SENSORY FIBRES IN THE HYPOGLOSSAL NERVE

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It has been found (Tarkhan, 1936a) that in the rabbit section of the hypoglossal nerve results in degeneration of all nerve endings in the muscles of the tongue, and that section of the anterior rami of the upper four cervical nerves causes no degeneration either in the fibres of the hypoglossal nerve or in its branches in the tongue. In another publication (1936b) the same author recorded a rise in blood pressure in the cat after stimulation of the central end of the hypoglossal nerve and concluded that this nerve is sensori-motor. This rise in blood pressure is not affected by extirpation of the superior cervical sympathetic ganglion. It was found also that stimulation of the central end of either the lingual or the hypoglossal nerve resulted in reflex movements of the tongue, provided the other hypoglossal nerve was intact. It was therefore concluded that the central afferent path of the lingual nerve is connected with the hypoglossal nuclei and that the sensory path of the hypoglossal nerve, contrary to its motor path, is partially crossed in the medulla oblongata.

Downman (1939) reported that electrical stimulation of the central end of the hypoglossal nerve in the decerebrate cat caused dilatation of the pupil, rise of blood pressure, and general muscular movement. He still obtained dilatation of the pupil even after bilateral removal of the upper two cervical spinal ganglia and section of the spinal cord below the second cervical vertebra. These reflex movements could no longer be obtained, however, after section of the vago-accessory-hypoglossal group of nerves close to the skull; in certain experiments the reflexes were abolished by section of the vagus and accessory nerves alone. Downman thereupon assumed that in some animals the afferent fibres of the hypoglossal trunk enter the skull with the vago-accessory group, while in others they enter with the hypoglossal fibres. He recorded, however, that removal of the ganglion nodosum did not modify the reflexes aroused by hypoglossal stimulation.

Weddell, Harpman, Lambley & Young (1940) obtained dilatation of the pupil by stimulation of the intact hypoglossal nerve in the rat. This reflex was abolished by removing the superior cervical sympathetic ganglion. The authors concluded that dilatation of the pupil was due to stimulation of the sympathetic fibres in the hypoglossal nerve.

Boyd (1941), studying the hypoglossal nerve in the rabbit, concluded that any afferent fibres in this nerve could reach the central nervous system only

by way of the upper cervical dorsal roots. He also stated that no nerve connexion between the hypoglossal nerve and the ganglion nodosum could be demonstrated in his preparations.

The present investigation has been carried out with the purpose of elucidating further the course and origin of the afferent component of the hypoglossal nerve.

METHODS AND MATERIAL

Our material was obtained entirely from dogs. Three series of experiments were performed.

In the first series, the rootlets of the hypoglossal nerve were divided intracranially, and the degenerative changes occurring in the trunk of the nerve peripheral to the point of division were studied.

˙ In the second series, the superior cervical sympathetic ganglion, the upper cervical spinal ganglia, or the ganglion nodosum were removed and any consequent degeneration in the hypoglossal nerve observed.

In the third series, we studied the effect of stimulation of the central end of the divided hypoglossal nerve on the blood pressure in normal animals and in animals treated as were those of the first and second series.

SERIES I

Intracranial division of the hypoglossal nerve

Operation. Dogs are anaesthetized by an intravenous injection of chloralose in doses of 65–90 mg./kg. body weight. To facilitate operative manipulations, shrinkage of the brain is first brought out by an injection of. 10–30 c.c. of 30 % hypertonic saline solution. Both common carotids are then temporarily occluded by bulldog forceps to minimize the amount of bleeding during the operation. After some experience the manipulations can be carried out with greater facility and the last two measures may be dispensed with.

