STUDIES OF TRIGEMINAL NERVE POTENTIALS
IN NORMAL COMPARED TO ABNORMAL
EXPERIMENTAL PREPARATIONS*

ROBERT B. KING, M.D.,† JOHN N. MEAGHER, M.D.,
AND JOSEPH C. BARNETT, M.D.

Division of Neurological Surgery, Department of Surgery, Washington
University School of Medicine, St. Louis, Missouri

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Succesful operations for the relief of trigeminal neuralgia were initially
developed on the basis of anatomic studies of the trigeminal sys-
tem. However, current modifications in the surgical treatment of tic
douloureux suggest that altered physiologic properties of the 5th
cranial nerve may be responsible for the clinical successes reported following
these modified procedures. Therefore we have undertaken an experimental
study of the trigeminal system using electrophysiologic techniques.

Three phases of investigation have been initiated: an electrophysiologic
survey of the evoked potentials in the trigeminal system of normal cats and
monkeys; the preparation of a chronic syndrome in cats characterized by
over-reaction to tactile facial stimulation with an electrophysiologic study
of this altered trigeminal system; and a study of trigeminal nerve potentials
in patients with and without tic douloureux. If any portion of the results of
the first two phases have a bearing on the clinical syndrome of tic douloureux,
such a correlation will depend entirely upon the results of the third phase
of the study.

Electrophysiologic studies of evoked trigeminal potentials in normal cats
have been reported. The present study of the second phase of this prob-
lem is based on observations obtained in experiments on 5 normal monkeys
and 30 normal cats compared with 17 chronic cat preparations.

METHOD

Several techniques were employed in attempts to produce a laboratory
animal with chronic over-reaction to tactile stimulation of the face. Thoro-
trast* and penicillin in oil injected into the gasserian ganglion occasionally
gave mild hypesthesia. Commercial alumina gel injected into the main
sensory nucleus of V caused no over-reaction to stimulation. Alumina gel
injected into the gasserian ganglion caused slight hypesthesia initially which
gradually diminished and 6 to 8 months later facial stimulation was associ-

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* Lestagar and Co., Inc., Detroit, Michigan.
ated with intermittent weak pawing of the operated side in 2 out of 6 animals. It seemed evident that these 2 animals were experiencing a mild abnormal sensation. However only when 0.02 to 0.03 cc. of a weak alumina gel suspension was injected into the spinal nucleus of V, did tactile facial stimulation cause a striking and abnormal response.

The recording system for evoked potentials in these animals is illustrated in Fig. 1. Using a Grass stimulator and isolation transformer single monophasic stimuli of 0.01 msec. duration were applied to the infra-orbital nerve, and increased in voltage from that required to evoke a threshold to that required for a maximum response in the 2nd division of the trigeminal nerve. Bipolar steel electrodes with uninsulated tips measuring 60 to 80 μ in diameter were placed in the 2nd division of the trigeminal nerve, the gasserian ganglion, the main sensory nucleus, and the trigeminal spinal nucleus and tract. A conventional push-pull amplifier with oscilloscope was used. Light Surital* anesthesia, Anectine† and artificial respiration were employed.

RESULTS

Recordings from the 2nd division, gasserian ganglion, and posterior root of a normal cat following stimulation of the maxillary nerve are illustrated in Fig. 2. The afferent potential (a) immediately follows the stimulus artifact. A delayed potential (b) can also be seen, lasting approximately 10 msec. It is activated at thresholds corresponding to touch fibers and has received particular attention in the course of these and earlier studies.12

In Fig. 3 (monkey) the potentials were recorded in the 2nd division in

\* Parke-Davis and Co., Detroit, Michigan.
† Burroughs Wellcome and Co. (U.S.A.) Inc., Tuckahoe, N.Y.
Fig. 2. Recordings following stimulation of the infra-orbital nerve of a normal cat, showing maximum responses of the evoked trigeminal potentials from the 2nd division, gasserian ganglion and posterior root. The evoked afferent spike potential (a) is followed by a delayed potential (b) which is conducted centrifugally and lasts approximately 10 msec.

