OBSERVATIONS ON THE PROBLEM OF THE PROPRIOCEPTIVE INNERVATION OF THE TONGUE

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THE problem of the proprioceptive innervation of the tongue still remains unsettled, for the available evidence which bears upon it is conflicting. Langworthy wrote in 1924 that, although hitherto muscle spindles had not been found in the tongue, he was able by Sutton's method to demonstrate their presence in the cat, dog, rat and opossum. Unfortunately, however, he gave no drawings or photographs in support of this finding, and his results still lack confirmation from other sources. It may be noted that Langworthy states in the same paper that muscle spindles are numerous and easily demonstrable in the extra-ocular muscles, whereas it is now generally agreed that, if they exist at all, they are very few and of a primitive type.

In the present study, muscle spindles have been diligently sought in the rabbit's tongue, using pyridine silver and also Bodian's (1936) activitated protargol technique, but with negative results. A search has also been made for them with the use of the pyridine-silver technique in the musculature of the prehensile tongues of *Chamaeleon dilapis* and *Myrmecophaga tridactyla* (where their presence might be reasonably expected), but in these cases, also, none were found. It is perhaps not legitimate to lay much emphasis on these negative findings in view of the relative sparsity of muscle spindles in some types of muscle. It remains possible, also, that proprioceptive impulses from the tongue musculature may be carried by afferent fibres whose nerve endings have no distinctive morphological characters.

If proprioceptive fibres are present in the tongue, there are three possible routes by which they can travel—the lingual, glosso-pharyngeal or hypoglossal nerves. Evidence in favour of the lingual route has been reported by Barron (1936). He cut the lingual, chorda tympani and hypoglossal nerves in cats, rabbits and rats, and recorded action potentials in their peripheral segments by means of an amplifier. No impulses set up by stretching, depressing, touching, burning or chemically stimulating the tongue were found to be transmitted by the hypoglossal nerve. The lingual nerve responded to stretching, touching and burning, and the chorda tympani to chemical stimuli only. Barron concluded that proprioceptive impulses from the tongue are conveyed by the lingual nerve and not by the hypoglossal nerve.

Against this conclusion there is Langworthy's (1924) observation that cutting one or both lingual nerves (or the ninth nerve) produced no apparent ataxia or weakness of the tongue, and it is also well established from clinical observations that no apparent ataxia of the tongue follows extirpation of the Gasserian ganglion or destruction of the sensory root of the trigeminal nerve. It would appear, on these grounds, that the hypoglossal nerve is the only possible route for proprioceptive fibres from the tongue musculature. If this is so, the question arises as to the location of their ganglion cells. There seem to be three possibilities:

(*a*) *The ganglion nodosum of the vagus.* The tenth and twelfth nerves communicate both at their exit from the skull, and through the lingual branch of the vagus to the pharyngeal plexus. (This latter branch is not mentioned in continental text-books.)

(*b*) *The ganglia of the upper four cervical nerves,* since the hypoglossal nerve communicates with the upper loop of the cervical plexus.

(*c*) *Ganglion cells* situated along the course of the hypoglossal nerve.

(1) *The ganglion nodosum.* This source of fibres has been eliminated by Hinsey & Corbin (1934). They cut the hypoglossal in sixteen cats, and, after allowing periods of 10–22 days to elapse, found no degeneration by the Marchi method in the nodose ganglion.

(2) *The root ganglia of the upper four cervical nerves.* This was also eliminated in cats by Hinsey & Corbin in the same group of experiments. But later Corbin *et al.* (1937) in five experiments on *Macaca mulatta* in which the second cervical dorsal root ganglion was removed (a first root ganglion rarely exists in the monkey), found degeneration in the twelfth nerve in all five cases. The degeneration affected only 1–2 % of the fibres. It was, however, traceable distally beyond the branch to the thyrohyoid, thereby proving that the fibres were not derived from the infrahyoid muscles but from the tongue itself. Surprisingly, in two of the five cases, degeneration was also found in the root of the twelfth nerve proximal to its connexion with the second cervical nerve. The passage of a few sensory fibres from the tongue via the descendens hypoglossi to the second cervical ganglion was also found in the hedgehog by Berkelbach van der Sprenkel (1924), who thought they probably came from the hyoglossus and styloglossus muscles. 1–2 % of fibres, however, even if they are all proprioceptive, contrasts markedly with Sherrington's (1898) estimate that one-third to one-half of the myelinated fibres in muscular nerve trunks generally are from cells of the spinal root ganglion.

