, as well as with art, literature, poetry and spiritual experience. The transdisciplinary approach involves an acceptance of the unknown, the unexpected and the unforeseeable.

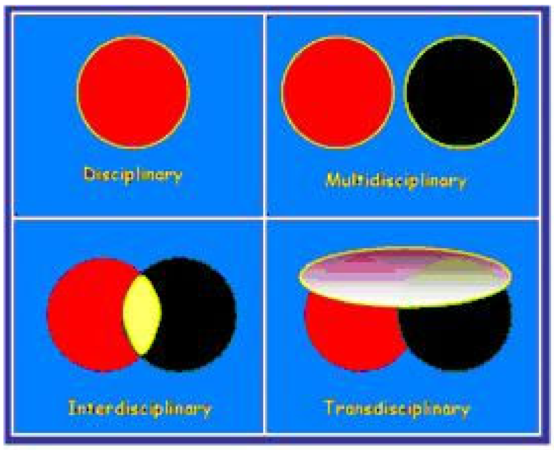

Fig. 1 An explicative figure for concepts

Interdisciplinary analysis is a requirement of a higher education and top research because it requires integration of knowledge from different disciplines for analysis of an object. A part of the disciplines boundaries between different disciplines disappear. Disciplinary knowledge, concepts, methods and tools of investigation are considered, and combined in such a way that the resulting understanding is greater than simply the sum of its disciplinary parts. In Fig. 1 an explicative diagram for these concepts in case of two disciplines is shown.

We live in a complex world and we are not isolated actors on the world scene. We cooperate and we are in positive competition, especially in the frame of the same objective. We include diverse information from our education and experiences in our decisions, the phenomena analysis, and generally in our viewpoint of this world. This informal process represents a sort of interdisciplinary analysis, especially in area of the engineering and science. In this way we use specialized knowledge, concepts, methods or tools of academic disciplines and integrate them for a new knowledge in our research area. Interdisciplinary research may be defined as a process of solving a problem that is too complex to be dealt with adequately by a single discipline.

The human body is the most complex system, a naturally controlled system in some ranges of the physical parameters and environment conditions. The mysteries of the body, the inner mechanisms that control its inner workings, are actually the most evolved systems in the universe. An analysis of behaviour of the human being involves an interdisciplinary research. The living tissues are the house of many physical fields that interact so that a complete analysis involves new models where the engineers, the physicians, the doctors and other science people must cooperate.

1.1. Alophatic vs. Holistic models in medicine

It is not the goal of this work to present different viewpoints of the health and disease because there is a long history and sometimes there are opposing viewpoints. In this area two opposing viewpoints of health and disease have been evident since ancient times. The holism was defined [8] as: "*The tendency in nature to form wholes that are greater than the sum of the parts through creative evolution*". Concept led on to General Systems Theory where the system is viewed more than the sum of its parts and there are hierarchical and interacting organisations.

Nowadays, we speak about two systems of medicine: allopathic and holistic. The first is focused on measurements; the second is based on experience. In this way we speak about alophatic health and holistic health, we speak about alophatic and holistic therapies. For example, the holistic therapy and medicine refers to **treating the whole person**. This means that disease is viewed as affecting a person's mind, body and spirit.

Alophatic medicine

Alophaty model is built largely on the contagion theory of disease and the suppression of symptoms, and therefore promotes medicines and counter measures that fight harmful agents and their effects. In this model, minute quantity of the very agent that causes the symptom also causes the immune system to handle it.

Holistic medicine

A good definition of this concept is the following [9]: ***"****Holistic medicine is the art and science of healing that addresses the whole person - body, mind, and spirit. The practice of holistic medicine integrates conventional and alternative therapies to prevent and treat disease, and most importantly, to promote optimal health. This condition of holistic health is defined as the unlimited and unimpeded free flow of life force energy through body, mind, and spirit."*

A holistic view differs that disease doesn't merely inhabit the body, but that it can infiltrate the mind and spirit as well. Therefore, holistic medicine uses both conventional and alternative medicine to treat disease. In a sense, holistic medicine is very practical. It seeks to use several avenues to reach and treat disease, rather than the more single-minded approach of other therapies. The premise of Holistic Medicine is to attempt to treat the whole patient on all levels, as opposed to the symptoms.

The holistic approach takes the broadest possible view of illness and disease, identifying multiple causes (both internal and external), and offering multi-dimensional "healing," as opposed to specific "cures." It is as concerned with one's propensity towards disease as it is with its transmission.

