The surgical anatomy of the extracranial segment of the hypoglossal nerve (HN) has been sparsely investigated in the literature. This article studies the course and anatomical and topographic relationships of the HN in 23 formalin fixed cadavers bilaterally dissected under a surgical microscope. The descriptive anatomy is presented with relevant clinical and surgical implications. Clin. Anat. 19:37–43, 2006.

Key words: facial nerve; hypoglossal nerve; surgical anatomy

INTRODUCTION

Anatomical studies focusing on the extracranial portion of the hypoglossal nerve (HN) are very rare although piecemeal information on some of the anatomical features of this segment of the nerve is scattered in different articles, mainly those dealing with surgical procedures in the relevant area (Byers, 1994; Homze et al. 1997; Sheen et al., 2000; Skandalakis et al., 1979). This segment of the HN, which is located in an area of complex anatomy, has to be exposed or manipulated during various surgical interventions in the upper neck, among them surgical treatment of primary and metastatic tumors, lesions of the skull base and temporal bone, pathologies or penetrating injury of the carotid artery, vertebral artery disease, and anterior approaches to the craniovertebral junction or upper cervical spine. The HN is also used in hypoglossal-facial neurorrhaphy for reanimation of the paralyzed facial nerve and in hypoglossal-recurrent laryngeal nerve neurorrhaphy for the treatment of unilateral vocal cord paralysis. Paniello (2000) wrote that the HN is a preferred donor for nerve neurorrhaphy due to its adequate temporal activity, abundant available axons and low donor site morbidity. Unilateral damage to the HN usually does not cause severe restriction in function, even in cases of complete hemiplegia of the tongue. Bilateral HN paralysis, however, may cause severe swallowing difficulty, dysarthria, and respiratory disturbances due to airway obstruction. Disabling morbidity could result from unilateral paralysis of the HN together with one or more of the adjacent nerves, such as the facial, glossopharyngeus, vagus and superior laryngeal, or recurrent laryngeal nerves.

The current research was part of a project that studied the anatomy of the HN in the neck and the facial nerve (FN) trunk, with emphasis on surgical implications, particularly hypoglossal-facial nerve neurorrhaphy. The first part dealt with the FN (Salame et al., 2002) and this study focuses on the topographic anatomy of the cervical segment of the HN.

*Correspondence to: Khalil Salame, MD, Department of Neurosurgery, Tel Aviv Sourasky Medical Center, 6 Weizmann Street, Tel Aviv, 64239 Israel. E-mail: salame@tasmc.health.gov.il

Received 8 July 2004; Revised 19 December 2004, 23 December 2004; Accepted 24 January 2005

Published online 26 September 2005 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/ca.20141
MATERIALS AND METHODS

Twenty-three formaldehyde-fixed cadavers from the department of anatomy and anthropology at the Sackler Faculty of Medicine, Tel Aviv University were dissected bilaterally under a surgical microscope. These cadavers were from 13 women and 10 men, ages 51–74 years at the time of death. Cadavers with pathological lesions, scars, or signs of previous injury in the neck or skull base had been excluded.

With the cadaver in the semi-lateral position, a linear skin incision was made starting at the level of the upper pole of the mastoid, descending behind the ramus of the mandible and then extending in two directions: downward along the anterior border of the sternocleidomastoid muscle (SCM) and forward, inferior and parallel to the mandible. The platysma was divided and retracted with the skin. The SCM was detached at its superior insertion and deflected inferiorly taking care to identify and preserve the accessory nerve to look for possible communication with the HN. The tip of the mastoid process was denuded of all muscles and periosteum with a periosteal elevator. The transverse process of the atlas (C1) was identified between the mandibular angle and the tip of the mastoid and it was exposed. The transverse processes of the second and third cervical vertebrae (C2 and C3) were located by palpation through the deep layer of the deep cervical fascia but they were not exposed. The posterior belly of the digastric muscle was identified at its origin in the digastic notch of the temporal bone and it was isolated until it reached the digastric tendon, after which its anterior belly was also isolated. The FN was exposed from its emergence from the stylo-mastoid foramen (SMF) until the point of its bifurcation inside the parotid gland or immediately proximal to it, as described previously (Salame et al., 2002). The HN was identified medial to the posterior belly of the digastric muscle and dissected proximally until its site of exit from the skull base at the hypoglossal canal and distally until its penetration into the glosso muscles. The diameter of the FN was measured immediately after its emergence from the SMF, the diameter of the HN was measured immediately before its entrance into the submandibular triangle, and the cross-sectional area of each nerve was calculated as well. The relationships of the HN with various structures in the neck, particularly the FN trunk, were recorded. The shortest distances were measured between the HN and the body of the hyoid bone, the SMF, the bifurcation of the FN trunk and the carotid bifurcation.

