

SURVEY OF IMPLANTED ELECTRODES*

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Many types of electrodes are being used today for a wide variety of clinical purposes. Interest has focused on these electrodes, or more specifically, the electrode-tissue interfaces, because they constitute the true junction between the living tissue and the equipment being employed to study it. Whether the electrodes are being used to monitor potentials or to pass currents, their properties influence the interaction between the equipment used and the physiological system being confronted. Both the effectiveness of the attempted procedure and the actual safety of the patient depend upon our understanding the properties of the electrodes being used.

For example, much effort has been expended on developing electronic stimulators with well-controlled and isolated outputs, in order to safely and effectively present stimuli to the body. Yet, if these stimuli are delivered through an electrode of inadequate size, configuration, or material, or if the stimuli have inappropriate parameters, the stimulation may be ineffective in achieving the desired physiological results, and, at worst, may be actually injurious to the patient. Even in the case of passive recording of bioelectric potentials with adequate amplifiers, there exist possibilities for error and insult, since all metals must by thermodynamic necessity release some ions into the surrounding tissues, as well as interfacing with physiochemical elements capable of catalyzing nonbiological chemical reactions. These factors may, over time, result in perturbations of the normal physiological behavior of the surrounding tissues or of producing changes in the physical properties of the electrodes themselves.

A survey of clinical applications of electrodes reveals little consistency of usage. A variety of electrodes have been implanted in many different regions of the body, for varying lengths of time, though the tendency is

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toward longer durations. They are fabricated from a wide range of materials in a variety of sizes and configurations, and the techniques for their implantation and anchoring differ. When electrodes are used for stimulation, the parameters of the applied pulses differ widely. Undoubtedly, these inconsistencies will be further compounded by the increasing use of electrodes by a growing percentage of clinicians and by the proliferation of new techniques and materials in electrode use.

A critical review of clinical electrode applications at this time will, therefore, serve several practical purposes. It will provide a survey of the various factors involved in electrode applications and will allow a comparison and evaluation of these factors, so that it will be possible to determine the best methods presently available to accomplish specific clinical objectives. It will serve to define the areas in which electrodes are now used, and to identify the areas which are currently the most active. It will help to project future developments. In addition, it will serve to improve communication between workers in this field.

Our review is being carried out through the Brain Information Service at UCLA. The survey of implanted electrodes is based on a comprehensive search of the literature which started first with the Brain Information Service data tapes. This was followed by a full Medlars search and searches of the data bases from the Bioresearch Index and from Biological Abstracts. Compendix was also searched, as was the Defense Documentation center. This latter source would produce the "AD" type [Astia Document, Astia now changed to NTIS] references. Odd and even Chem Abstracts and the Government Reports Announcements data tapes were searched, as were those from SPIN, the tapes from the American Institute of Physics, and NASA. Finally, selected bibliographies were solicited from a number of workers.

The search of these ten computerized data bases is completed and has yielded slightly over 10,000 references. These have now been screened and categorized, and the bibliography itself is finished. The review is presently being written. This will be introduced by a discussion of the properties of the electrode-tissue interface which influence electrode behavior, and the ways in which various electrical waveforms passing through the interface affect it. The review will then deal successively with electrodes used for monitoring bioelectric potentials and with electrodes used to pass current. Since at present a major area of emphasis concerns stimulation, the greatest detail of the review will be placed here.

Each section of the review will deal specifically with the questions of what is being attempted, what techniques are in use, and what successes and failures are being encountered. The final section will deal with new materials and techniques which may play a significant role in future electrode technology.