Taking into account one's body, mind, emotions, and spiritual life, holistic health combines the best of modern scientific diagnosis and monitoring techniques with both ancient and innovative health promotion methods. It addresses not only symptoms, but the entire person, and his or her current life predicament, including family, job, and religious life. It emphasizes prevention, health maintenance, high-level wellness and longevity. It views the client as an active participant in the healing process, rather than simply a passive recipient of "health care."

1.2. A holistic model for the thermal system

The conventional view, or Allopathic (literally, "other disease") sees problems coming from outside the body. In short, the cause of disease comes from outside, then invades the body and the person gets "sick." The **allopathic viewpoint** means disease, symptoms, drugs, surgery. Allopathic philosophy says that when the body has symptoms of a disease (like pain, fever, or nausea), these symptoms must be treated, usually with drugs. If this approach is not possible, and the disease is localized in one certain part of the body, then that part of the body may have to be cut out with surgery.

Holistic medicine is often defined as a medical discipline that studies the whole person, not just the physical body, but also the mind, body and spirit. The **holistic** view is different in the sense that it says that the cause and cure of all disease lie within the body. There is an internal and natural balance state of the human body, of different interrelated parts. This state is so naturally and sophisticated orchestrated and exquisitely tuned. The body can heal itself if provided with the opportunity. It does this from the inside out - from the brain and spinal cord, outward through the nervous system, to every organ, and cell. For every time you have ever been sick, there have been hundreds of times when your immune system has conquered a disease without any overt symptoms being expressed. We are dealing with the life forces, the life substances - that which can never be viewed in dissection or isolated in laboratory culture. To influence these subtle, delicate interweavings, natural cures seek to nourish and encourage the body back into a condition of balance, by gentle support.

In a complete analysis of the human body we must develop holistic models as in Fig. 2. This is the case of the analysis of thermal system of the human body [4]. A holistic model for quantifying thermal pain, which directly correlates the stimulus and pain sensation level, can couple the thermomechanical models and the biophysical and neurological mechanisms of pain sensation

We identify three subsystems that are not isolated and interact by physical properties of the tissues and field sources. Electrical and mechanical fields represent the source of the thermal pain and the link of the local effects of these fields with the brain can be modelled in an interdisciplinary research.

2 Thermal therapies

In medical praxis it is very useful to use simulation tools that allow a temperature prediction of the thermal treatment in terms of the source and tissue parameters. This simulation helps practitioners in the selection of the appropriate source intensity and exposition time for the particular pathology.

The human body can be modelled as two concentric cylinders: core and skin. The core consists of the brain and the internal organs in the trunk. A healthy human body maintains its core temperature of about 37°C within small margins. Temperatures in the remaining parts of the body - surface tissue and the limbs - are much less constant. The environmental conditions can lead to small disturbances in thermal equilibrium of the body. The core temperature is maintained partly by person behaviour (e.g. clothing), and partly by the body's thermoregulatory system.

Many classic and modern clinical treatments and medicines are based on the temperature distribution in the living tissues. Heat distribution in any material is related with heat transfer processes. These are conduction, which treats heat transmission in a solid; convection, which deals with heat interchange between a solid and a fluid in contact with it; and radiation, which has to do with the infrared energy

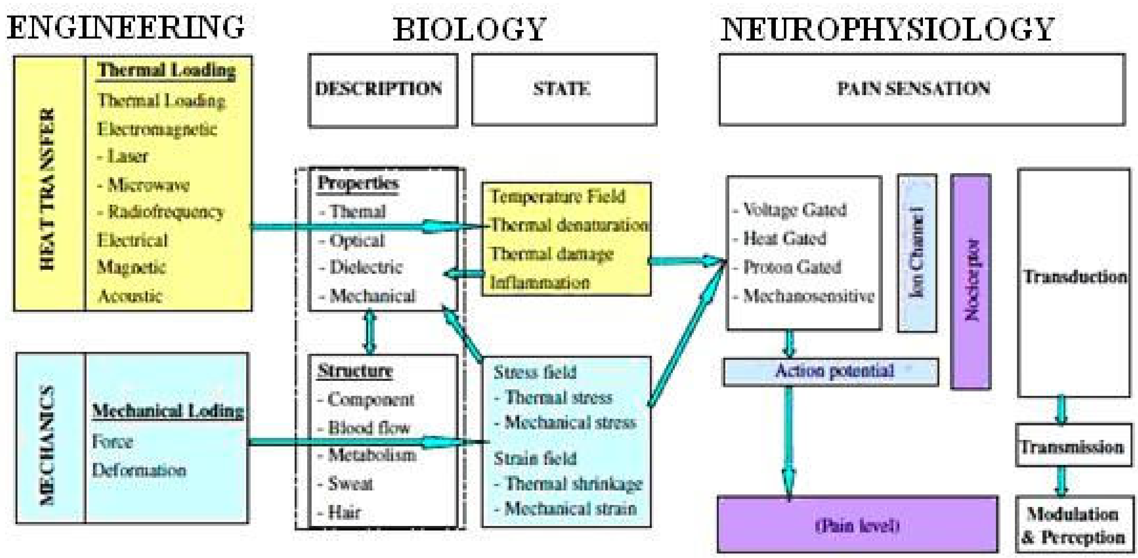

Fig. 2 A holistic model of the skin biothermomechanics

that any body at nonzero temperature emits naturally.

