Nonhomogeneous Heat Transfer Simulation Using a Female Human Model

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Abstract

Previously researchers have modeled the human body using CAD software to create geometries that are approximately the same shape as the human body. While these CAD designs appear similar, they do not account for complex organ anatomy or sudden changes at the skin surface. Now, the human body can be better approximated by using medical imaging techniques to create a mesh of a human body where all the organs are mapped out. We can use this mesh to perform heat transfer simulations with the COMSOL Multiphysics® software to observe how variations to the environment can affect the temperature profile of the female human body.

The mesh used was a female torso with mapping of skin, fat, muscle, and organs. It was created from the XCAT phantom data set from Duke University (1) and segmented and processed in Simpleware ScanIP (Synopsys, Mountain View, CA). A heat transfer simulation was performed using the Heat Transfer module. Each of the organs was given a thermal conductivity, density, specific heat, metabolic rate, and blood profusion rate. All of the values are constant and were derived from the literature. Also, blood temperature was set to a constant 37°C and ambient temperature was set to 28°C.

Overall the simulation illustrated the difference in temperature throughout the human body as shown in figures 1 and 2. The average skin temperature was 32.5°C and its range was 30.1 to 34.7°C. At the skin surface, the minimum temperature was the same, but the maximum decreased to 34.0°C. In physiological research the internal core temperature is usually measured by intestinal or esophageal measurements. This simulation shows that the average intestinal temperature was 37.0°C, ranging from 36.1 to 37.2°C. Figure 3 illustrates how the intestinal temperature decreased in areas closest to the body surface. Esophageal temperature can be approximated as the heart temperature due to their proximity to each other. Here, the average, minimum, and maximum esophageal temperatures were 37.3, 37.0, and 37.5°C respectably. Overall the temperature of the heart does not change much.

The COMSOL Multiphysics® software can be used to simulate internal temperatures using the Heat Transfer module coupled with an anatomically correct human mesh. This technique can help advance physiology and better ways to help optimize human performance.

Disclaimer

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Reference

1. Segars WP, Bond J, Frush J, Hon S, Eckersley C, Williams CH, Feng J, Tward DJ, Ratnanather JT, Miller MI, Frush D, and Samei E. Population of anatomically variable 4D XCAT adult phantoms for imaging research and optimization. Med Phys 40: 043701, 2013.

Figures used in the abstract

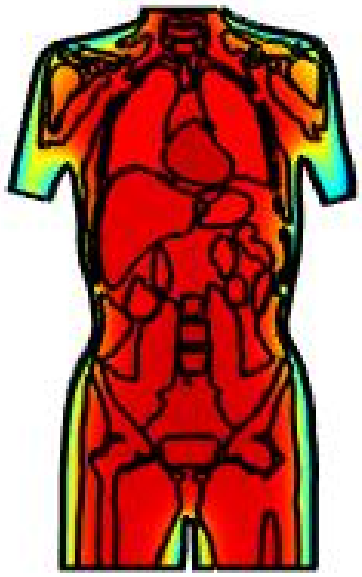

Figure 1: Steady state internal temperature cut of female model at ambient temperature 28°C