A midline incision is made extending from the external occipital protuberance to the spine of the third cervical vertebra. The median raphe is longitudinally divided, the neck muscles retracted laterally and the suboccipital membrane carefully divided. The dura mater is punctured to allow gradual escape of cerebrospinal fluid and, finally, a paramedian incision exposes the medulla. The latter is gently displaced until the fan-like hypoglossal rootlets become apparent, and with an iris knife these are divided. The field is cleaned and the divided structures sutured. When the animal recovers from anaesthesia and begins to lap water, the tongue is found to be deviated towards the operated side if the rootlets have been successfully divided. Further confirmation is obtained by careful dissection of the site of the operation after death.

The hypoglossal nerve was cut intracranially in five dogs. The animals were allowed to live 33–134 days after the operation. After death the hypoglossal nerve and the vagus, accessory and glossopharyngeal nerves were

dissected out. This material was fixed, embedded in paraffin, serially sectioned longitudinally and then stained with silver. The silver technique adopted was in most cases that described by Tarkhan (1934); in a few instances, the Gros-Bielschowsky method was employed instead.

RESULTS

Exp. I. Dog killed 33 days after the operation. Most of the fibres of the hypoglossal nerve were completely degenerated and had been absorbed. Some healthy nerve fibres, however, were seen in the middle of the degenerated mass. They were noticeable in the trunk of the nerve both above and below the origin of the descendens hypoglossi. In addition, there were some separate bundles of healthy thick fibres in the part of the nerve proximal to the point of origin of its descending branch. Most of these bundles were found to direct themselves into the descendens hypoglossi. A connexion which, during dissection, was seen to exist between the vagus and the hypoglossal nerves was found on histological examination to be completely fibrous; but another filament which reached the hypoglossal nerve from the vertebral column consisted mainly of nerve fibres. These fibres seemed to run separately along the side of the nerve and in all probability are the same fibres which travelled into the descending branch.

On the proximal part of the hypoglossal nerve, a typical unipolar cell with a glomerulus and an epithelioid capsule was observed (Pl. 1, fig. 1). A collection of nerve cells, i.e. a nerve ganglion, was also seen along the course of the descending branch of the hypoglossal nerve, just after it had left the trunk of the main nerve (Pl. 1, fig. 2). The ganglion was found to be connected by a bundle of nerve fibres with the distal portion of the hypoglossal nerve.

Exp. II. Dog killed 42 days after operation. Study of the degenerated nerve showed the presence of both thick and thin healthy fibres dispersed among completely degenerated ones, this picture being present throughout the whole nerve, including all its lingual branches. No nervous connexion could be demonstrated between the hypoglossal and vagus or accessory nerves. A bundle of healthy fibres, most probably spinal in origin, proceeded separately on the lower margin of the nerve and continued into the descendens hypoglossi. The descendens hypoglossi was seen during dissection to receive a similar, but totally separate, bundle directly from the spinal nerves.

About fifteen ganglion cells were found to be distributed either singly or in groups along the whole length of the cervical course of the nerve. They were either unipolar or bipolar (Pl. 1, fig. 3) and extended as far as the entrance of the nerve into the muscles of the tongue.

Exp. III. Animal killed 61 days after operation. Healthy fibres were observed as in the previous experiments (Pl. 1, fig. 4). A bundle of fibres came to the nerve from the first and second cervical nerves, and continued into the descendens hypoglossi.

More than ten ganglionic cells were seen along the trunk of the nerve. Some

cells formed a group at the origin of the descendens hypoglossi. No connexion was seen between the hypoglossal nerve and the other cranial nerves.

Exp. IV. Animal killed 134 days after operation. Healthy fibres were demonstrated in the degenerated nerve and only two cells were seen.

Exp. V. Animal killed 55 days after operation. The healthy fibres observed in the previous experiments were demonstrable both in the trunk and in the branches of the nerve. All fibres in the descendens hypoglossi were completely healthy. No nerve cells were seen along the course of the hypoglossal nerve.