The biological tissue has a behaviour which is different of the materials behaviour from industry. Although the heat transfer mechanism is the same as in a general material, the consideration of blood flow generates a special case of the heat conduction equation. It is known that heat transfer within the human body is a complicated process involving metabolic heat generation, heat conduction and blood perfusion in soft tissue, convection and perfusion of the arterial-venous blood through the capillary, and interaction with the environment.

Perfusion in vessels of biological tissue must be considered in the thermal model. This blood flow provokes convection with the surrounding tissue, and as a consequence temperature decreases. Heat transmission mechanisms are usually treated by including them in a so-called bio-heat equation. This is a spatial-temporal differential equation that models temperature distribution in tissue. It was developed by Pennes but in time many transformations were made to include clinical considerations.

The large number of applications of the heat transfer in clinical treatments can not be treated in a unified theory because of the individual properties of the skin tissues and the goal of the therapy. This is one of the reasons to treat each type of thermal therapy as a unique case and limit our study to some therapies.

Treating tumour with little alteration to the surrounding normal tissue has long been the goal of medical research. Both cryosurgery and radiofrequency (RF) heating have attracted a top research. In cryosurgery, the freezing process causes direct cellular injury, vascular injury, and possible immunologic responses. On the other hand, RF heating has demonstrated its effectiveness in treating many types of tumours, among the higher temperature treatment methods. Because of the relatively long wavelengths, the RF signals penetrate deeply into the tissue. In the hyperthermia treatment between 43 ^{0}C and 45 ^{0}C, the tissue temperature mildly raised for a certain period of time is expected to induce cell death by affecting the membrane fluidity, cytoskeletal, protein structure, nuclear structure and disruption of DNA replication. But, there are concerns lying in: (1) its effective treatment region, especially in the tumour periphery where the heating is rapidly attenuated by locally augmented blood flow and (2) possible metastasis induced by single local heating.

Hyperthermia is a type of tumour treatment in which body tissue is exposed to high temperatures. It is usually used with other forms of cancer therapy, such as radiation therapy and chemotherapy, because hyperthermia may make some cancer cells more sensitive to radiation or harm other cancer cells that radiation cannot damage. The effectiveness of hyperthermia treatment is related to the temperature achieved during the treatment. In order to kill cancer cells without injury to normal tissues, the ability to predict the temperature of the tumour and surrounding tissue is important in hyperthermia therapy.

Although Pennes equation [2] is the base of many mathematical models for predicting the temperature in the living tissues, many researchers have investigated new models that substitute or modify the perfusion term in Pennes' model, or that add energy equations for dealing with non-equilibrium conditions.

Because the heat absorptions of tissue and blood are different during thermal therapy, particularly ultrasound treatment, the assumption of thermal equilibrium may not be valid even for tissue with a distribution of small blood vessels. Therefore, the criterion of thermal equilibrium during hyperthermia may be different from that in the normal situation where only metabolic heat generation occurs.

Electromagnetic heating is widely used in modern thermal therapies, including microwave, radiofrequency and laser. The electromagnetic spectrum is very large from waves increasing in frequency from Extremely Low Frequency and Very Low Frequency (ELF/VLF), through Radio Frequency (RF) and Microwaves, to Infrared (IR) light, Visible Light, Ultraviolet (UV) light, Xrays, and Gamma rays. During all medical electromagnetic applications based on heating, it is desirable to have complete knowledge of the temperature and corresponding thermal stress distributions.

