Subdivision of the trigeminal sensory root

Experimental study in the monkey

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In 16 rhesus monkeys, rhizotomy of the whole trigeminal nerve and selective rhizotomy of each division were carried out, and neural degeneration techniques used, to determine whether a trigeminal root component exists which projects only to the main sensory or spinal nucleus of the trigeminal nerve. Such a root component was not found. Section of the rostral trigeminal fibers resulted in degeneration in both the main sensory nucleus and the spinal trigeminal nucleus. Section of the caudal fibers of the root produced degeneration similar to third division transection, indicating that the caudal fibers are from that division. The first- and third-division fibers were found to project to the ventral and dorsal portions of the main sensory nucleus and spinal nucleus. Findings showed that the most rostral portion of the root immediately adjacent to the motor root is predominately from the ophthalmic division. Some proprioception from the trigeminal area appears to be mediated through the medial cuneate nucleus because all the trigeminal divisions send some fibers to this nucleus.

Key Words: trigeminal nerve, trigeminal sensory root, rhizotomy, cuneate nucleus, nerve degeneration

Dandy concluded that the trigeminal sensory root adjacent to the pons consists of a caudal portion (which projects into the spinal tract and nucleus and mediates pain) and a rostral or accessory portion (which terminates in the main sensory nucleus and conveys touch). The clinical results of Jannetta and Rand, after transtentorial section of the trigeminal root, lend support to this concept. The sensory deficit resulting from surgical and ischemic brain-stem lesions in man indicates that pain is mediated in the caudal or spinal portion and that touch is mediated in the rostral or main sensory portion of the trigeminal nuclear complex. However, Dandy’s concept that touch and pain separate in the trigeminal root is disputed.

The present study, utilizing neural degeneration techniques, was done to determine whether a trigeminal root component that projects only to the main sensory or spinal nucleus of the trigeminal nerve can be identified. The few previous studies of degenerating trigeminal nerve axons in human autopsy material are not applicable to this question because they used the Marchi staining method, which does not demonstrate the unmyelinated fibers that carry pain. Our study used the rhesus monkey because this species has a posterior trigeminal root and ganglion that are similar to the human’s and...
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because there is a close resemblance between the central connections of the trigeminal nerve in monkey and man. The Nauta-Gygax technique and the Fink-Heimer modification were selected because they show the course of the brain stem of both degenerating unmyelinated and myelinated axons.

Methods

Operations using the surgical microscope were done on 16 rhesus monkeys anesthetized with pentobarbital. For rhizotomy of the whole trigeminal nerve and selective rhizotomy of each division, the nerve was exposed by a temporal extradural approach and sectioned behind the gasserian ganglion. For selective rhizotomy, each division was isolated distal to the ganglion, and that portion of the ganglion was selectively destroyed, leaving the other two divisions intact. The transtentorial approach, used for section of the rostral and caudal fibers, exposes the root where it enters the pons and requires opening the temporal lobe, elevating the temporal lobe, and dividing the tentorium just posterior to the petrous ridge. Through this exposure, the rostral sensory fibers directly adjacent to the motor root were sectioned, after identification of the motor root with a nerve stimulator. In addition, selective cuts were made in the caudal, lateral, and medial portions of the posterior root in an attempt to determine whether any of these fibers extended only to the main sensory or spinal nucleus. Also the most caudal fibers of the root were selectively cut by the suboccipital approach through the posterior fossa.

Animals were killed 7 days after operation, by perfusion of saline followed by formalin. All brain stems were removed with the trigeminal root and ganglia attached. The posterior roots were examined under magnification to verify the site of the lesion. Serial transverse sections 20 μ thick were used throughout. Every tenth section was stained by the Nauta-Gygax method routinely, except when more frequent inspection became necessary. For identification of the nuclei in which terminal degeneration was occurring, the section adjacent to the one used for the Nauta-Gygax stain was frequently colored with buffered thionine.

Results

The results after section of the whole trigeminal nerve and of each division will be reviewed briefly to provide a comparison for the results after section of the other portions of the root.

