Br. J. Cancer (1982) **45**, Suppl. V, 93-94

A QUANTITATIVE SIMILARITY BETWEEN SOME BIOLOGICAL EFFECTS OF ULTRASOUND AND MICROWAVES

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THE 10TH L. H. GRAY MEMORIAL CONFERENCE, being dedicated to "Biological Action of Radiofrequency Microwave and Ultrasonic Radiations", has given us the opportunity to continue a discussion begun 7 years ago. Two independent sets of events had occurred to initiate that discussion: the enunciation of the microwave standard for operation of microwave devices in the vicinity of human activity (American National Standards Institute, 1974) and the accumulation of sufficient data on ultrasonic bioeffects to allow speculation on safe use in clinical diagnosis (Reid & Sikov, 1973). The present authors had observed that a remarkable similarity might exist among the exposure dose–biological effects responses to these two forms of energy. The occasion of the Gray Conference, and the seeming division of the participants' interests and session topics into acoustical and electromagnetic subjects, respectively, prompted us to renew the discussion.

The discussion is associated with the Figure, in which the American Institute of Ultrasound in Medicine (AIUM) Statement and the Microwave Standard are portrayed. The Statement adopted by the Biological Effects Committee of the AIUM is, in its entirety (AIUM, 1977, 1978), as follows

STATEMENT OF MAMMALIAN *IN VIVO* ULTRASONIC BIOLOGICAL EFFECTS

In the low megahertz frequency range there have been (as of this date) no independently confirmed significant biological effects in mammalian tissues exposed to intensities* below 100 mW/cm². Furthermore, for ultrasonic exposure times† less than 500 seconds and greater than one second, such effects have not been demonstrated even at higher intensities, when the product of intensity* and exposure time† is less than 50 J/cm².

*Spatial peak, temporal average as measured in free field in water.

†Total time; this includes off-time as well as on-time for a repeated-pulse regime.

The significant points of the statement are that mammalian systems are involved, *in vivo* exposures only are included, and independent confirmation of reports is necessary. Whilst the statement provides a terse and compendious rendering of a huge literature, the appearance of new data may require its modification since: (1) most of the data on which, the statement is based are from mammals other than man and extrapolation to man is not always a clear and straightforward procedure; (2) the influence of exposure parameters such as pulsing conditions and acoustic frequency are not included; and (3) the most sensitive biological tests may not yet have been employed. Nevertheless, as can be seen from the Figure, the AIUM Statement provides a graphic declaration of confirmed *in vivo* mammalian biological effects.

The Microwave Standard, also shown in Fig. 1, embodies the ANSI (1974) and OSHA voluntary standard for continuous

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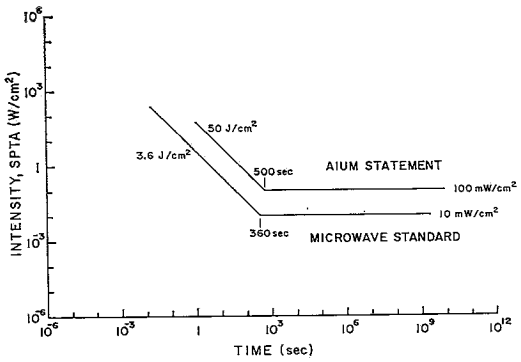

FIGURE.—Graphic representation of the AIUM Statement and the Microwave Standard.

occupational exposure to microwaves of 10 mW/cm² and the time-dependent region for exposures of less than 6 min.

The microwave standard includes a safety factor of about 10. The human tolerance to total-body irradiation is considerably less than that resulting from partial-body irradiation.

A further reduction of the microwave standard is anticipated in the "resonance range"; from 30 to 300 MHz is suggested. Considerably higher specific absorption rates can exist than anticipated without the resonance phenomena which occur when body dimensions compare with half a wavelength. The same limitations quoted above for the acoustic standard apply also to the microwave standard.

It is clear that, with the experimental precision extant, the 2 forms of energy yield the same dose–response relationship, in the intensity–time domain shown in the Figure. It can be conjectured that this represents the same physical mechanism of interaction for both ultrasound and microwaves, *viz.*, the thermal mechanism. For ultrasound exposures of less than approximately 100 msec, the relationship describing threshold is, under certain circumstances, $It^{1/2} = 200$ W/cm² sec$^{1/2}$ (Johnston & Dunn, 1976) and represents influence from other than thermal mechanisms of interaction.

Thus the relationship between ultrasound and microwaves in producing biological effects is conjoined, at least for thermal events.

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