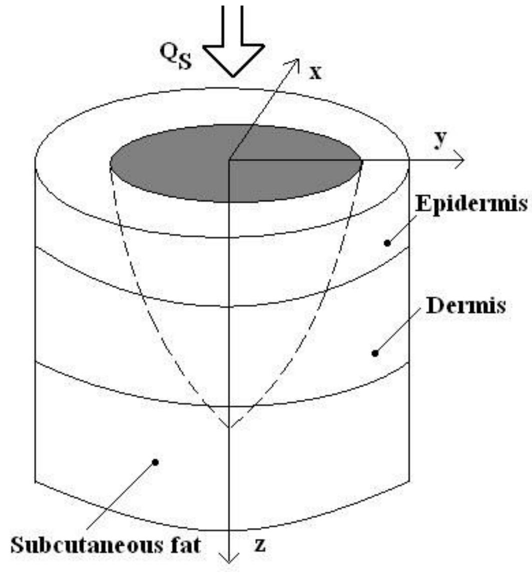

Fig. 3 Computational domain for laser therapy

Temperature prediction in **laser irradiated biological tissues** is frequently required in some medical applications, like thermotherapy, hyperthermia or tissue ablation. The aim of this procedure is tissue destruction, and is specially indicated in tumour elimination. On the other hand lower temperatures imply no tissue damage but a therapeutic effect in some cases. For instance, low intensity laser therapy consists on the irradiation of the pathological tissue with a low irradiance source, and sometimes with several wavelengths. A similar technique, called thermotherapy, uses a controlled temperature increase in the pathological tissue to provoke the therapeutic effect.

In all these optical treatment techniques that have to do with thermal interaction, it is necessary to control the temperature increase. An abnormal high temperature could lead to undesired thermal damage, either in the pathological tissue or in a healthy adjacent one. The temperature distribution depends mainly on the optical source parameters (power, wavelength, spatial beam pro file) and on the opto-thermal parameters of the biological tissue. Modelling the thermal process in light–tissue interaction requires on one hand an adequate consideration of optical propagation in tissue.

Skin can be modelled as a complicated multilayer structure. According to this concept, the tissue is considered to be composed by layers (fig. 3). In an opto-thermal model the tissue is considered to be composed by six layers from the optical point of view, and by four for the thermal analysis. The layers are ordered starting from the outside of the skin: epidermis, upper dermis, blood plexus, lower dermis, subcutaneous fat and muscle. These layers differ by geometrical dimensions and physical properties. Whilst the thermal properties of different skin layers have similar magnitudes, the mechanical properties vary greatly, by up to three orders of magnitude, from one layer to another.

It is obviously that an interdisciplinary analysis must be accomplished starting with engineering considerations and ending with neuropsihology effects as pain sensation.

3 Mathematical modelling

The Pennes bioheat equation describes the thermal behaviour based on the classical Fourier's law and has the form:

$$\rho c \frac{\partial T}{\partial t} = \nabla(k\nabla T) + \omega_b \rho_b c_b (T_a - T) + q_{met} + q_{ext} \quad (1)$$

Here, ρ, c, k and T denote density, specific heat, thermal conductivity and temperature of tissue. The density, specific heat, and perfusion rate of blood are denoted by ρ_b, c_b and ω_b, respectively. The heat source is denoted by q and represents the sum of two components: q_{met} which is the metabolic heat generation in the skin tissue and q_{ext} is the heat source due to external heating. T_a is the arterial temperature and it is regarded as a constant and equal to 37 ^{0}C.

The Eq. (1) can have different forms for a particular therapy. For example, the irradiation of biological tissue by means of a light source is used in certain medical treatment applications. Light–tissue interaction depends on the irradiance source and the exposition time [1]. Thus, the ablation of the tissue is used in laser surgery and this is the effect of irradiance around 10^{10} W/cm^2 and an exposition time selected around pico seconds or nano seconds, case when the photoablation or photodisruption occur.

In light-tissue interaction, if the internally generated heat is zero, the Pennes bioheat equation has the form:

$$\rho c \frac{\partial T}{\partial t} = \nabla(k\nabla T) + \omega_b \rho_b c_b (T_a - T) + Q_S \quad (2)$$

where Q_S (W/m^3) contains the energy delivered by the optical source absorbed by the tissue.

The subsidiary problem is the modelling of light propagation in tissue. An approach is to use Beer-Lambert law [1]:

$$Q_S = \alpha I_0 e^{-\alpha z} e^{-s(x^2+y^2)} \quad (3)$$

where α is the absorption coefficient (cm^{-1}) in depth, I_0 is the incident irradiance (W. cm $^{-2}$), and s (cm^{-2}) takes into account the Gaussian beam spatial radius r_0 ($s=1/r_0^2$).

Boundary conditions depend on the particular problem we are dealing with. The most usual case is a biological tissue irradiated from the outside. In this situation the heating area is normally only a part of that tissue. In the surfaces in contact with air, convection, radiation and vaporization effects appear

The boundary condition for the heat transfer occurring at skin surface is generally included in one of the following kinds of conditions:

1. Dirichlet condition (constant temperature):

$$T_{skin} = T_\infty \quad (4)$$

2. Neumann condition (specified heat flux):

$$-k \frac{\partial T}{\partial n}\bigg|_{skin} = q_S \quad (5)$$

3. Convective condition:

$$-k \frac{\partial T}{\partial n}\bigg|_{skin} = h(T_\infty - T) \quad (6)$$

4. Radiation condition:

$$-k \frac{\partial T}{\partial n}\bigg|_{skin} = \varepsilon\sigma(T_\infty^4 - T^4) \quad (7)$$

where n is the outward normal at the boundary of computational domain, ε is skin emissivity and σ is Stefan–Boltzmann's constant in W/ (m^2 K^4).

