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Influence of the fat layer, size, metabolism, and blood perfusion of thyroid tumors on the surface temperature of a human neck

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Abstract

Thyroid cancer is most common in the head-neck region. One of the most promising and non-invasive ways to identify this disease is thermography. The main objective of this work is to numerically simulate the process of bioheat transfer in the neck region, thus obtaining its temperature field and the behavior of its surface temperature. Parameters such as a fat layer, nodule size, blood perfusion, and metabolism are analyzed. Prior knowledge of the behavior of surface temperature as a function of these parameters is essential in applying thermal imaging for the detection of neck cancer.

1. Introduction

The thyroid is a butterfly-shaped gland located in the neck. Your Its primary function is the regulation of basal metabolism, which can also influence blood pressure, muscle tone, and heart rate. Its disorders can be hypo and hyperthyroidism, goiters, benign nodules, and cancer.

The unrestrained proliferation of tumors is one of the significant causes of death in this day, mainly due to the recent growth and aging of the population.

According to [1], thyroid cancer is the type of most common cancer in the head-neck region. The main diagnostic techniques for thyroid tumors are scintigraphy, ultrasonography, needle aspiration puncture (FNA), tomography, X-ray, and magnetic resonance imaging. Although these techniques are the most used to diagnose thyroid tumors, they have limitations such as high cost and the presence of radiation. Thermography is a non-contact, non-invasive, non-traumatic, and simple mapping of body temperature.

The main objective of this work is to numerically simulate the heat biotransfer process of the affected neck of a thyroid nodule. Thus, it is possible to observe the thermal behavior of the neck surface as a function of several thermophysical parameters, comparing them with thermal images obtained from an infrared camera.

2. Methodology

The present work shows a numerical simulation in the COMSOL software environment to simulate the surface temperature distribution of the human neck affected by a thyroid nodule. To this end, a three-dimensional geometry was developed, which represents the neck with its main components: skin, fat layer, muscle, and thyroid gland, in addition to the thyroid tumor. Each component has different values for the main thermophysical parameters, as shown in Table 1. The parameters presented are found in [2] and [3].

Table 1. *Thermophysical parameter*

Parameter	skin	fat	Muscle	Thyroid	Nodule	Unity
Thermal conductivity	0.37	0.21	0.47	0.52	0.89	W/(m.K)
density	1109	911	1090	1050	1050	kg/m^3
specific heat	3391	2348	3421	3609	3770	J/(kg.K)
Arterial temperature	37.0	37.0	37.0	37.0	37.0	°C
Blood perfusion	0.00196	0.000501	0.000708	0.098	0.465 (0.98)	(mL/s)/mL
Metabolism	1829.85	464.61	1046	4200	2455386.6 (122769.33)	W/m^3

The simulation is carried out in three stages. Initially, the neck is considered in equilibrium with the ambient air. Then the neck is subjected to cooling for 5 min (300 s), and then the metabolism itself reheats it for 17 min (1020 s).

Temperatures are compared for different simulation conditions: fat layer thickness, nodule size, nodule metabolism and blood perfusion parameters. The fat layer varies between 0, 3 and 6 mm; the different sizes of the nodule are $(0.003\text{x}0.004\text{x}0.011)$ m, $(0.006\text{x}0.008\text{x}0.015)$ m and $(0.012\text{x}0.010\text{x}0.019)$

3. Results and Conclusions

The simulations developed had as standard configuration the model that had a fat layer of 0 mm; the nodule of size $(0.012\text{x}0.010\text{x}0.019)$ meter; tumor blood perfusion of 0.465 (mL/s)/mL and tumor metabolism of 2455386.6 W/m^3. The default configuration was maintained for studying each of these parameters, and the tested property was varied.

Surface temperatures were collected at a point previously defined. Some analyses also included a counter collateral point; its location is symmetrical concerning the neck symmetry axis.

The results obtained are shown in Fig. 1.

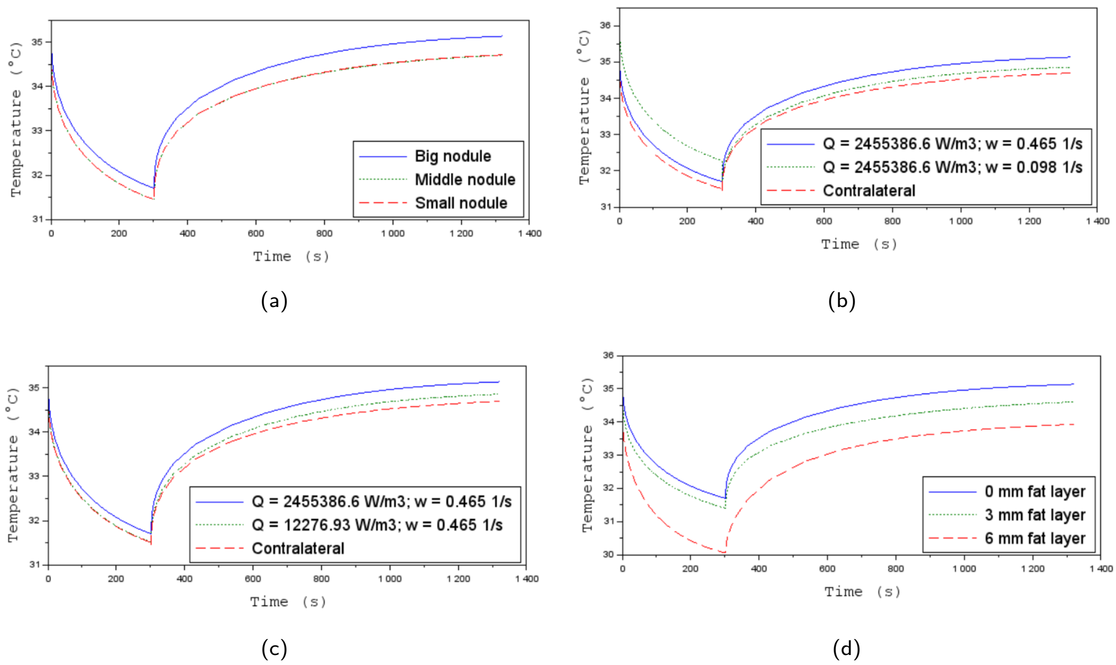

Fig. 1. *Surface temperature evolution in the neck: (a) Temperature for different tumor sizes; (b) Temperature for various perfusions; (c) Temperature for various combinations of metabolism; (d) Temperature for different thicknesses of fat*

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It can observe in Fig. 1.a that the size of the nodule has a significant influence on the surface temperature of the neck: the largest nodule had a higher surface temperature when compared to the others. However, only this one presented a more significant temperature difference, being the temperature evolution of the nodules of sizes 2 and 3 practically the same.

Both blood perfusion and tumor metabolism showed similar behaviors, as shown in Figs. 1b and 1c: the higher the parameter studied, the higher the surface temperature presented in the neck.

It is observed in Fig.1d that the greater the layer of fat, the lower the surface temperature of the neck. It is due to the low thermal conductivity of the fat, making this layer insulating and, thus, making it difficult for the heat to propagate from the tumor.

References

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