We looked at branches that originated from the HN in the neck before its penetration into the tongue muscles and at the communications between the HN and other nerves. The upper root of the ansa cervicalis (ansa hypoglossi), formed by fibers from the first ventral cervical ramus, was identified at its emergence from the HN and it was dissected caudally. The lower root of the ansa (descendens cervicalis), which consists of fibers from the ventral rami of the second and third cervical nerves, was also exposed in the dissection field. The occipital artery was identified at its origin from the external carotid artery (ECA) and dissected until the point where it crossed the HN. The distances of this site from the origin of the occipital artery and from the carotid bifurcation were measured. All distances and lengths were measured using a compass with a millimeter scale.

RESULTS

The transverse process of the atlas was identified posterior to the styloid process, approximately 10–15 mm anterior-inferior-medial to the mastoid tip and it could be exposed by dorsal retraction or section of the posterior belly of the digastic muscle. In all the dissections, the HN exited the skull through the hypoglossal canal, which was invariably located anterior-inferior to the jugular foramen in the posterior cranial base. The HN continued downward until the level of the inferior vagal ganglion, to which it was attached by a dense connective tissue. Few nerve filaments crossed through this tissue to connect between the HN and this ganglion. The nerve continued its course caudally, lying medial to the internal jugular vein, internal carotid artery and cranial nerves IX, X, and XI. All these structures descended in a plane between the styloid process anteriorly and the transverse process of the atlas posteriorly and could be better exposed by resection of the styloid process. The HN descended almost vertically in a plane between the internal jugular vein and the internal carotid artery, remaining outside the carotid sheath. It descended below the level of the mandibular angle, passing medial to the posterior belly of the digastic muscle. In all the dissections, the HN was crossed by the occipital artery, which hook superficially to the nerve in its course backward. After covering a short distance, the HN assumed a horizontal position and continued in a forward course, lying inferior-medial to the posterior belly of the digastic muscle (Fig. 1). The HN was now close to the internal branch of the superior laryngeal nerve, which ran antero-inferiorly toward the larynx...
on the lateral aspect of the genioglossus muscle until it branched into the tongue.

The distance between the HN and the carotid bifurcation (Fig. 3) averaged $14.69 \pm 5.80$ mm (0–27.26). The shortest distance between the HN and the bifurcation of the FN trunk was $16.1 \pm 3.3$ mm (13.85–21.42). The minimal distance between the horizontal segment of the HN and the mandibular bone was $24.65 \pm 5.47$ mm (10.73–33.76). The minimal distance between the HN immediately before entering the submandibular triangle and the SMF was $33.54 \pm 12.71$ (22.30–49.15) (Table 1).

The diameter of the HN as measured immediately preceding its entrance into the submandibular triangle was $2.69 \pm 0.36$ mm (1.92–3.84 mm) and its cross sectional area was $6.88$ mm$^2$. The diameter of the FN immediately after it emerged from the SMF was $2.66 \pm 0.55$ mm. and its cross sectional area was $5.56$ mm$^2$ (Table 1).