SERIES II

A. *Removal of the superior cervical sympathetic ganglion with or without previous section of the intracranial rootlets of the hypoglossal nerve*

(1) *Without section of the XII n. rootlets.* This operation was performed on two dogs, one of which was killed after 5 days and the other after 14 days. The hypoglossal nerve on the side of the operation was dissected out, serially sectioned longitudinally and stained with silver as in series I. Examination of the hypoglossal nerve distal to the origin of the descendens hypoglossi showed that its component fibres in both cases were completely healthy.

(2) *With section of the XII n. rootlets.* The same operation was performed on two dogs in which the hypoglossal rootlets had been cut intracranially 1 week previously. The animals were killed 55 days after the second operation, and the material was prepared and examined as before.

Examination of the hypoglossal nerve in both animals showed the presence of completely healthy fibres, mainly of small calibre, in the trunk of the degenerated nerve. These could not be due to regeneration, since it was our invariable practice in all dissections to verify the absence of any connexion across the site of division of the nerve.

B. *Removal of the upper cervical spinal ganglia*

In the dog the first spinal ganglion is a minute body located in a tunnel in the posterior arch of the atlas. The second ganglion is easily found outside the vertebral column; the third lies hidden underneath the articular process of the vertebra above.

In two dogs these three ganglia were removed on one side. One of the dogs was killed after 6 days and the other after 15 days.

Neither by silver in the first dog, nor by the Marchi technique in the second could any degeneration be detected in the trunk or branches of the hypoglossal nerve.

C. *Removal of the ganglion nodosum*

Since the jugular ganglion lies deeply buried in the bones of the skull, we had to content ourselves with the removal of the ganglion nodosum. The operation was performed on four dogs. In the first two experiments, the central stump of the vagus nerve was avulsed with the hope of removing or

injuring the jugular ganglion, while in the third and fourth experiments avulsion was avoided for fear of injuring the trunk of the hypoglossal nerve. The dogs were killed after 5 days, and the hypoglossal nerve was then prepared for microscopic examination.

In the first two dogs the hypoglossal nerve on the operated side was found to contain a certain proportion of degenerating fibres, approximately 5 % of the total in each section of the nerve. An accurate count in longitudinal sections, however, is misleading; while in transverse sections stained with silver after the lapse of this short period such a count is hardly justifiable, since many of the degenerating fibres may appear healthy. In the third and fourth experiments—where no avulsion was performed—nearly the same amount of degeneration was found, but was much less in the case of the fourth experiment, where ganglionic cells happened to be present on the trunk of the hypoglossal nerve at the origin of the descendens hypoglossi. Most probably these ganglionic cells gave origin to the greater part of the sensory fibres supplying the muscles of the tongue in this animal.

SERIES III
Blood-pressure experiments

Animals were anaesthetized with chloralose. The hypoglossal nerve, on one side, was exposed in the neck and freed from the surrounding tissue by careful dissection, from the base of the skull distally towards the tongue. The trunk of the nerve was ligatured peripherally and cut distal to the ligature. All possible connexions with the central part were severed, and in this manner a long stretch of the central end of the nerve was prepared. This was stimulated mechanically or by a faradic current, care being taken to avoid diffusion of the current to adjacent structures. The arterial blood pressure was recorded from the femoral artery.

Results. In a normal dog, mechanical stimulation of the hypoglossal nerve produced a rise of blood pressure of about 22 mm. Hg, while electrical stimulation produced a rise of about 10 mm. Hg.

In another animal (Pl. 1, fig. 5) either mechanical or electrical stimulation produced an initial rise of 12 mm. Hg, followed by a steep fall. Stimulation of the central end of the cut sciatic nerve produced similar results.

The same procedures were repeated in two dogs 5–6 days after intracranial section of their hypoglossal rootlets. Electrical stimulation of the central end of the hypoglossal nerve in these two dogs on the operated side produced a rise of blood pressure of about 20 mm. Hg. Then the ganglion nodosum was removed in both animals and the stimulation of the nerve repeated. No rise of blood pressure was produced in the first animal and only a slight rise in the second.