On the boundary of the computational domain we can have a mixed condition (convection and radiation) including the evaporation. These cases do not create difficulties in the development of a numerical model. In the surfaces in contact with air, convection, radiation and vaporization effects appear. The boundary condition at this surface, usually the upper one, can be expressed as [1]:

$$-k\left.\frac{\partial T}{\partial n}\right|_{skin} = h(T-T_\infty)+\varepsilon\sigma(T_\infty^4 - T^4) + h_f h_s(\rho_e-\rho_{sat})$$

where h_f is the phase-change enthalpy of water at T_∞, h_S is the convection mass transfer coefficient (cm/s), ρ_e is the density of water vapour in air, and ρ_{sat} the density of saturated water vapour at T_∞.

The Eq. (2) must be solved with initial condition for a specified time interval [0, t_f] where the final time t_f has an important role in a thermal therapy. This equation can be solved with different numerical approaches and the simpler one is the explicit finite-difference technique for time and finite-element method for spatial discretization.

4 Numerical simulations

In the numerical simulation of the parabolic system the finite element method [6] was used for spatial discretization, and finite difference method for time discretization.

Laser heating in pulsed mode

Lasers have been widely used for medical applications for their advantages such as directivity, ability to be used in pulsed mode, monochromaticity and its controllable effects. In general, there are three types of laser tissue thermal interactions depending on the degree and the duration of tissue heating: Hyperthermia, Coagulation and Volatilization [1].

Hyperthermia causes a moderate rise in temperature in the range of 41–44 ^{0}C for some tens of minutes, resulting in cell death due to changes in enzymatic processes.

Coagulation refers to an irreversible necrosis without immediate tissue destruction with temperature in the range of 50–100 ^{0}C for around a second.

Volatilization refers to a loss of material with temperatures above 100 ^{0}C for a relatively short time of around one tenth of a second.

In our study we considered a cylindrically symmetrical heating source so that a cylindrical coordinate system can be used ([11]-[14]). In this way the 3D model can be reduced to a 2D model. The heated depth of biological tissue is usually less than 8 mm, especially at the initial stage.

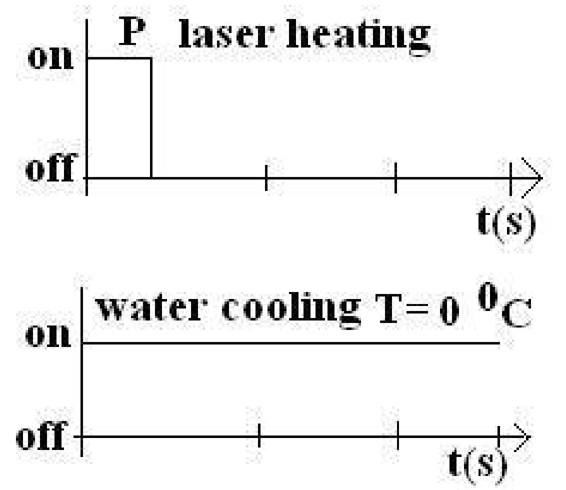

Fig. 4 Heating and cooling process

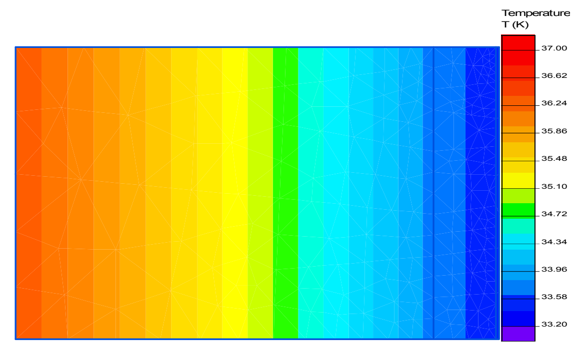

Fig. 5 Initial temperature distribution

The skin is initially cooled by the natural convection of environmental air (T_∞ = 25 ^{0}C, h = 7 W/m^2 K). At t = 0, a short laser pulse with power P = 15 W/cm^2 and duration of 0.1 s is applied to its surface. At the same time, the skin surface is cooled by cold water at 0 ^{0}C with exception of the irradiated area. The temporal profiles of the treatment pulse and surface cooling are shown in Fig.4. The impulse of amplitude P and duration *b-a* is defined by the function:

$$h(t,a,b)=\begin{cases}0 & t \prec a\\ P & a \le t \le b\\ 0 & t \succ b\end{cases}$$

In our study we considered a three-layered model of the skin with the physical and geometrical characteristics presented in the table1 [2].