The middle fossa and spinal V. The afferent spike can be clearly seen (a) with a delayed potential following it (b). In spinal V the afferent spike is again illustrated (a) with delayed activity (b). A tractotomy was performed in this animal at a level 2 mm. above the obex of the 4th ventricle and 2.0 mm. caudal to the spinal V recording electrode. Following the tractotomy, although the afferent spike (a) is still clearly evident, the delayed activity is markedly reduced or absent. Posterior root section also abolishes this delayed activity in the peripheral nerve. These two features indicate centrifugal conduction of the delayed activity into peripheral components of the trigeminal nerve from a source between the lower medulla and the upper cervical region.

After the evident source of this activity was identified within the caudal portion of the spinal trigeminal system, the second phase of the study was initiated.

An alumina gel suspension was injected into the caudal portion of spinal V in cats. The majority showed no immediate after-effect. Some vestibular imbalance was noted in 3 preparations. One to 2 months later they began to lose hair from the eyebrow and the upper lip homolateral to the side of injection. The cleansing ritual was neglected and thin incrustations accumu-
Fig. 4. A dilute suspension (0.03 cc.) of commercial alumina gel was injected on the left side into the caudal portion of spinal V below the obex of the 4th ventricle 4 months before these pictures were made. Series 1 indicates the normal response following light tactile stimulation on the right. Series 2 indicates the brisk onset and prolonged over-reaction which follows similar stimulation on the left. Consecutive frame letters indicate a deletion of every second frame from the original movie film. The interruption of consecutive lettering in Series 2 indicates further deletions between 2-B and 2-O.
lated on the inner canthus and nose of that side. The corneal reflexes remained equal.

Approximately 3 months following injection, these animals developed marked over-reaction to tactile stimulation on the side of the face corresponding to the side of the alumina gel injection (Fig. 4:2). Trigger points could be demonstrated in that the blunt end of a pin touched very lightly to a few hairs at the inner canthus or lateral to the nares on that side caused a brisk squint, twitch and withdrawal. Frequently the animals pawed at

![Image](image_url)

Fig. 5. Alumina gel lesions in the medulla of 6 chronic over-reactive cats are illustrated in sections A–F. Sections, G, H and I are 3 of a series of control lesions. Sections G and I are sections in the region of the main sensory nucleus and in section H the lesion is ventral to spinal V. Each illustration has been chosen from the portion with the largest diameter. Sections A–F were made 4 to 5 months after the injections were made. The control sections were examined after an 8- to 12-month period of observation.

the air on the affected side. Such a response could also be elicited occasionally from the 3rd division and from the anterior portion of the external ear, although never from the posterior two-thirds of the ear. Two apparently spontaneous paroxysms of this character have been observed. No such response was elicited on the uninjected side (Fig. 4:1).

Ultimately the animals avoided all contacts with the affected side of the face, and would not eat. Warm milk brought in contact with the whiskers was vigorously avoided. At this point they were maintained on parenteral fluids and tube feedings to prevent rapid deterioration.

Sections A–F of Fig. 5 illustrate lesions from 6 such chronic animals. In each instance the sections have been chosen from the region of maximum diameter of the lesion. In each, the lesion involved the nucleus of spinal V.
No animal to date with a verified injection of alumina gel into spinal V (that has lived 3 months) has failed to show this abnormal response. Sections G, H, and I represent 3 of a series of control preparations. The control preparations G and I demonstrate alumina gel lesions in the region of the main sensory nucleus. In Section H, the alumina gel was placed ventral to spinal V. None of these preparations developed any abnormal response to tactile stimulation.

Evoked potentials from the 2nd division of the trigeminal nerve in the middle fossa in 3 normal cats are shown at the top of Fig. 6. Recordings in

![Fig. 6. Recordings from the 2nd division of the trigeminal nerve in the middle fossa following stimulation of the infra-orbital nerve. The four on the left were obtained at a slower time line than the two on the right. Three normal records are illustrated above and 3 from chronic preparations with marked over-reaction to tactile facial stimulation are shown below. That in the right-hand lower corner was recorded from the preparation shown in Fig. 4. There is a clear increase in the amplitude of the delayed activity (b) in the lower records compared to the control records above.](image)

the lower line are from 3 cats in which alumina gel had been injected into spinal V. Each of these 3 preparations demonstrated over-reaction to tactile facial stimulation (as in Fig. 4:2). The delayed potential varies from 60 to 80 per cent of the amplitude of the afferent spike in the experimental chronic animals in contrast to 10 to 25 per cent of that size in the normal animals.

