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30–4 Determination of Electromagnetic Heating Patterns in Human Tissues by Thermographic Studies on Phantom Models

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Quantitative information on the relative heating in human tissues due to various type EM (electromagnetic) energy sources is important in (a) optimization of diathermy heating modalities, (b) optimization of EM energy transfer for operating implanted prosthetic devices, and (c) establishing safe tolerance criteria for personnel exposed to powerful EM fields. Theoretical approaches to the problem are complicated by the complex geometries of human tissue structures. Point by point temperature measurements with thermistors or thermocouples are time consuming and tedious, and great care must be taken to prevent modification of the applied EM fields. Thermographic studies of electrically equivalent phantom models of human tissue structures have facilitated the acquisition and interpretation of these data.

Method. Phantom models having the same geometry, dielectric constant and electrical conductivity as human tissue structures are synthesized by epoxy resins loaded with carbon and titanium dioxide powder. Full size models of portions of the human anatomy may be used or scale models of portions or the entire body may be utilized by proper scaling of EM source and frequency and electrical conductivities of the model. The model is first pre-cut so that it can be separated along certain planes where information on both superficial and deep EM heating patterns is required. The model is then reassembled and exposed for a short time to the EM energy source. After exposure the model is quickly disassembled and the temperature pattern over any pre-cut surface can be observed and recorded by means of a Sierra Philco thermograph camera. Since the heating is applied during a five to thirty second time interval, the observation and recording is performed over a five second time interval, and the thermal conductivity of the model is low, the measured temperature distribution corresponds very closely to the relative heating distribution.

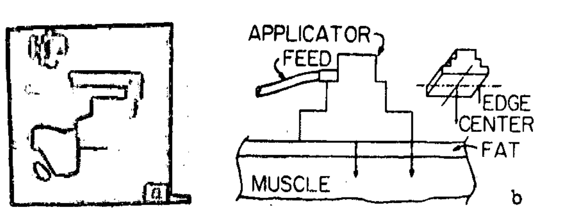

Fig. 1. Orientation of Applicator and Model

Applications. The application of the technique discussed here was the verification of the EM heating patterns in stratified subcutaneous fat and muscle layers due to an experimental diathermy modality. Fig. 1 illustrates the orientation of the 12 x 16 cm aperture diathermy applicator and the 25 x 25 x 8 cm phantom model during the heating mode. Theoretical relative heating profiles along the arrows in Fig. 1-b for various frequencies are given in Fig. 2. The maximum heating in the muscle was normalized to unity and the horizontal scale is given in centimeters. The problem here was the optimization of the deep heating in the muscle layer with minimal heating in the 2 cm thick fat layer. A series of thermograms taken of the phantom model after an application of 750 mc EM energy is discussed below.

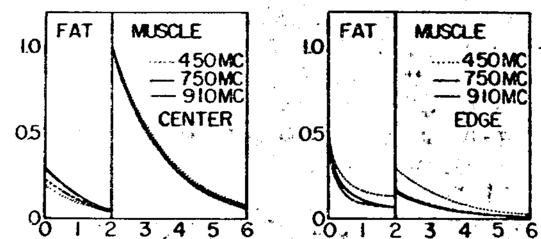

Fig. 2. Theoretical Heating Patterns of Model

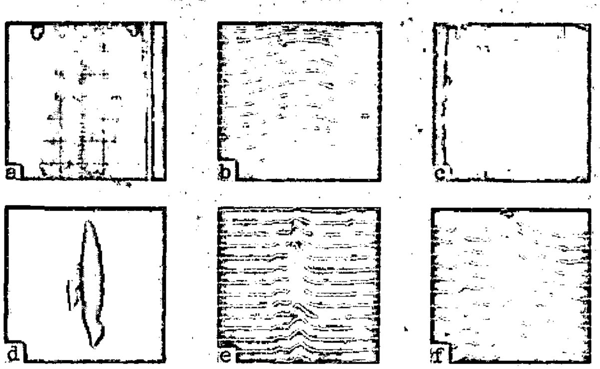

Fig. 3. 750 mc Heating Patterns in Model

Discussion. Fig. 3-a is a "C" scan (intensity proportional to temperature) taken of the model's surface, and Fig. 3-b is a "B" scan (vertical deflection proportional to temperature) of the same area. Fig. 3-c illustrates how the model is separated along the mid-section in a plane perpendicular to the stratified layers. Fig. 3-d is a "C" scan thermograph at the plane of separation of the right half of the model. Fig. 3-e is a "B" scan of the same plane and Fig. 3-f is a close-up "B" scan taken near the center line of the separated model. Note the reduced heating in the fat layer and the intense heating in the muscle near the fat-muscle interface. Except for a rounding of extreme temperature nulls and peaks due to conduction effects, the thermograms are closely related to the theoretical curves of Fig. 2. Although a simple planer geometry was discussed here, the technique can easily be applied to more complex tissue geometry.

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