Table 1

Parameters	Epidermis	Dermis	Fat
Thickness [mm]	0.075	1.5	3.42
Density [Kg/m^3]	1190	1116	971
Specific heat [J/Kg.K]	3600	3300	2700
kx=ky [$Wm^{-2}K^{-1}$]	0.21	0.37	0.16
q_{meat} [W/m^3]	368.1	368.1	368.3

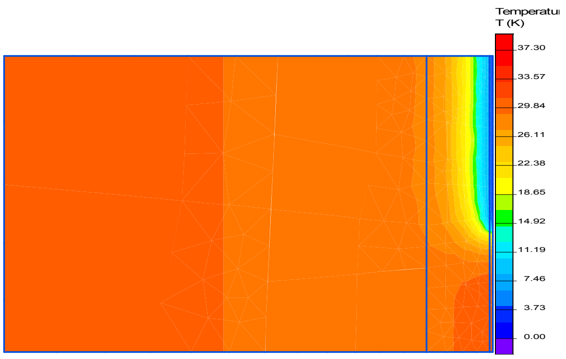

Fig. 6 Final temperature distribution

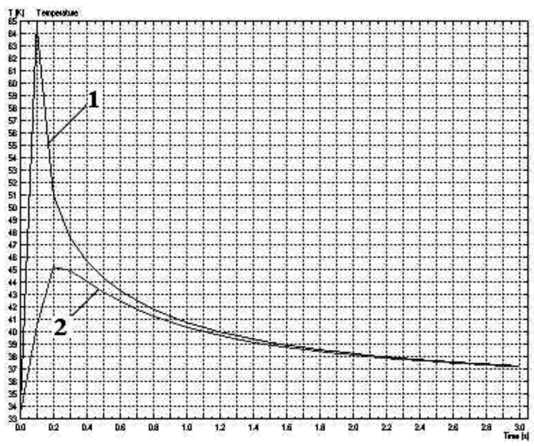

Fig. 7 Temperature vs. time

In numerical simulation we used the following values for problem parameters:

- Body core temperature, T_{body} (^{0}C): 37
- Convection coefficient, h (W m^{-2} K^{-1}): 7
- Ambient temperature, T_∞ (^{0}C): 25
- Sweat evaporation rate, Q (W m^{-2}): 10
- Pulse amplitude P: 15 W/cm^2
- Pulse duration: 0.1 s
- Time interval: 3 s

In this first study we neglected the blood perfusion rate. In the Fig. 4 the map of the initial temperature is plotted. In Fig. 5 the final temperature at time t_f=3 s is plotted using Quickfield program [7].

The time distribution of the temperature in the centre of laser irradiated area is plotted in Fig. 6 (curve 1) and at epidermis-dermis (ED) interface (curve 2). The skin surface and ED interface are both subjected to large tensile stresses, especially during heating, indicating severe thermal damage.

It is obviously that we can easily analyze the influence of the source parameters on the temperature depth and tissue damage in the neighbourhood of the irradiated tissue. The amplitude of the impulse and the duration are simple data in the simulation program. In this way we can have an inverse problem, that is, from an imposed performance of the whole system body-environment, we can select optimum values of the physical parameters of the laser source.

4.1. Relevant parameters

Numerical simulation offers a set of relevant parameters of the therapy. The temperature evolutions in time and space in different interest points depend on the input parameters (laser pulse). One of the relevant parameter of the pulse is the power P. The parameters of the input refer to:

- Spatial distribution
- Temporal distribution of the laser pulse
- Attenuation of the laser light

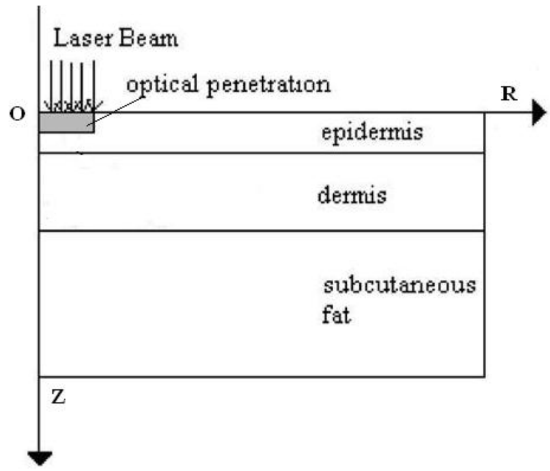

Fig. 8 Computational domain

In the case of axisymmetric field we can use the cylindrical coordinates Orzθ. The analysis domain is shown in Fig. 8 where the axis of symmetry is axis Oz. The bioheat equation (2) in cylindrical coordinates becomes:

$$\rho c_p = k(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2}) + \omega_b \rho_b c_b (T_a - T) + Q_S$$

