Secondary Projections from Trigeminal Nucleus Caudalis in Cat Rendered Overreactive to Tactile Facial Stimulation

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Noxious stimuli applied to the fields of the peripheral receptor of the trigeminal nerve are relayed in nucleus caudalis of the trigeminal spinal complex. Clinical observations incident to spinal V tractotomy have affirmed consistently the participation of this relay in the appreciation of painful stimuli in man. However, studies utilizing single-unit techniques of recording have failed to establish the presence of neurons in nucleus caudalis that respond specifically to noxious stimuli. This dichotomy of clinical and experimental observation serves to emphasize the complexity of the neuronal mechanism subserving noxi-perception.

It has been suggested that the primary neurons of relay are not specific in modality but rather act as "common carrier cells" which relay and encode a pattern of peripherally evoked activity which is decoded and integrated centrally. Recent anatomic and physiologic studies suggest that the trigeminal input to certain regions of the midbrain and thalamus is relayed primarily through nucleus caudalis. These regions are the centrum medianum-intralaminar nuclear complex, portions of the substantia reticularis mesencephalicus, and pars magnocellularis of the corpus geniculatum medialis. To consider further characteristics of the trigeminal input to these loci, strychnine was applied to the surface of the medulla at the level of the trigeminal nucleus caudalis has been reported to induce marked behavioral overreaction to light mechanical deformation of facial hair and skin of cat. This preparation of strychnine was utilized to compare evoked responses in midbrain and thalamic loci dependent upon a nucleus-caudalis relay and those responses evoked by impulses relayed at all other levels of the trigeminal nuclear complex.

Methods

Fifty-two adult cats weighing 2 to 4 kg. were anesthetized with ether. After tracheostomy they were placed in a Johnson "210" stereotaxic frame. The infraorbital nerve, gasserian ganglion, lower medulla, and contralateral cerebral cortex were exposed. Rectal temperature was monitored and was maintained between 36°C to 38°C. with external heat. Bipolar silver-hook electrodes were placed on the infraorbital nerve for stimulation. Bipolar steel needles (1.0 mm. apart, 1 mm. offset and with exposed tips measuring 60-100 μ) were inserted with a micromanipulator into the ipsilateral trigeminal nucleus caudalis for stimulation or recording. Similar bipolar electrodes were used for recording at the ipsilateral gasserian ganglion and selected regions of the mesencephalon and diencephalon contralateral to the side of stimulation. Recording electrodes were positioned in subcortical regions using stereotaxic measurements adapted from the atlas published by Jasper and Ajmonc-Marsan. The electrical activity led from as many as three subcortical regions was observed in each preparation at approximately 0.2 mm. intervals during descent of the electrodes.

In establishing the adequacy of each preparation for study, the evoked response in nucleus caudalis and the gasserian ganglion incident to stimulation of the infraorbital nerve, and the evoked response at the gasserian ganglion incident to stimulation of nucleus caudalis were examined. The primary neuronal "spike" and a delayed centrifugally conducted potential at the
gasserian ganglion in each instance were identified. These responses confirmed that the stimulating electrodes at nucleus caudalis and the infraorbital nerve were positioned appropriately and that the preparation had sustained adequate blood pressure and respiration and little trauma to neural elements involved. With mild anoxia, deep anesthesia, lowered blood pressure or trauma the delayed activity recorded at the gasserian ganglion diminished rapidly in amplitude and duration. \[\text{[Equation]}\] Monitoring of these elements was repeated throughout and at the end of each experiment to consider further the reliability of evoked neural activity in the midbrain and thalamus.

Monophasic stimuli (Grass stimulator Model S4D), 0.01 msec. in duration, were delivered through an isolation transformer and raised slowly in intensity to establish the voltage required to evoke a threshold and a maximum evoked response at each site of recording. The intensity of stimulus required to evoke a maximum response was used in this study.

When responsive sites were located in the mesencephalon and diencephalon and records had been obtained incident to stimulation of the infraorbital nerve and nucleus caudalis, a tiny collection of powdered strychnine on a moist 1 mm. cottonoid pledger was applied over the surface of nucleus caudalis caudal to the electrode which was positioned below the obex. As the preparation gradually developed overreaction to tactile facial stimulation and the delayed activity recorded at the gasserian ganglion increased, recordings of evoked potentials from the upper brain stem were again obtained for comparison with the responses obtained before the application of strychnine. Only one position of the recording electrodes could be studied in any one preparation as it occasionally required as long as 1 to 2 hours for changes incident to strychnine to subside even with copious irrigation of the posterior fossa.

Recording electrodes were led to capacity-coupled amplifiers. The evoked responses were photographed from a dual-beam oscilloscope.

Ether anesthesia was administered at intervals throughout recording periods without interfering with the overreaction to tactile stimulation or the amplitude of evoked responses.

Spinal V tractotomies rostral to the electrode in nucleus caudalis and midline medullotomies from the obex to C2 were performed in selected circumstances to isolate the peripheral trigeminal afferents from central projections arising from nucleus caudalis and to interrupt projections from nucleus caudalis to higher relays. Decerebration was accomplished in some preparations by transection at the intercollicular level.

Recording sites were marked by the technique described by Hess. Frozen serial sections of the medulla and upper brain stem were stained by a Nissl method and examined microscopically to establish the extent of the tractotomies and medullotomies and to relate the recording sites to anatomic structures.

We have employed the nomenclature used in the atlas of Jasper and Ajmone-Marsan.

**Observations**

Many regions of the midbrain and thalamus have shown an evoked response incident to stimulation of the trigeminal nerve. \[\text{[Equations]}\] Our observations relate primarily to those portions of the upper brain stem that are altered by the application of strychnine to nucleus caudalis.

In this circumstance the animal characteristically developed overreaction* to tactile facial stimulation and an increase in amplitude and duration of the delayed potential recorded at the gasserian ganglion.

The overreaction to tactile facial stimulation was abolished by a dorsolateral tractotomy across spinal V. It was diminished markedly by contralateral hemidecerebration and was abolished by a total decerebration. We have therefore considered that projections from nucleus caudalis to the thalamus that were interrupted by decerebration may have relayed at the thalamus and been essential to sustaining the behavioral change described as overreaction to tactile facial stimulation. Further, we have attempted to determine whether under this circumstance a change in the evoked re-

* A quick ipsilateral squint, a twitch of the corner of the mouth and occasionally of the ear, pupillary dilatation and occasional mild movement of the ipsilateral forepaw occur in response to light mechanical displacement of vibrissae, hair or skin with a light rigid probe.