Neuroanatomical Considerations of Palatal Muscles: Tensor and Levator Veli Palatini

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The tensor veli palatini (TVP) and levator veli palatini (LVP) muscles are intimately associated with the soft palate and knowledge of their anatomy and physiology is essential for palatoplasty. Controversy regarding the function and innervation of these muscles still exists. The purpose of this study was to identify the location of motoneurons within the brainstem which innervate the TVP and LVP using the current neuroanatomical tracing technique of retrograde axonal transport of horseradish peroxidase (HRP). HRP was injected into each of these muscles in adult cats. Following a twenty-four hour survival the animals were sacrificed, the brain removed and processed using tetramethyl benzidine. TVP motoneurons were located in the rostral two-thirds of the ventromedial division of the trigeminal motor nucleus. LVP motoneurons were located in the rostral 2 mm of the nucleus ambiguus ipsilaterally and to a lesser extent contralaterally as well as in the retrofacial nucleus ipsilaterally.

Our study has addressed neuroanatomical aspects essential to an understanding of the structure and function of the palatal muscles. Unraveling the central connections of the TVP, LVP motoneurons may clarify understanding of such complex functions as swallowing, sucking, blowing and speech.

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and serous otitis media (Seif and Dellon, 1978).

As implied by its name, the purported function of the TVP is to tense the soft palate. This is a misnomer according to Rich (1920 a) who observed no effect of TVP contraction on the velum but rather considered the TVP as the exclusive dilator of the Eustachian tube. Honjo et al., (1979 a, b) also indicated that the TVP plays no role in palatal function but rather served as the dilator of the Eustachian tube. Electromyographic studies demonstrate TVP and LVP contraction during swallowing, blowing and sucking. The TVP is also active during the inspiratory phase of respiration (Hairston and Sauerland, 1981).

Although the innervation of TVP is by cranial nerve V, innervation of LVP has not yet been determined. Standard textbooks of anatomy attribute LVP innervation to cranial nerve X (Crafts, 1979). Ibuki et al., (1978) using electromyographic techniques determined the monkey LVP was innervated by the greater petrosal nerve, a branch of VII. Rich (1920 b) concluded from experimental studies of the dog LVP that the muscle was innervated by the bulbar portion of the spinal accessory nerve (XI). This, he stated, would more properly implicate the inferior rootlets of the Xth nerve.

The purpose of this study was to identify the location of motoneurons within the brainstem which innervate TVP and LVP. Armed with this information, questions of embryology, innervation and function would be re-evaluated.

Materials and Methods

Injections of 10–20 μl of 30% horseradish peroxidase (HRP, Sigma, Type VI) in saline were given to adult cats with a Hamilton syringe. Multiple paramedian injections were made through the soft palate (12 cats) into the TVP and/or the LVP and their aponeuritic tendons. Spread and therefore potential contamination of surrounding structures by HRP is a disadvantage of indirect injection. Therefore in seven other cats, the TVP and/or LVP were exposed using microsurgical technique and injected under direct vision. An approach was made by partial resection of the ramus of the mandible and removal of the temporal mandibular joint (TMJ). A plane of dissection was created deep to the medial pterygoid muscle and along the anterior surface of the bony bulla tympanicum. Medial to the bulla tympanicum the connective tissue of the nasopharyngeal wall was identified. On the lateral surface of this wall a triangle comprised of three muscles was identified. The posterior side of the triangle was formed by the LVP, the anterior side of the triangle (superficial to the LVP) was formed by the TVP, and the base of the triangle was formed by the pterygopharyngeus muscle. No other muscles exist in this plane. In several animals a metal clip was placed on the TVP muscle and a careful dissection carried out after sacrifice to assure the accuracy of the operative technique.

Following postoperative survivals of 24–48 hours, the experimental animals were anesthetized (Rompun 0.3 ml; Ketalar 0.6 ml) and perfused through the left ventricle of the heart. Best results were achieved after a 24-hour survival period. Prior to perfusion, the animals received injections of 500 units of Heparin and 0.5 ml of 1% sodium nitrate. The animals were perfused with 2.0 l of 0.9% normal saline followed by 2.0 l of fixative (1.25% paraformaldehyde, 1.5% glutaraldehyde in 0.1 M phosphate buffer [pH 7.4]). The brain and upper cervical spinal cord were immediately removed from the skull en bloc and cut transversely into blocks. In three animals the brain was cut in the sagittal plane. Tissue blocks were immersed in the same fixative overnight at 4°C and transferred to a solution of 30% sucrose in 0.1 M phosphate buffer until the blocks sank. The blocks were sectioned at 40 μm on a freezing microtome and serial sections collected in phosphate buffer. Selected sections were reacted with tetramethyl benzidene (TMB) (Sigma or Electron Microscopy Service) according to Mesulam and Mufson (1980). Sections were mounted on chrome-alum subbed slides and counterstained with neutral red.

Sections were examined microscopically with bright and dark field illumination.
Photomicrographs were made with both a Bausch & Lomb stereomicroscope and a Zeiss photomicroscope. Selected sections were drawn with the aid of a Bausch & Lomb microprojector.

Results

HRP labeled cells were located in the ventromedial division of the trigeminal motor nucleus following injection of TVP and in the rostral nucleus ambiguus (NA) and retrofacial nucleus (RFN) after injection of LVP. Labeled cells in both instances were medium sized multipolar neurons while smaller fusiform cells were also labeled with TVP injections.