In Fig. 9 the curves of the relevant parameters of input are plotted. Thus, the curve in Figure 9.a represents the spatial distribution. In Fig. 9.b the temporal distribution of the laser pulse is shown and Fig. 9.c illustrates attenuation of the laser light. It is obviously that these parameters influence the

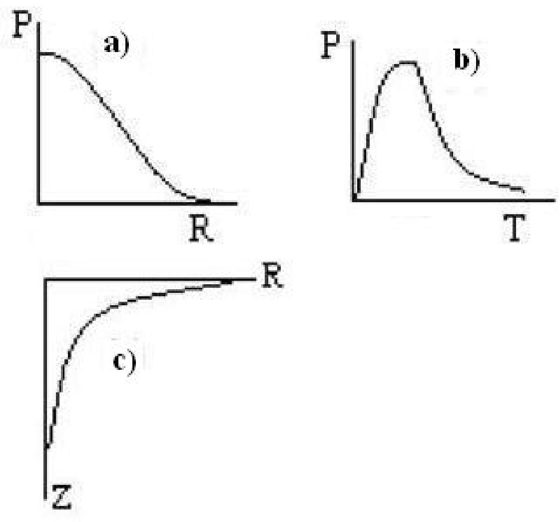

Fig. 9 Curves of the relevant parameters

treatment performance and can be controlled by the user. Although we limited our presentation to an analysis problem, for the clinicians an inverse problem can be formulated where the performance criterion can include geometrical and physical parameters.

4.2 Damage profiles of the skin tissue

It is obviously that a wrong treatment can damage the skin tissue. The skin damage can be represented as a chemical rate process that can be calculated by using a model that was proposed by Arrhenius and developed by other researchers. Damage is related to the rate of protein denaturation (k) and exposure time (τ) at a given absolute temperature T. The measure of thermal injury Ω was introduced and its rate k is defined by:

$$k(T) = \frac{d\Omega}{d\tau} = A \cdot e^{-E_a/RT} \qquad (9)$$

where A [1/s] is a material parameter equivalent to a frequency factor, E_a is the activation energy, R=8.314 [J/mol K] is the universal gas constant and T(x, t) is local tissue temperature (K). The constants A and E_a are obtained experimentally.

Many researchers proposed other models. In [4] the reaction rate of the thermal damage process is computed with formula:

$$k(T) = e^{(E_a - 21149.324)/2688.367} e^{-E_a/RT} \qquad (10)$$

The following correlations between Ω-values and degrees of burn injury were found:

- Ω=0.53 is the first degree burn (irreversible epidermal injury)
- Ω=1.00 is the second degree burn
- $\Omega=10^4$ is the third degree burn (complete trans-epidermal necrosis

In the case of laser therapy we can compute the surface temperature and finally we can obtain a damage function.

For different input parameters we can plot a set of damage functions. From these functions we can estimate the shortest time at which constant predetermined cutaneous surface temperature produces transepidermal necrosis (denoted by Ω=1). This time can be computed analytically from Eq. (10). Thus, for a constant temperature T and a specified value of E_a, the thermal damage function is [6]:

$$\Omega(t) = k(T).t$$

Assuming that Ω=1 .0 denotes the beginning of irreversible damage, we can calculate the time for the appearance of irreversible damage at temperature T, as:

$$t_{\Omega=1} = \frac{1}{k(T)}$$

We considered some examples that are plotted in Fig. 8. Thus, for a surface temperature T=60 ^{0}C, the value of t_Ω=2.709 [s], and for T=61 ^{0}C the value of time t_Ω=1.376 [s].

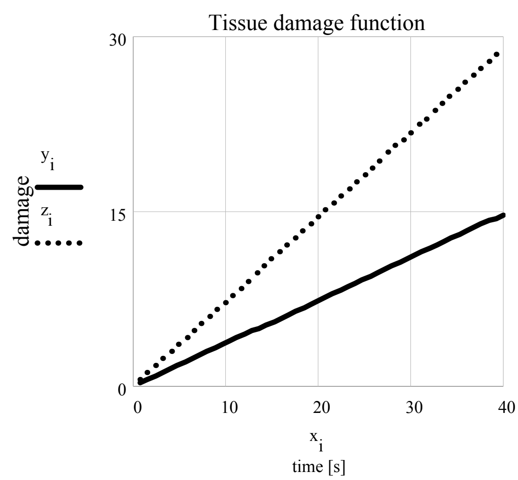

Fig. 10 Damage function Ω vs. time

5 Discussions

In our study we tried to present a modern tool for the analysis of the thermal response of the skin tissue in thermal therapies. The numerical results can be used in a biomedical model but a holistic model can be used. In a holistic model the following steps can be considered:

1. Doctor provides information and options for treatment; patient makes informed decisions about the course of treatment. Doctor and patient have a

partnership type of relationship with shared decision making.