(3) It therefore appears that, if proprioceptive fibres arise in the tongue in any but the meagre proportion of 1–2 %, they must be served by ganglion cells along the course of the twelfth nerve. Okamura (1936) gave a series of drawings of ganglion cells in the cat's tongue with free terminals which form a network around the adjacent muscle fibres. Tarkhan (1936) cut the twelfth nerve in rabbits, and after allowing time for degeneration, examined the distal end for undegenerated fibres. In one case he found a few scattered fibres

(no percentage given). In another case he found a ganglion near the origin of the descendens hypoglossi, distal to which 50 % of the nerve fibres were undegenerated. He concludes that proprioceptive sensation in the tongue is served either by a definite ganglion or by scattered ganglion cells along the course of the twelfth nerve.

In order to test Tarkhan's assumption, the following experiments were made. In nine rabbits, the hypoglossal was cut a short distance from the base of the skull. When possible the section was made proximal to the origin of the descendens hypoglossi branch. This nerve often does not exist in the rabbit, being then replaced by a fine independent filament from the first cervical nerve. The rabbits were killed at different periods after the operation, viz. 6, 8, 9, 10, 11, 15, 16 and 21 days. Immediately after death the proximal end of the cut nerve was removed, and in two cases also a part of the distal end close to the section. When the portion directly involved by the lesion had been cut away it was not possible to get more than $\frac{1}{2}$–1 cm. length of nerve for examination. The nerves were fixed for 6 hr. in 1 % osmium tetroxide and then washed in water for 3 days. They were dehydrated in graduated ascending concentrations of alcohol, cleaned in xylene, placed in xylene-paraffin, and embedded in paraffin. To avoid extraction of the stain, the time for cleaning was limited to half an hour.

Examination of serial sections of cut nerves. Neither in the short proximal piece of the hypoglossal nerve close to the skull, nor in the peripheral segments removed from midway along its course, were ganglion cells ever found, whether scattered or grouped together. In eight cases no degeneration was found above the section. In one case, in which the nerve had been sectioned 10 days previously, a small bundle of fibres lying beside the main trunk showed complete degeneration. In this instance, however, the presence of all the degenerated fibres together in a separate bundle suggests a source other than the tongue—possibly a loop of connexion with a nerve of cervical origin, but it was not possible to trace their source. Except for this single and doubtful case no support was found for Tarkhan's suggestion that ganglion cells exist along the course of the hypoglossal nerve. In the two cases where the distal end of the cut nerve was examined histologically, degeneration was complete (Figs. 1, 2).

In order further to test the possibility of proprioceptive fibres related to ganglion cells in the course of the hypoglossal nerve, and also to test the suggestion made by some previous observers that proprioceptive fibres accompany the lingual nerve, the following experiment was made. In rabbit No. 6, the lingual nerve was cut on the right side in the submaxillary region, and 10 days later the left hypoglossal nerve was sectioned proximal to the position where ganglion cells on its trunk were described by Tarkhan. The animal was killed 11 days later. Serial sections were made of the right and left sides of the tongue, and stained with pyridine-silver. On the right side numerous motor nerve endings terminating in typical end-plates were found in the muscle fibres. On the other hand, since the lingual nerve had been sectioned,