DISCUSSION

Langworthy (1924) was the first to report that section of the hypoglossal nerve leads to complete degeneration of both motor and sensory endings in the muscles of the tongue. The nervus hypoglossus was therefore assumed to convey proprioceptive fibres from these muscles. The same results were obtained by Tarkhan (1936a), who confirmed that this nerve is sensori-motor. It was therefore expected that section of the efferent fibres only of this nerve would leave a certain amount of unaffected healthy fibres in the mixed trunk. In the present investigation, the hypoglossal rootlets were divided intra-cranially; the examination of the degenerated nerve always showed the presence of a certain number of intact fibres. Such intact fibres, which must have joined the nerve extracranially, may be either afferent or efferent, and if the latter can come from the sympathetic chain only.

Langworthy (1924), 30 days after extracranial section of the hypoglossal nerve in the cat, observed within the tongue 'fibres of small calibre which apparently followed the arteries' (p. 280). Weddell *et al.* (1940), in rats killed 5 days after section of the hypoglossal nerve at the base of the skull, found undegenerated sympathetic fibres of hypoglossal origin passing to the blood vessels. Boyd (1941), in the rabbit, traced fibres from the superior sympathetic ganglion to the hypoglossal trunk and suggested that they were sympathetic fibres proceeding to the lingual vessels. Such communicating fibres, however, were quite inconstant, so he suggested 'that a number of the sympathetic fibres reach the lingual blood vessels along the alternative route of the lingual artery'. From this it appears that no definite evidence has been put forward to support the presence of sympathetic fibres in the trunk of the hypoglossal nerve.

We removed the superior cervical sympathetic ganglion in two dogs which were then killed, 5 and 15 days after the operation. No degeneration whatso-ever was detected by the silver technique in the trunk of the hypoglossal nerve. Furthermore, removal of the superior sympathetic ganglion after section of the hypoglossal rootlets left unaffected, after the lapse of 55 days, some fibres in the trunk of the nerve which therefore are not of sympathetic origin.

That the intact fibres, found in the trunk of the hypoglossal nerve after section of its rootlets, are afferent fibres finds support in the work of Tarkhan (1936b), Acheson, Partington & Rosenblueth (1936) and Downman (1939), all of whom recorded a rise of blood pressure in the cat and dog on central stimulation of the hypoglossal nerve. The first author also recorded that such stimulation provoked reflex movements of the tongue provided the other hypoglossal nerve was intact. Such reflex movements, or such a rise in blood pressure, must, therefore, be mediated through afferent fibres in the central end of the cut hypoglossal. Downman (1939), in the decerebrate cat, reported reflex dilatation of the pupil on central stimulation of the cut hypoglossal.

Weddell *et al.* (1940) obtained similar results from stimulation of the intact nerve in the rat, but they also claim that such reflex action disappears on removal of the superior cervical sympathetic ganglion.

They expressed their doubts, however, as to the validity of accepting such a rise of blood pressure, dilatation of the pupil and contraction of the nicti-tating membrane as indicative of the presence of afferent impulses in such a nerve. Such doubts, though perhaps justifiable when the intact nerve is stimulated, as was their practice, are groundless when the central cut end is stimulated. Any rise of blood pressure, as was obtained with such stimulation in our experiments, can only be explained by the presence of afferent fibres in the trunk of the stimulated nerve.

In this investigation we obtained in dogs a rise of blood pressure after central stimulation of the divided hypoglossal nerve. A similar effect was recorded in animals in which the intracranial rootlets had previously been cut. This seems to prove that afferent fibres in the hypoglossal trunk do not accompany its efferent fibres into the brain.

Concerning the place of origin of these afferent fibres, three possibilities present themselves: the upper cervical spinal ganglia, the ganglion cells on the hypoglossal nerve or the ganglia associated with the neighbouring cranial nerves.

