BIOLOGICAL TISSUE IN A TIME VARYING ELECTROMAGNETIC FIELD

PRAFULLA KUMAR SHARMA

Centre for Biomedical Engineering

Thesis submitted to the Indian Institute of Technology, Delhi

for the award of the degree of

DOCTOR OF PHILOSOPHY

Department of Electrical Engineering

Indian Institute of Technology, Delhi

1978

CERTIFICATE

This is to certify that the thesis entitled "BIOLOGICAL TISSUE IN A TIME VARYING ELECTROMAGNETIC FIELD' being submitted by Mr. Prafulla Kumar Sharma to the Indian Institute of Technology, Delhi, for the award of the degree of Philosophy of the Indian Institute of Technology, Delhi, is a record of bonafide research work carried out by him under my supervision and guidance, and to my knowledge, has reached the standard fulfilling the requirement of the regulations relating to the degree.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

SKGuha

(S.K.GUHA)
Professor
Biomedical Engineering
Indian Institute of Technology
New Delhi

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to his thesis supervisor Prof. Sujoy K. Guha for introducing him to the field of Biomedical Engineering. It is difficult to put in words the appreciation he has for Professor Guha for the valuable guidance and incessant help, which he received from him throughout the period of research.

The author is thankful to Professors S.K. Kacker and P.Ghosh, Department of Otolaryngology, All India Institute of Medical Sciences, New Delhi for helping him in the surface specimen technique, conducting clinical trials and for their thought provoking discussions on auditory research. Thanks are also due to Mr. Rajpal and his team for assisting in audiometric evaluations of patients.

The author wishes to thank his colleagues for having created a congenial atmosphere in the laboratory. The author is also grateful to his numerous friends and well wishers who encouraged and helped him in many ways.

The author is grateful to his family members for being understanding and considerate.

Thanks are also due to Mr. T.N.Gupta for doing an excellent job of typing.

Prafulla Kumar Sharma

(Prafulla Kumar Sharma)

ABSTRACT

A survey of literature reveals that low frequency electromagnetic fields have a definite effect on biological systems. A critical examination of the few well documented, past studies shows that electrotherapy has been used extensively from time to time and tall claims of its beneficial effects have been made by clinicians, scientists and engineers. The main lacuna of all past studies has been that no proper correlation of various underlying principles of the two divergent fields, that is, biology and physics, has been made to investigate the interaction of electrical currents with biological tissue and its pathological state. The other lacuna brought out is that whenever electrotherapy was proposed for its therapeutical benefits, its use was advocated for almost all types of body ailments without giving any consideration to its specificity of action to different body organs. The present study therefore, focusses attention on a specific organ, that is, the internal ear.

The internal ear is the region where mechanical energy is converted into electrical energy. It is speculated that this portion of the auditory system, and its pathology, is more amenable to external electric

currents effects than systems being controlled by purely hormonal means. A review of the past attempts to cure auditory afflictions shows that the following major lacunae exist: (i) adequate studies to assess the current densities in the auditory region due to external surface electrodes have yet to be carried out, (ii) sensori-neural deafness can be due to either cochlear lesions or retrocochlear lesions. In cases where electric currents have been used for curing this ailment, no attempts have been made to assess the efficacy of RF currents for these two types of pathologies separately and (iii) no plausible explanations have been suggested to elucidate the interaction of electric currents with such auditory pathologies.

To start with, the possibility of using a time varying magnetic field as therapeutic agent has been explored. For this purpose the head has been modelled as a combination of two cylinders. Quantitative analysis shows that for practicable magnitudes of magnetic fields the induced eddy currents are of such low magnitudes that the currents cannot be biologically effective. Therefore, for therapy, passage of electrical currents by hook-up to a signal generator has been suggested instead of inducing eddy currents by means of time varying magnetic fields.

Computations show that current levels carried by the cochlear region, due to external surface excitation electrodes, are of such magnitude that they preclude the possibility of thermal effects of electrical currents on hair cells. As an alternative, a hypothesis, based on electrostrictive effects of electrical currents on hair cell membrane, has been advanced. Various cochlear pathologies have been assumed to be the result of changes in cell shape of the hair cells. Also the manifestation of pathologies have been shown to fit very well with the model suggested. Theoretical calculations show that low level electrical currents, through dielectric effects on hair cell membrane, can lead to the desired changes in cell shapes. Two modalities are: (i) mechanical exercise effects mediated through cuticular free region of the hair cells and (ii) progressive sphericalisation of the elongated hair cells which build up the required neuro transmitter quanta storage for proper functioning of the hair cell. A few anatomical,physiological findings have been correlated to suggest a mechanism which elucidates the poor speech discrimination and the phenomena of recruitment and tinnitus due to pathologically elongated hair cells.

Using the guinea pig as the animal model, experiments were conducted to study interaction of electrical currents with cochlear cells to give some credence to the suggested hypothesis. Cochlear morphology was studied by surface specimen technique. The statistical analysis of cochlear cell data of animal experimentation shows that (i) low levels of RF current do not damage the normal cochlear cell organisation and the functional state of normal cells is also not impaired, (ii) current delays the effect of ototoxic drug on the cochlear cells and (iii) the drug damaged hair cells do not regrow due to electrical currents but their organisation is improved.

The results of the clinical trials show that (i) for cochlear afflicted cases, both, pure tone threshold (PTT) and speech discrimination score (SDS) improve significantly, (ii) different age groups respond differently to electric currents, (iii) the time variations in PTTs and SDSs have got a bearing on the proneness of a patient to improve with electrical therapy, (iv) patients having mixed pathology behave differently with increasing doses as compared to pure cochlea afflicted cases and (v) in general, apical regions of the cochlea are more affected by electrical therapy as compared to basal regions. Mechanisms to explain the preferential affinity of various regions of the cochlea to electrical currents have also been described.

Finally, limitations of the work are indicated and scope for further investigations in this area has been outlined.

CONTENTS