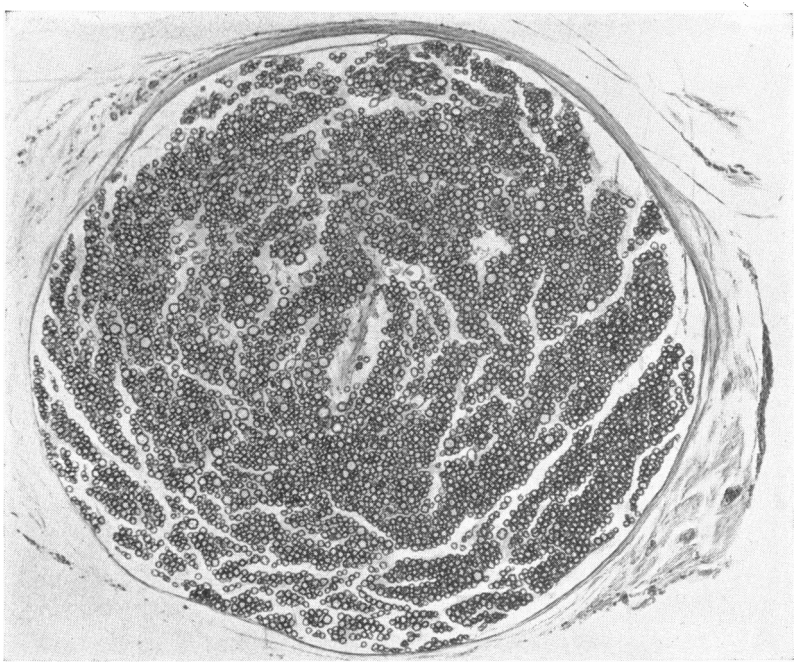

Fig. 1. Section of hypoglossal nerve, proximal to section. (Rabbit 6, killed 11 days after section.) ×155.

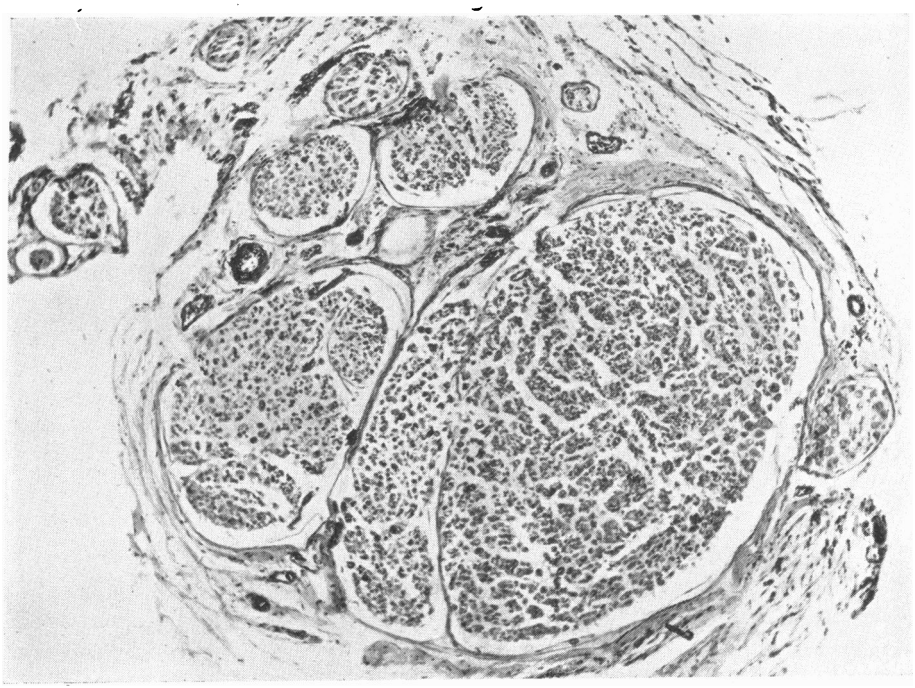

Fig. 2. Section of hypoglossal nerve, distal to section showing complete degeneration. (Rabbit 3, killed 8 days after section.) ×125.