The trigeminal motor nucleus forms a column approximately 1.3 mm long just medial to the trigeminal principal sensory nucleus. The nucleus extends from a level just rostral to the abducens nucleus to the rostral limit of the superior olivary complex. Throughout its length two morphological divisions are apparent, a dorsolateral division of large motoneurons, and a smaller ventromedial division of slightly smaller neurons. Caudally, these cells were loosely arranged among unlabeled cells while more rostrally labeled cells were located along the medial edge of the ventromedial division (Figure 1). No label was seen in the trigeminal mesencephalic nucleus.

The NA of the cat forms a long column of cells, extending from the spinomedullary junction to the RFN, lying in the ventrolateral tegmentum of the pons. The nucleus is divided into a caudal diffuse formation and a rostral compact formation which contains more numerous cells in a readily identifiable round cluster in transverse section. The RFN is just rostral and ventrolateral to the NA. LVP motoneurons were located in the rostral 2 mm of the NA in all cases (Figure 2). This is most impressively visualized in sagittal section. A few labeled cells were scattered in the more diffuse portion of the NA from the area postrema to the compact portion of the NA. In two cases where HRP was injected directly into LVP, labeled cells were identified in the contralateral NA. These contralateral labeled cells were in a similar location and arrangement, but fewer in number and did not extend as far rostral as those on ipsilateral side. HRP labeled cells were also identified in the RFN. These cells were more diffusely arranged, usually no more than 3-4 cells per transverse section. There were no labeled cells in the facial nucleus.

Discussion

The anatomy of the epipharynx (nasopharynx) and base of the skull have not been thoroughly investigated due to its relative inaccessability. Included in this region is the velopharynx which contains two muscles critical to successful reconstruction of the cleft palate—TVP and LVP. Current controversies regarding the embryology, morphology and physiology of this region are not reflected in standard anatomical texts and require clarification.

There is general agreement that TVP is the primary dilator of the Eustachian tube (Lupin, 1969; Ross, 1971; Rood, 1973; Proctor, 1973; Dickson, 1975; Rood and Doyle, 1978; Seif and Dellon, 1978; Honjo, Okzaki and Kumazawa, 1979 a.; Honjo, Okazaki, and Nozoe, 1979 b.). Kriens (1975) in an excellent review of the anatomy of the velopharynx reported that the commonly used name “tensor veli palatini” was considered a misnomer by Ruedinger in 1865. Support for this statement comes from Rich (1920 a.) in the early part of the twentieth century and more recently from Honjo, Okazaki and Nozoe (1979 b.). In contrast, Rood (1973) and Dickson (1975) state that since the TVP does insert into the palatal aponeurosis, one cannot unequivocally dismiss a role in tensing the soft palate.

There is consensus among investigators that the LVP is a primary elevator of the soft palate (Rich, 1920 a.; Kriens, 1975; Dickson, 1975; Atkins, Byrd, and Tebbetts, 1982; Kuehn et al., 1982). This action of LVP resulting in closure of the velopharyngeal orifice is significant for normal speech. Whether the LVP has any role in Eustachian tube function is still undetermined according to Proctor (1973) and Seif and Dellon (1978).

Our study was designed to examine the
FIGURE 1A. Projection drawings of serial brainstem sections from caudal (A) to rostral (D) illustrating the location of labeled motoneurons (X) following HRP injection of TVP. Trigeminal motor nucleus (Vm), principal sensory nucleus (Vp), tract of trigeminal nerve (Vt), superior olivary complex (SO), tract of trigeminal mesencephalic nucleus (ms). FIGURE 1B. Darkfield photomicrograph of brainstem section at the level of the trigeminal motor nucleus. HRP labeled cells following injection of TVP are located along ventromedial edge of the nucleus. FIGURE 1C. Higher magnification of HRP labeled cells from 1B.
FIGURE 2A. Projection drawings of serial brainstem sections from caudal (A) to rostral (D) illustrating location of labeled motoneurons (■) following HRP injection of LVP. Area postrema (AP), cuneate nucleus (C), external cuneate nucleus (Ce), nucleus intercalatus (Int), inferior olive (Io), nucleus ambiguus (NA), nucleus prepositus (P), retrofacial nucleus (RFN), nucleus of the solitary tract (SN), solitary tract (St), trigeminal spinal nucleus (Vn), trigeminal spinal tract (V), dorsal motor nucleus of vagus (X), hypoglossal nucleus (XII). FIGURE 2B. Darkfield photomicrograph of a brainstem section at comparable to section C in the diagram. HRP labeled cells following injection of LVP are located within NA. FIGURE 2C. Higher magnification of HRP labeled cells in the NA.
controversy regarding innervation of LVP. We have excluded involvement of cranial nerve VII since there were no labeled cells in the facial nucleus. Our report is the first to identify LVP motoneurons within the NA. However, their location still implicates either cranial nerves IX or X since NA is known to send efferent fibers via these cranial nerves (Kalia and Mesulam, 1980; Carpenter and Sutin, 1983). The innervation of TVP is quite clear although the specific location of the motoneurons was until recently uncertain. Our findings (Keller et al., 1982; Keller et al. 1983) as corroborated by Mizuno et al. (1982) described the somatotopic arrangement of TVP motoneurons within the rostral two-thirds of the ventromedial division of the cat trigeminal nucleus.

Neuroanatomical aspects essential to an understanding of the structure and function of palatal muscles have to date been incompletely described. Although localization of TVP and LVP motoneurons has no immediate application to the current techniques of palatoplasty, unraveling the central connections of the motoneurons may clarify our understanding of such complex functions as swallowing, sucking, blowing and speech.

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