THERMAL DRIFT IN MICROWAVE THERMOGRAPHY

J. Shaeffer, Ph.D. and A. M. El-Mahdi, M.D., Sc.D.
Department of Radiation Oncology and Biophysics
Eastern Virginia Medical School
Norfolk, Virginia 23507

and

R. J. Bielawa, J. F. Regan, and K. L. Carr*
M/A-COM, INC.
Burlington, Massachusetts 01803

Abstract

Thermal drift in microwave thermography results from prolonged contact between a microwave antenna at one temperature and a subject at a different temperature. Appropriate antenna heating can minimize thermal drift, permitting more accurate temperature measurements.

Introduction

Passive microwave thermography is a noninvasive technique for the measurement of subcutaneous temperature. This technique has exciting clinical possibilities for the detection and diagnosis of pathologic conditions, including malignancy, in which there are disease-related temperature differentials, for following the clinical course (prognosis) of diseases with thermal differentials, and for the subcutaneous thermal mapping of patients receiving thermotherapy for malignant neoplasia.

The laboratory of Eastern Virginia Medical School is involved in the evaluation of the cancer detection capabilities of a microwave thermography system which uses a 4.7 GHz radiometer.[1] Preliminary clinical results in patients with known malignancies appear encouraging. Temperature differentials consistent with biopsy-proved malignancies were demonstrated in 19 of 23 cancers of the breast and lymph glands.[2]

One problem common to these studies, to those involving microwave thermal profiles in healthy male and female volunteers[3], men with and without varicocele and various studies with tumor models in animals, has been that of thermal drift which is the apparent change in the subject's temperature following prolonged contact between the subject and the radiometer antenna. This paper will present examples of thermal drift in patients and animals, define the extent of thermal drift in a water bath phantom, and demonstrate how thermal drift can be minimized by appropriate antenna heating.

Materials and Methods

Technical details regarding the microwave thermograph system have been published previously.[1]

The radiometer antenna was heated by either immersion in a controlled temperature water bath, or by using a strip heater attached directly to the antenna body. Antenna temperatures were measured by a platinum sensor mounted on the antenna body, and absolute temperature was displayed on a digital panel meter.

Results

Thermal drift may be positive or negative. An example of extreme positive thermal drift is shown in Figure 1. This microwave thermal measurement was taken on a 51 year old female patient with multiple nodules of breast cancer recurrent on her left anterior chest post mastectomy. A strip-heated (37.0°C) antenna was placed in contact with the tumor-bearing region on her incisional scar for approximately 2.2 minutes. The thermal drift in this case was about 1.2°C/minute as shown by the dashed line (Figure 1).

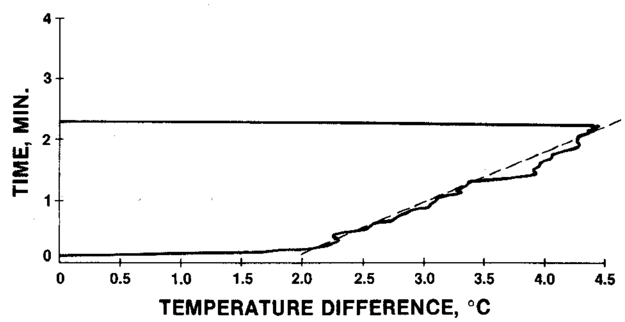

Figure 1

A level of thermal drift more commonly encountered is illustrated in Figure 2. This second patient was examined with the same antenna placed on the right breast for about 3.3 minutes. The thermal drift in this case was about 0.1°C/minute. The patient was a 58 year old female with a 3cm infiltrating ductal carcinoma in the upper outer quadrant of her right breast.

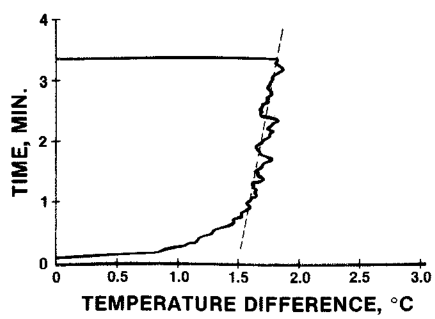

Figure 2

* Senior Member

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The face diameter of the strip-heated antenna used for the two previous patients is about 6cm, although the waveguide aperture is only 0.8 x 1.6cm. This 6cm face does not facilitate radiometric determinations on smaller laboratory animals, so a smaller (unheated) antenna with a face of 2.2cm was fabricated for this purpose. Negative thermal drift (Figure 3) resulted when this room temperature (24°C) antenna was used to measure temperature differentials from the VX2 carcinoma in the ears of New Zealand rabbits. Following an initial reading of about 1.1°C, there was a drop in temperature to a value of about 0.5°C within a 30-60 second contact between the antenna and ear (Figure 3).