Much controversy has raged over the first possibility. Langworthy (1924), in one cat, claimed that avulsion of the hypoglossal nerve resulted in chromato-lysis of the cells of the second cervical spinal ganglion. One such observation, however, cannot be conclusive. Van der Sprenkel (1924) speaks of connexions between the second cervical nerve and the descendens hypoglossi in serial sections of hedgehog embryos. This author suggests that afferent fibres from the second cervical ganglion pass into the descendens hypoglossi and continue distally into the hypoglossal nerve, but no experimental evidence was adduced in favour of this suggestion. Corbin, Lhamon & Petit (1937), found in the rhesus monkey, that removal of the second cervical ganglion caused de-generation of about 1 % of the fibres of the hypoglossal nerve. On the other hand, Hinsey & Corbin (1934) found no degeneration in the trunk of the hypoglossal nerve after removal of the anterior rami of the second, third and fourth cervical nerves.

We removed the upper three cervical ganglia in the dog and obtained no degeneration whatsoever in the trunk of the hypoglossal nerve.

The silver technique we employed has been constantly reliable. We are, therefore, certain that, at least in the dog, the upper cervical ganglia con-tribute no fibres to the hypoglossal nerve. Those who speak of such a possi-bility report a small percentage of degeneration in the hypoglossal nerve after the removal of the upper cervical ganglia. Such a percentage, even if proven, is so meagre that it can account for only a very small proportion of the afferent fibres from the tongue.

As to the question of the presence of ganglion cells along the course of the hypoglossal nerve, the data obtained by the different investigators seem to be

conflicting. From the work of Tarkhan (1934), from the present investigation and from some recent data obtained in this department, we feel justified in concluding that sensory cells, few or many, singly or in groups, do exist in some cases along the course of this nerve; their occurrence, however, is inconstant. The negative findings reported by both Boyd (1937, 1941) and Carleton (1938) may be ascribed to their different methods of approach. A discussion of the differences between our respective methods, together with a report on new data already referred to above, will be included in a subsequent communication to this *Journal.*

Pearson's reports (1943, 1945) on the presence of sensory cells on the intra-medullary course of the hypoglossal nerve in man are in support of the mixed nature of this nerve, and may explain in part why sensory cells are such an inconstant finding on the extramedullary part of this nerve.

Finally, there remains the third possibility: that the afferent fibres in the hypoglossal nerve may arise from cells incorporated within ganglia present on the neighbouring cranial nerves. Langworthy (1924), after avulsion of the hypoglossal nerve in the cat, described chromatolysis in the cells of the ganglion nodosum. Downman (1939), on the other hand, reported that the reflex responses he obtained on central stimulation of the hypoglossal were abolished in certain cats by section of the vagus-accessory group but not by removal of the ganglion nodosum. Boyd (1941), in the rabbit, found no connexion between the ganglion nodosum and the hypoglossal nerve.

In the present investigation we removed the ganglion nodosum in four dogs. In three of them, degenerated fibres were easily demonstrable in the trunk of the hypoglossal nerve. In the fourth experiment, where a ganglion was found on the trunk of the hypoglossal nerve, the number of degenerated fibres was greatly diminished. It is therefore justifiable to conclude that the gang-lionic cells on both hypoglossal and vagus nerves share in supplying the afferent fibres in the former nerve; the number of fibres originating from either source varies from one animal to another.

As to the path by which these afferents enter the central nervous system, Downman (1939) states that though all the fibres enter in the bulbar region, the exact path they take into the cranium appears to vary. In cats they enter either through the jugular foramen with the vagal fibres or through the hypoglossal canal with the hypoglossal nerve. He added that it seems very probable that the fibres entering through the hypoglossal canal communicate later with the vagal fibres.

We have stimulated the central end of the hypoglossal nerve in two dogs, after intracranial section of its rootlets, and obtained a rise of blood pressure nearly as high as the rise we obtained from normal dogs. Then the ganglion nodosum was removed in both animals; subsequent stimulation of the central cut end of the hypoglossal nerve still produced a rise of blood pressure in one animal but not in the second. Possibly, in the first animal a more centrally placed connexion existed between the hypoglossal and vagus nerves.