From a clinical standpoint it is of some interest that in a chronic animal with violent over-reaction to tactile stimulation, mild contusion of the gasserian ganglion was followed by a normal response to tactile facial stimulation without demonstrable hypesthesia. At the end of a 2-week observation period histologic examination confirmed the location of the alumina gel in spinal V and showed mild chromatolysis and round cell infiltration of the gasserian ganglion.

In other chronic preparations it has been a common observation that mild trauma to the ganglion caused by repeated electrode placement will markedly reduce or abolish entirely the unusually high voltage delayed activity.

**DISCUSSION**

These animals appear to experience an unpleasant sensation following tactile stimulation. The interpretation of this behavior must be guarded.
Injection of alumina gel into the main sensory nucleus, which is the primary touch fiber relay station, fails to produce this reaction. Injection into spinal V, on the other hand, consistently produces this response, despite the very limited representation of touch in this center.  

In these apparently oversensitive animals, there is a 300 to 600 per cent increase in the recorded voltage of the centrifugally conducted delayed activity in the peripheral divisions of the trigeminal nerve. The source of this activity is in the region of the subnucleus caudalis of spinal V and although it has been seen to increase in amplitude with greater stimulation, it is first activated at the same threshold as are touch fibers in the peripheral trigeminal nerve.  It may be that under these circumstances the increased voltage of the delayed activity in the peripheral trigeminal nerve and the over-reaction to tactile facial stimulation reflect increased activity at the central terminus of those touch fibers which do synapse in spinal V.

As the primary pain relays for the face are known to be centered in spinal V, it is possible that components of the touch and pain modality mechanisms have been altered in these chronic preparations so as to allow induction of a painful sensation by tactile stimulation. Under abnormal conditions of increased neural activity in the nucleus caudalis then, the larger touch fibers may transmit delayed potentials of higher voltage as direct evidence of the increased neural activity at the source of the delayed potential.

Under these circumstances, with over-reaction to tactile facial stimulation and increased voltage in the delayed activity, a direct correlation between the two phenomena may not be justified. The change in the delayed activity in the peripheral nerve may not relate primarily to the animals’ altered behavior. The increased neural activity in spinal V may relay to higher centers in the thalamus or even cortex and the over-reaction to tactile stimulation may require that the secondary cephalic relay be intact.

Preliminary recordings of thalamic potentials however have shown no difference in amplitude or duration of single evoked thalamic responses in the acute compared with a limited number of chronic over-reactive preparations. Decerebration at the superior colliculi has not altered the delayed potential in the peripheral nerve in acute preparations but has on the other hand abolished the over-reaction to facial stimulation. This phase of the study is under investigation at the present time using modifications of the techniques described in this report and acute rather than chronic over-reactive preparations.

An altered neural mechanism in spinal V alone does not seem adequate to explain all of our observations. Mild trauma to the trigeminal nerve in the region of the gasserian ganglion markedly reduces or abolishes the unusually high voltage delayed activity in chronic preparations and can eliminate the over-reaction to tactile facial stimulation in these cats. After such trauma, there is no gross evidence of hypesthesia to account for the decrease in sensitivity. Furthermore, the threshold for an afferent evoked potential remains unchanged in the same division of the trigeminal in which the de-
layed activity is no longer apparent. It may be, therefore, that the delayed activity that is conducted centrifugally from spinal V alters the state of excitability of cutaneous end organs and thereby alters the normal response to tactile stimulation through its influence at the sensory end organ. Such an influence at present must remain conjectural.

SUMMARY

1) We have presented some observations made during electrophysiological studies of the trigeminal system in normal cats and monkeys.

2) An afferent spike recorded in the peripheral trigeminal component is followed by a delayed potential which arises from spinal V between the first cervical segment and the lower medulla. A portion at least of this delayed activity is activated at touch thresholds and is conducted in a centrifugal direction from the brain stem back into the peripheral elements of the trigeminal nerve.

3) Over-reaction to tactile stimulation of the face has been produced in chronic preparations by injection of alumina gel into the caudal portion of the spinal tract and nucleus of the trigeminal nerve. In these animals a marked increase in voltage has been noted in the centrifugally conducted delayed potentials in the trigeminal nerve.

REFERENCES