2. Illness is the effect of multiple factors and circumstances. Treatment options broad, multiple models considered (e.g., nutrition, environ-mental factors, lifestyle decisions).

3. Treatment directed toward the person, that is, we recognize the patient's uniqueness.

4. Goal of treatment is based on patient's value system. End point is reached by consensus.

5. Interaction of bodily systems and role of emotions, personality, and faith are included in consideration of diagnosis and treatment.

6. Patient is given credit for outcome of process. Role of patient's involvement is given more credence.

7. Role of hope is recognized.

6 Conclusions

In this paper we considered some computational aspects in thermal therapies considering a variant of disciplinarity: interdisciplinarity. While the traditional view regards disciplines as discrete and autonomous, interdisciplinarity usually arises in areas of study where the topic under investigation is too complex for a single discipline to address. Topics such as the thermal responses of the human body at different external and internal stimuli require coordinated efforts of many specialists: doctors, engineers, mathematicians, chemists, computer's programmers etc. It is *Nature,* not science or scientists, which entails interdisciplinarity.

To make interdisciplinarity research, certain conditions have to be met. The major conditions must include: mutual trust and respect among team members; confidence in one's own discipline but without being defensive; space and time for sharing of knowledge, different framing of problems and construction of methods; acknowledging that the aim is problem setting and problem solving rather than doing interdisciplinary work for its own sake; and, availability of intermediaries which are not necessarily people but can also be processes.

In an interdisciplinary research we meet a lot of barriers, as:

- there are a number of epistemological challenges, notably the persisting disciplinary silos with regard to: the understanding of what constitutes knowledge and what is seen as legitimate methods for producing new knowledge;
- the intellectual traditions, and
- problem definitions.

Disciplinary experts tend generally to regard fields other than their own with considerable suspicion – spurious at worst, at best irrelevant. More, there are several institutional barriers to interdisciplinary working, such as: research and educational funding mechanisms, institutional practices, research assessment exercises, journals' publication strategies, refereeing processes, and so on.

As target example we considered the thermal therapy based on laser pulse. The numerical results obtained in thermal simulation of the skin tissue can be used for computation of other physical quantities: the corresponding thermal damage and thermal stress fields [4, 5]. The effect of blood perfusion rate on temperature distribution can be analyzed. It is known that blood perfusion rate has a significantly larger influence on temperature distribution during cooling than that during heating. In general, the skin temperature decreases with an increasing blood perfusion rate.

Laser interaction with tissues is based on several mechanisms [3] which include photo-thermal, photo-mechanical (or photo-acoustical), photo-chemical and photo-ablation (achieved using short pulsed lasers). We limited our analysis to a laser heating using a controlled pulse or in the tissue subjected to a flash fire.

The results of the numerical simulation of the skin tissue using the bioheat equation can differ by the real data. The reason of this difference is that destruction of tissue during heating has not any effect on parameters values in the numerical model. In reality, the high values of temperature can lead to dangerous phenomena in skin tissue. Thus, when tissue temperatures reach 60 to 65°C, proteins are denatured and tissue necrosis can be expected. Over 100°C, water in tissue changes phase, increasing pressure in tissue resulting in explosive vaporization and shutting down the vasculature (thrombosis). When temperature is above 150°C proteins are broken down, releasing hydrogen, nitrogen and oxygen, leaving layer of carbonization. These natural phenomena can be estimated. Tissue damage could be predicted by means of an Arrhenius integral formulation and the perfusion coefficient is dependent on the tissue injury integral. A formula for this estimation must include two clinical aspects: perfusion rate increases as tissue is heated and vasodilatation occurs, and blood flow decrease as the vasculature begins to shut down (thrombosis).

In a real analysis of the thermal responses of the skin, the numerical results must be compared with measured results and an improvement of the mathematical model must be accomplished. Measurement of temperature rise in tissues during thermal therapies as laser irradiation helps determine the size of the heat affected zone, but it does not show the extent of cellular damage produced during laser irradiation. A detailed histological study is therefore required to correlate energy input, temperature rise, and the extent of cellular damage.

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