**Branches of the HN**

No branches left the HN proximal to the ansa hypoglossi (Fig. 3). The number of nerve branches that originated from the HN distal to the origin of the ansa hypoglossi, but before piercing the tongue muscles, ranged from 1–4 (Table 2). The most consistent of these branches was the nerve to the geniohyoid muscle, which was identified in 36 cases, and

(Fig. 2). The superior laryngeal nerve originated from the vagus at the caudal part of the inferior vagal ganglion and branched into its internal and external branches posterior to the ECA. The HN entered the submandibular triangle bounded superiorly by the mandibular bone, anteroinferiorly by the anterior belly of the digastric muscle, and posteriorly by its posterior belly. The nerve was superior to the digastric tendon in 21 dissections (45.7%) and inferior or directly deep to the tendon in 25 dissections (54.3%). The HN was superior to the body of the hyoid bone and the distance between them was $9.7 \pm 3.4$ mm (6.80–12.35). The horizontal segment of the HN crossed the lingual artery in 33 dissections (72%), whereas it was inferior to the origin of the lingual artery from the ECA in the other 13 dissections (28%). The HN was inferior to the deep portion of the submandibular gland and then coursed

(Fig. 2). The hypoglossal nerve (1) at its entrance into the submandibular triangle and its relationship with the superior laryngeal nerve (2) of the vagus (3). 4, External carotid artery; 5, superior thyroid artery; 6, internal jugular vein; 7, submandibular gland; 8, mandibular bone; 9, digastric muscle.
originated from the HN at an average distance of 10 mm after the ansa hypoglossi. A direct branch from the HN to the thyrohyoid muscle was identified in 17 cases, whereas it was seen to be supplied by a branch from the ansa cervicalis, like the other infrahyoid muscles, in the remaining 29 cases.

**Communications With Other Nerves in the Neck**

In all the specimens, the HN was connected by small nerve twigs to the inferior vagal ganglion with which it was encased within a connective tissue (Table 3). There were additional communications between the HN and the vagus in five cases (11%). The HN communicated with the sympathetic trunk through the superior cervical ganglion in 21 (46%) dissections. There was a branch connecting the ansa hypoglossi to the main trunk of the HN in three cases (Fig. 4). More distally, communicating branches between the HN and the lingual nerve were found in 11 (24%) dissections. There was a communicating branch between the HN and the accessory nerve in one case (2%).

**Ansa Hypoglossi**

The ansa hypoglossi (Figs. 3,4) was identified in 44 (96%) of 46 dissections and absent in two (4%). It separated from the HN at a point around the site where the nerve turned from a vertical to a horizontal direction. This point was at a distance of 27.96 ± 5.72 mm (14.93–36.64) from the angle of the mandibular bone, and 17.92 ± 8.29 (0–35.85) mm from the carotid bifurcation.

The ansa hypoglossi took off from the HN as a single branch in 43 (93%) of the 44 specimens, while it was formed from two branches that united together within few millimeters after leaving the HN in the other three specimens. The diameter of the ansa hypoglossi as measured at a point 10 mm after its separation from the HN was 1.62 ± 0.36 (0.60–2.19) mm. The ansa hypoglossi passed downward in an almost vertical plane, anterior to and outside the carotid sheath, in all the 44 cases in which it was identified. The descendens cervicalis, which was formed from the ventral rami of C2 and C3, was located posterolateral to the ansa hypoglossi and descended infero-anteromedially until they both connected to form the ansa cervicalis loop. A branch from the ansa hypoglossi to the superior belly of the omohyoid muscle was identified in each of the 44 dissections. In nine cases (20%) the ansa hypoglossi had anastomotic connections with small branches of the cervical spinal nerves before joining the descendens cervicalis. The ansa hypoglossi also had communications with the vagus in three dissections (7%) and with the HN in three cases (7%), whereas it had...