SUMMARY

1. Stimulation of the central cut end of the hypoglossal nerve in dogs causes a rise of blood pressure. This may be taken as evidence that this nerve is mixed.

2. Section of the hypoglossal rootlets, in the dog, leaves unaffected a certain number of myelinated fibres. These presumably constitute the afferent component of this nerve. In the trunk of the nerve the number of afferent as compared to efferent fibres is proportionately smaller than in other predominantly motor nerves.

3. Removal of the upper three cervical spinal ganglia in the dog results in no degeneration in the fibres of the hypoglossal nerve.

4. Removal of the superior cervical sympathetic ganglion in the dog results in no degeneration in the fibres of the hypoglossal nerve. Thinly myelinated fibres seen in the trunk of the nerve after the section of its rootlets are not of sympathetic origin, since they persist after removal of the superior cervical sympathetic ganglion.

5. The ganglion nodosum contributes a certain amount of fibres to the hypoglossal nerve. The number of these fibres seems to be inversely proportional to the number of ganglionic cells on the hypoglossal nerve.

6. Sensory cells on the trunk of the hypoglossal nerve are frequently present in the dog. They occur both singly and in ganglionic collections.

7. It is suggested that peripherally these afferent fibres run entirely through the hypoglossal nerve, while intracranially they enter the brain mostly with the vagal fibres.

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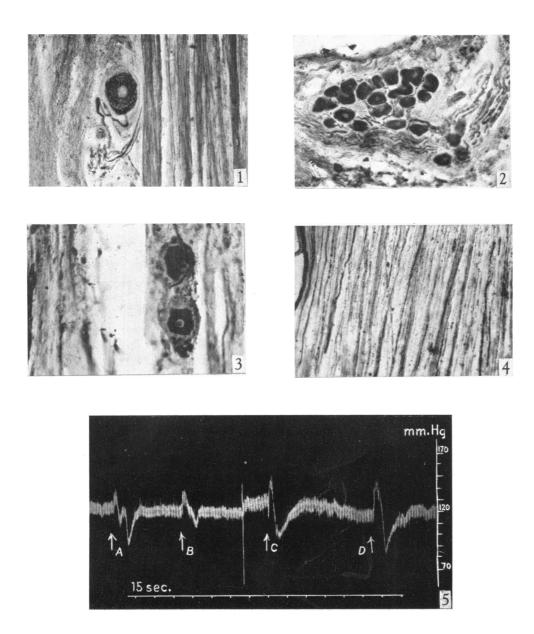TARKHAN, A. A. (1934). *J. Anat., Lond.,* **68**, 293.
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EXPLANATION OF PLATE

Fig. 1. Microphotograph of a typical unipolar cell seen on the trunk of a degenerated hypoglossal nerve the rootlets of which were cut 33 days before killing the animal. Exp. I. ×200.

Fig. 2. Microphotograph of a longitudinal section of the hypoglossal nerve at the origin of the descendens hypoglossi. A sensory ganglion is seen in the section. Fibres from this ganglion were traced in serial sections and found to run distally in the hypoglossal nerve. Exp. I. ×200.

Fig. 3. Microphotograph showing the presence of two ganglionic cells along the course of a degenerated hypoglossal nerve. Exp. III. ×200.

Fig. 4. Microphotographs from a longitudinal section of the hypoglossal nerve 61 days after section of its rootlets. Healthy nerve fibres can easily be seen in between the degenerated ones. Exp. III. ×200.

Fig. 5. A, rise of blood pressure succeeded by a steep fall after applying a ligature to the left hypoglossal nerve in a chloralosed dog; B, a similar effect obtained on faradic stimulation of the same nerve central to the ligature; C, after ligature of the right sciatic nerve; and D, after faradic stimulation of the right sciatic nerve. Blood pressure recorded from left femoral artery.

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