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Manifestation of Neurological Abnormalities Through Frequency Analysis of Skin Temperature Regulation

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•Fourier Transform analysis of small sample areas on hundreds of consecutively acquired digitized thermal images of the human back yielded thermoregulatory frequencies of skin temperature. In asymptomatic subjects the amplitudes of the contributing frequencies were relatively small (<0.2C) and the distribution of these frequencies over the human back was fairly uniform. Subjects with back pain showed significantly larger amplitudes (>1.0C) and the distribution of the regulatory frequencies was asymmetrical and non-uniform. Thermal stress invoked a more than tenfold increase in one of the regulatory frequencies in an asymptomatic subject. These findings have implications for diagnostic thermology.

Introduction

In most classical thermographic examinations, abnormalities are identified visually in pictorial representations of temperature distribution over the region of interest. Abnormally warm or cold regions and lateral asymmetry in skin temperature distribution indicate vascular or neurological disorders. Lateral asymmetry of 1C has been considered clinically significant.

In a preliminary study using a scanning infrared camera, we obtained digitized thermal images of the backs of patients with back pain. We found inconsistent temperature distribution patterns when the images were obtained at different times. Temperature distribution changed significantly in subjects with back pain (see Figure 1a) and in asymptomatic subjects (Figure 1b) within as little as one hour under a stable environment. Using a phantom, we found that the observed inconsistencies were not of instrumental origin. We then proceeded to follow the thermal distribution as a function of time, obtaining a digitized thermal image every 8 sec. Following the average temperatures of small areas of the backs of both symptomatic and asymptomatic subjects as a function of time revealed oscillations in all areas studied. This paper, which updates a recent preliminary report,* describes the quantitative analysis of these observations.

Experimental Setup

The amplitudes of the local fluctuations of the average temperatures of small areas (40 × 40 mm) on backs of asymptomatic subjects were found to be less than 1C. To measure such small temperature fluctuations reliably, we modified a commercial thermographic system** by installing an internal black body reference surface regulated to better than 0.01C. The image was calibrated against the reference every 16 msec—i.e., 256 times during each complete 4-second scan. Another black body, also regulated to better than 0.01C and used as an external reference, verified that the electronic drift of the average temperature measured over 0.6% of the total image area (400 pixels, with a thermal resolution of 0.08C) was <0.02C per hour.

We developed software to enable the system to repeatedly scan and store digitized images (64K per image) at a rate of 7.5 images per min. Other software developed conducts a statistical analysis of populations of temperature point values confined within prescribed boundaries. This software checks whether the pixels under consideration constitute a normal population.

Next we developed software that displays the average temperature of any designated area as a function of time (see Figure 2a). We then analyzed these time profiles using Fast Fourier Transform (FFT) to yield the characteristic frequencies of the temperature oscillations and their amplitudes (Figure 2b). These amplitudes represent the relative contribution of each frequency to the overall temporal behavior. The software was written in the C language and runs on a 386-based IBM AT clone.

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* Montoro J., Anbar M. Visualization and analysis of dynamic thermographic changes. 1st Conference on Visualization in Biomedical Computing. Proceedings IEEE Computer Society, Atlanta, May, 1990.

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