Section of the whole sensory root resulted in dense degeneration in the full cross section of the sensory root as it entered the pons and throughout the main sensory nucleus, which is located dorsomedial and slightly rostral to the entry zone of the root (Fig. 1). Extensive degeneration was also seen throughout the caudally directed spinal trigeminal tract and within all subdivisions of the spinal nucleus located medial to the tract. The most caudal level in which degenerating fibers were seen was in the C-3 dorsal horn. The spinal tract fibers terminated mainly in the spinal trigeminal nucleus; at the level of the rostral medulla, however, some fibers streamed medially from the dorsal third of this tract to terminate in the solitary nucleus (Fig. 1b). At a more caudal medullary level, degenerating fibers turned sharply in a dorsal direction out of the medial edge of the spinal trigeminal tract and terminated in the ventrolateral portion of the neighboring medial cuneate nucleus (Fig. 1c). The only other connections seen were a few fibers that entered the cerebellum and the reticular formation of the pons and medulla.

Cutting the third-division fibers resulted in degeneration, predominantly in the dorsomedial portion of the main sensory nucleus and the dorsal portion of the spinal trigeminal tract and nucleus (Fig. 2 right column). In the upper cervical region, degeneration was most intense in the small dorsal region of white matter surrounding the dorsal horn and in the dorsomedial portion of the dorsal horn. Mandibular-division section resulted in degeneration in the solitary and medial cuneate nuclei.

First-division rhizotomy produced degeneration that was most pronounced in the ventrolateral portion of the main sensory nucleus and in the ventral portion of the spinal trigeminal tract and nucleus (Fig. 2 central column). Caudally, the degeneration extended into the white matter, capping the dorsal horn, and terminated in the dorsal...
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a. From trigeminal root entry, the zone of the pons shows degeneration in the trigeminal root (RV) and throughout main sensory nucleus (NV).

b. Section from the rostral medulla showing fibers terminating in the solitary nucleus (NS).

c. Section from just below the obex showing fibers terminating in the medial cuneate nucleus (NCM).

d. Section from the C-2 cord level showing degeneration fibers in the matter over the dorsal horn and within the dorsal gray matter.


Gray matter of C1-3. The ophthalmic division also contributed to the medial cuneate nucleus but not to the solitary nucleus.

Sectioning the maxillary fibers produced degeneration predominantly in the midportion of the main sensory nucleus, in the middle third of the spinal tract and nucleus, in the dorsal gray matter as far caudal as C-3, and in the medial cuneate nucleus, but not in the solitary nucleus.

The following data represent the results after differential section of the rostral and caudal portions of the root adjacent to the brain stem to determine if a portion could be found that projected only to the main sensory or spinal trigeminal nucleus. If touch...
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Fig. 2. Outline drawings from transverse sections of the brain stem of the rhesus monkey showing degeneration after rhizotomy of the first (center column) and third (right column) divisions. **Left Column:** Transverse section of the brain stem from which figures in other columns were taken. **Upper figures** are from the level of the trigeminal root entry into the pons. **Lower figures** are from the rostral medulla. After first-division rhizotomy, degeneration was most intense in the ventrolateral portion of the main nucleus and in the ventral portion of the spinal tract and nucleus. After third-division rhizotomy, degeneration was most intense in the dorsomedial portion of the main nucleus and in the dorsal portion of the spinal tract and nucleus.

were selectively represented in the rostral portion of the trigeminal nucleus as postulated by Dandy and others, selective section should have resulted in isolated degeneration of the main sensory nucleus. After division of the rostral or caudal components of the trigeminal root by the transtentorial technique, degeneration was seen in both the main sensory and the spinal trigeminal nuclei (Fig. 3 second and third columns). After division of the rostral fibers adjacent to the motor root, the degeneration was most intense in the ventrolateral portion of the main sensory nucleus and the ventral portion of the spinal trigeminal tract (Fig. 3 second column). That is, it was most intense in those regions shown by selective rhizotomy to come from the ophthalmic division. After division of the caudal fibers, adjacent to the brain stem, degeneration was seen in both the main sensory and trigeminal nuclei and was most extensive in those regions that come from the mandibular division, namely, the dorsomedial portion of the main sensory nucleus and the dorsal portion of the spinal trigeminal tract and nucleus. Although the degeneration after section of the rostral and caudal fibers of the root tended to maintain patterns similar to those seen after section of the third and first divisions respectively, the degeneration after these rhizotomies adjacent to the brain stem was more widespread through the main sensory nucleus and trigeminal tract than after section of the divisions just posterior to the ganglion. This is in agreement with the findings of Guillaume, 4

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Tract or rootlet degeneration cut longitudinally
• Tract degeneration cut transversely
** Preterminal and terminal degeneration

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who noted that the tendency for divisional localization becomes less discrete as the brain stem is approached and that it is more pronounced just posterior to the ganglion.

