PRODUCTION OF FOCAL DESTRUCTIVE LESIONS IN THE CENTRAL NERVOUS SYSTEM WITH ULTRASOUND*

W. J. FRY, M.S., W. H. MOSBERG, JR., M.D.,†
J. W. BARNARD, Ph.D. AND F. J. FRY, M.S.
Bioacoustics Laboratory, University of Illinois, Urbana, Illinois
(Received for publication May 26, 1954)

With the contemporary development of surgical methods of treating the symptoms of painful, psychiatric, and basal ganglion disorders, the neurosurgeon is frequently called upon to produce a focal destructive lesion in the nervous system. The universal and obvious objective is to create a localized lesion in the desired area with no damage to adjacent or intervening tissues. Recorded experiences of neurosurgeons attest to the fact that this ideal has not yet been attained. Paraparesis and bladder dysfunction following anterolateral chordotomy, vegetation following prefrontal lobotomy, and hemiplegia following surgical treatment of basal ganglion disorders are examples of damage to adjacent tissues known to all neurosurgeons. Damage to blood vessels (including those within the site of the lesion) at time of operation may increase the operative morbidity and render it impossible to evaluate the effect of a focal ablation. Stereotaxically placed electrocoagulative lesions have frequently resulted in death from hemorrhage.

As the result of animal experimentation1–4,6 we believe that the use of ultrasound in making human focal destructive lesions will overcome some of these objections. A focussed beam of ultrasound can be used to produce selective, accurately localized lesions in the central nervous system which are quantitatively reproducible from one animal to another. Discrete lesions can be produced without destruction of blood vessels. A lesion in the depths of the brain can be effected without disturbance of intervening tissue. Accurate localization is accomplished by focussing a fine beam of ultrasound in the region to be treated. The nature of the destruction depends upon the intensity and duration of the exposure.

The term “ultrasound” refers to sounds whose frequency (pitch) is above the range of human audibility (15,000 to 20,000 cycles per second). Most of the work up to the present time has been accomplished at a frequency of one

* Partially supported by Contract Nonr 336(00), NR 119-075 with the Physiology Branch of the Office of Naval Research.
† Department of Neurological Surgery, University of Maryland School of Medicine, Baltimore, Maryland.
million cycles per second. In addition to its frequency a sound is characterized by its intensity (loudness) which is measured in watts/cm.². The sounds used in producing the lesions to be described are more intense than any sounds that we experience. Indeed the sounds are of a sufficiently high intensity that they must be transmitted through a liquid medium. Sound intensities used in these experiments have been in the range of 50 watts/cm.² to 1000 watts/cm.².

The sound is generated by a quartz crystal excited electrically to vibrate in resonance. The sound is focussed by a polystyrene lens placed in front of the vibrating crystal. Focussed beams of sound as small as 1.5 mm. in diameter are readily attained. Transmission of the sound from the lens to the tissue is accomplished through physiological saline. This liquid must be degassed by boiling to prevent the formation of bubbles which would interfere with acoustic transmission at the high intensities used in these experiments. The bone overlying the region of the central nervous system through which the sound is to enter must be removed in order to eliminate absorption by the bone, which causes local heating, and to insure a well defined focussed beam in the nervous tissue.

In the animal experimentation to date the animal's head has been supported in a standard stereotaxic apparatus, and the head held rigidly in position in the machine. Localization of the focal spot in the region of the brain to be affected is determined as follows: Before the animal is placed in the apparatus a pointer attached to the irradiator (vibrating crystal, lens, etc.) and coinciding with the focal spot of the irradiator is positioned on the midline of the apparatus and is collinear with the line through the bars which support the skull of the animal at the ears. The coordinate values on the system that supports the irradiator are read corresponding to this ear-bar zero. One can then transform the coordinates from the stereotaxic apparatus to the coordinates of the system supporting the irradiator. The pointer is then removed from the irradiator and the animal is mounted in the stereotaxic machine. The soft tissues are then incised over the appropriate area of the nervous system and the bone is reflected or removed. The dura mater need not be opened. In practice a flanged cap which is used to contain the physiological saline, which acts as a transmitting medium for the sound, is tied to the skin of the animal. At this time irradiation with ultrasound is carried out.

In order to produce a lesion beneath the surface of the brain or spinal cord without damage to intervening nervous tissue, it is necessary to use an irradiator that produces a beam the intensity of which decreases very rapidly as one moves away from the center of the focal point. One of the ways in which this has been realized is by coupling together four single beam focussing irradiators with suitable adjustments to make the four beams intersect at a common point (Fig. 1). Although the distance from the face of the irradiator to the focal point is fixed (7.5 cm. for the irradiator illustrated), the depth of the lesion in the tissue may be varied by moving the irradiator ver-