nerve fibres in the mucosa were completely absent. On the left side, the motor terminals of the hypoglossal nerve had undergone total degeneration. No nerve terminals of any kind could be found, even after prolonged study of the serial sections, in relation to the muscle fibres. Fasciculi of lingual nerve fibres were seen in the intermuscular septa of the tongue, and in many cases these could be traced through to the mucous membrane where they terminated in fine endings either immediately deep to the epidermis, or in the deeper layer of the epidermis. Fine nerve fibres were also evident in immediate relation to blood vessels. The fact that on the side of the tongue on which the hypoglossal nerve had been sectioned proximally no nerve terminals at all were found in relation to muscle fibres is strong evidence (1) that no proprioceptive fibres travel in the lingual nerve, and (2) that no proprioceptive fibres have their cells of origin on the trunk of the hypoglossal nerve in its peripheral course in the neck. This is in agreement with the work of Boyd (1937), who made complete serial sections through the heads of full-time rabbit foetuses, and could find no evidence for sensory cells on the course of the hypoglossal as described by Tarkhan, nor any trace of a Froriep's ganglion. Further, no histological evidence was seen of a direct connexion between the intramedullary fibres of the hypoglossal and any cell group other than the nucleus of Stilling.

Another aspect of the question of the proprioceptive innervation of the tongue may be considered. Evidence of the existence of proprioceptive fibres may be provided by the existence of position sense. Langworthy has stated that "human beings are aware of the position of the tongue even when it is held away from the walls of the mouth". This statement was tested in a series of individuals with the assistance of Mr R. G. Macbeth (whose help I wish gratefully to acknowledge). A 5 % freshly made solution of cocaine was applied to the lips, labio-dental groove, floor and roof of the mouth, the tongue and pyriform fossa. This was repeated in 10 min., and if anaesthesia was still light, a 10 % solution was used. With the eyes closed, the tongue was gripped by a forceps and pulled by an observer in various directions. Of eight individuals tested, four were unable to note the position of the tongue or even whether it was moved at all, unless it was pulled to its limit when they were conscious of traction at its base. One individual could interpret upward movement of the tongue but not movements in other directions. Two could interpret the movements correctly in approximately 50% of trials, and one could interpret correctly every movement. It remains possible that, owing to inadequate cocainization, there was incomplete loss of tactile sensation in those cases in which movements of the tongue could still be recognized.

CONCLUSIONS

The observations recorded above in regard to the proprioceptive innervation of the tongue are negative in their implications. The absence of demonstrable muscle spindles in the tongue musculature so far as this was examined with silver techniques, the failure to identify nerve fibres or nerve cells which might

subserve proprioceptive impulses, and the fact that in a certain proportion of cases all sense of position of the tongue is lost after cocainization of the mucous membrane of the tongue and mouth—all these suggest the possibility that proprioceptive innervation may not exist in the tongue musculature. The complete absence of nerve endings in direct relation to muscle fibres after section of the hypoglossal nerve indicates that, if proprioceptive fibres are indeed present, they must run in the trunk of this nerve. No positive evidence, however, has been found to support Tarkhan's conclusion that such hypothetical proprioceptive fibres have their ganglion cells along the course of the hypoglossal nerve.

SUMMARY

1. The proximal part of the hypoglossal was cut in nine rabbits and time allowed for degeneration, varying from 6 to 21 days. Except for one doubtful instance, no evidence was found to support Tarkhan's suggestion that ganglion cells exist along the course of this nerve.

2. No muscle spindles have been found in the tongue of the rabbit, or in the prehensile tongues of the chamaeleon (*Chamaeleon dilapis*) and the anteater (*Myrmecophaga tridactyla*).

3. The lingual nerve in one rabbit was cut on one side, and the hypoglossal nerve on the other. Nerve terminals in relation to muscle fibres of the tongue were found on the side where the lingual had been cut, but were completely absent on the other side.

4. The mucous membrane of the tongue and mouth was anaesthetized with 5–10 % cocaine in eight individuals. All sense of position of the tongue was lost in four, there was partial loss in three, and no loss in one case.

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