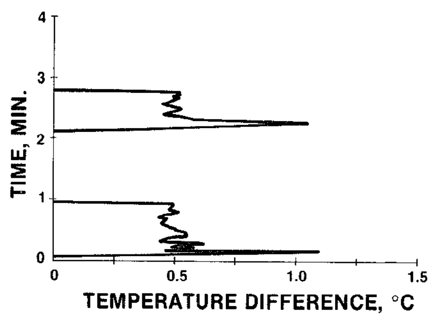

Figure 3

A series of experiments was conducted to evaluate the relationship between thermal drift, antenna temperature, and subject temperature. Results are summarized in Table 1. The antenna was heated from 25 to 37°C by water bath immersion in one bath, then transferred to a second bath (32, 34, or 36°C) and the thermographic reading of the second bath was recorded. Results shown in the table are the mean ± standard deviation of three determinations of thermal drift (°C/min) in the radiometric measurement of the 32, 34, or 36°C water bath temperature.

Discussion

As shown in Table 1, the thermal drift may be positive or negative depending on the nature of the thermal mismatch between antenna and subject. For each water bath, thermal drift is minimal when antenna and bath temperatures are approximately equal. Based on these considerations, another antenna was fabricated which had the advantage of being both small and temperature-controlled. From empirical experience, the optimal temperature setting which minimizes thermal drift for radiometric measurement on the "average" patient is about 34.6°C. This setting is too high, however, for measuring testicular temperatures when looking for varicocele by microwave radiometry. Antenna temperatures of 33.5-33.8°C were found to be optimal for testicular applications.

The magnitude of the thermal drift shown in Figure 1 (1.2°C/min) cannot be explained solely on the basis of thermal mismatch between a 37°C antenna and the subject, and is most likely explained by vagaries in the instrument and/or subject. Thermal drift of the magnitude shown in Figure 2 can be explained by thermal mismatch between antenna and subject, and can be eliminated or minimized by appropriate thermal matching of antenna and subject. The types of negative thermal drift shown in Figure 3 (also seen in testicular measurements using unheated antennae) have been eliminated by improvement in antenna design to

ANTENNA TEMP., °C	THERMAL DRIFT, °C/MIN.		
	32° BATH	34° BATH	36° BATH
25	0.09 ± 0.05	0.13 ± 0.01	0.14 ± 0.06
26	0.11 ± 0.04	0.08 ± 0.01	0.11 ± 0.01
27	0.08 ± 0.01	0.08 ± 0.03	0.11 ± 0.02
28	0.07 ± 0.03	0.07 ± 0.02	0.10 ± 0.02
29	0.05 ± 0.02	0.05 ± 0.02	0.09 ± 0.01
30	0.03 ± 0.02	0.04 ± 0.01	0.07 ± 0.01
31	0.02 ± 0.01	0.03 ± 0.01	0.07 ± 0.02
32	0.02 ± 0.03	0.02 ± 0.01	0.04 ± 0.01
33	0.01 ± 0.01	0 ± 0	0.03 ± 0.01
34	-0.01 ± 0.02	-0.01 ± 0.01	0.01 ± 0.01
35	-0.03 ± 0.01	-0.05 ± 0.01	-0.01 ± 0.01
36	-0.04 ± 0.01	-0.04 ± 0.02	-0.02 ± 0.01
37	-0.06 ± 0.01	-0.05 ± 0.02	-0.02 ± 0.02

Table 1. Thermal drift vs antenna temperature in subjects (water baths) at 32, 34, and 36°C.

allow for a smaller overall size with temperature regulation.

References

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(2) J. Shaeffer, A. M. El-Mahdi, and K. L. Carr, "Microwave Radiometry Thermal Profiles of Breast and Drainage Lymph Node Areas," IEEE 1981 Frontiers of Engineering in Health Care, pp. 102-104, September 1981.

(3) J. Shaeffer, A. M. El-Mahdi, and K. L. Carr, "Thermographic Detection of Human Cancers by Microwave Radiometry," presented at the International Symposium on Biomedical Thermology in Strasbourg, France, July 1981.