The pattern of degeneration after section of the caudal sensory fibers adjacent to the brain stem by the suboccipital posterior fossa approach was similar to that seen after section of the caudal fibers by the transtentorial approach and resembled the degeneration seen after section of the mandibular fibers (Fig. 3 fourth column). Sectioning the medial and lateral fibers of the root resulted in degeneration throughout all the trigeminal connections without any marked occurrence in any one portion of the main sensory or spinal trigeminal nucleus.

Discussion

A component of the posterior root that projected to the main sensory or spinal trigeminal nucleus was not found. If touch were selectively represented in the rostral portion of the trigeminal root, as suggested by Dandy, who noted that the tendency for divisional localization becomes less discrete as the brain stem is approached and that it is more pronounced just posterior to the ganglion.

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ular. Actually, the degeneration after the sectioning of small bundles of rostral or caudal fibers was not as discretely localized to the regions of the first and third division, as seen after section of the division just posterior to the ganglion. This is in agreement with Guillaume’s findings that the tendency for divisional localization becomes less discrete as the brain stem is approached and that it is most pronounced just posterior to the ganglion. Dandy also found evidence of divisional localization even in the posterior fossa. He reported that when the sensory root was incompletely sectioned by the suboccipital route with preservation of the dorsomedial fibers, the most frequent sensory preservation was over the forehead, with the least being in the chin.

Dandy’s and our findings are in agreement with electrophysiologic studies of Pelletier, et al.,11 which show that the sensory root contains three spatially distinguishable but overlapping divisions even at the root entry zone, with the mandibular and ophthalmic divisions being ventrolateral and dorsomedial respectively. They did not find any evidence to support functional modality subdivision within the root, but noted that sensory modalities appeared to be distributed randomly throughout the root.

The finding of dorsoventral lamination of fibers within the spinal tract, with the ophthalmic division being placed ventrally and the mandibular fibers being placed dorsally, is in agreement with previous studies in the monkey8 and with most observations at surgery in man.14 The observations regarding localization in the main sensory nucleus, with the third division projecting dorsomedially and the first division projecting ventrolaterally, are similar to those reported by Kerr8 for the cat and monkey.

There is considerable disagreement regarding the caudal termination of spinal tract fibers. Previous investigators have noted that the trigeminal fibers descend in such a manner that the most caudal level is reached by mandibular division,10 by the ophthalmic division,5,15 or by all three divisions.18 Our findings that all divisions terminated at the level of C-3 are in agreement with other nerve degeneration studies, indicating that they end at C-2 and C-3.8,12,16 We did not find any evidence for descent of one division below that of another division.

The connection of the trigeminal nerve to the medial cuneate nucleus had only been previously noted in the cynomolgus monkey.12 The medial cuneate nucleus is known to convey proprioceptive impulses from the upper portion of the body and, although most proprioception from the trigeminal region is believed to be mediated through the main sensory nucleus, it appears that some proprioception is mediated through the medial cuneate nucleus because all three divisions give some fibers to this nucleus. The medial cuneate nucleus then becomes another site of convergence for sensory fibers of the head and upper portion of the body. This convergence is also present in the upper cervical region where fibers from the trigeminal nerve and upper cervical roots terminate in the C-1 through C-3 dorsal horns. Kerr7 noted that these sites of convergence of sensation may be important to the mechanism of referred pain and cervical cranial pain syndromes.

The trigeminal solitary connections have been described previously in man and animals.5,12,17 It is postulated that the trigeminal solitary fibers carry general visceral afferent impulses from the glands and vascular structures to the nose, mouth, teeth, dura, and intracranial blood vessels rather than conveying a gustatory sensation. It appears that the trigeminal solitary fibers function as afferent limbs of the cardiorespiratory and other visceral reflexes, mediated through the caudal end of the solitary nucleus.

Conclusions

Degeneration studies were done in the monkey to determine whether a selective portion of the trigeminal root projected only to the touch-conveying main sensory or to the pain-mediating spinal nucleus. The results do not support the concept that touch is selectively conveyed in the rostral portion of the trigeminal root because section of these fibers resulted in degeneration in both the main sensory and the spinal nucleus. The most rostral sensory fibers are predominantly from the first division and the caudal fibers from the third division. The first- and third-division fibers project to the ventral and dorsal portions of the main sensory and spinal nucleus,
Subdivision of the trigeminal sensory root respectively. It appears that some proprioception from the trigeminal area is mediated through the medial cuneate nucleus because all three divisions project to this nucleus. A trigeminal projection to the solitary nucleus originates from the third division and is believed to be important in visceral reflexes.

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