![Fig. 3. Right side. The relationship between the hypoglossal nerve (1) and the carotid bifurcation (2). Small branches (3) arise from the hypoglossal nerve distal to the ansa hypoglossus (4), which descends anteriorly outside the carotid sheath and joins the descendens cervicalis (5).](image)

**TABLE 1. Different Topographic Measurements**

<table>
<thead>
<tr>
<th>Points</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HN to hyoid body</td>
<td>9.7 ± 3.4 mm (6.80–12.35)</td>
</tr>
<tr>
<td>HN to carotid bifurcation</td>
<td>14.69 ± 5.8 mm (0–27.46)</td>
</tr>
<tr>
<td>HN to FN bifurcation</td>
<td>16.1 ± 3.3 mm (13.85–21.43)</td>
</tr>
<tr>
<td>HN to mandible</td>
<td>24.65 ± 5.47 mm (10.73–33.76)</td>
</tr>
<tr>
<td>HN to SMF</td>
<td>33.54 mm (22.30–49.15)</td>
</tr>
<tr>
<td>Ansae to mandibular angle</td>
<td>27.96 ± 5.72 mm (14.93–36.64)</td>
</tr>
<tr>
<td>Carotid bifurcation</td>
<td>17.92 ± 8.29 mm (0–35.85)</td>
</tr>
<tr>
<td>Diameter of HN (b)</td>
<td>2.69 ± 0.36 mm (1.92–3.84)</td>
</tr>
<tr>
<td>Diameter of FN</td>
<td>2.66 ± 0.55 mm (1.10–3.69)</td>
</tr>
<tr>
<td>Length of FN trunk</td>
<td>16.44 ± 3.20 mm (12.20–18.68)</td>
</tr>
</tbody>
</table>

\(a\)HN, hypoglossal nerve; FN, facial nerve; SMF, stylomastoid foramen.

\(b\)Measured at the point where the HN enters the submandibular triangle.

\(c\)Measured from the origin of the ansa from the HN.
no communications with any other nerves in the neck in the remaining 29 specimens (66%).

**Blood Supply of the HN**

The HN was supplied by small arterial twigs directly arising from the ECA in all the specimens. In 42 dissections (91%), it received additional supply from the occipital artery, which was identified in each of the 46 dissections and seen to have originated from the ECA at 17.59 ± 6.80 mm (0.0–30.06) distal to the carotid bifurcation. The occipital artery crossed the HN at a distance of 12.66 ± 5.87 mm (2.20–26.79) from its origin from the ECA and then passed posterosuperiorly, crossing the internal carotid artery, internal jugular vein, and vagus nerve (Fig. 1).

**DISCUSSION**

We had no difficulty in identifying the HN in the neck in this cadaver study. Difficulties may be encountered if the anatomy is distorted, such as in the presence of tumor, radiation injury or a scar from previous surgery. Buchheit and Delgado (1985) stated that the easiest way to expose the HN in this area is to find the ansa hypoglossi and follow it proximally. We found that the posterior belly of the digastric muscle is a reliable guide to identify the HN as it passes deep to it. This method is safe because the only significant structure located superficial to this muscle is the mandibular branch of the facial nerve. Damage to this nerve causes paresis of the ipsilateral corner of the mouth with drooling.

Further anteriorly, the HN lies caudal to the submandibular gland and can easily be exposed by gentle upward retraction of the gland. An alternative method is to use the carotid bifurcation as a landmark. Dissecting from the carotid bifurcation in a directly rostral direction, the HN will be found at an average distance of 15 mm superior to the bifurcation and, in a minority of cases, it may lie on the bifurcation itself.

The location of the HN close to the carotid vessels in the neck may explain the vulnerability of this nerve from direct vascular compression, especially in cases of a high lying carotid bifurcation or a laterally located external carotid artery (Dehn and Taylor, 1983). In addition, injury to the HN is a known complication of surgery on the carotid system in the

---

**TABLE 2. Branches from the Hypoglossal Nerve Proximal to the Tongue**

<table>
<thead>
<tr>
<th>No. of branches</th>
<th>No. of dissections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

**TABLE 3. Communications Between the Extracranial Hypoglossal Nerve and Other Nerves**

<table>
<thead>
<tr>
<th>Nerve</th>
<th>No. of Dissections</th>
<th>(% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inferior vagal ganglion</td>
<td>46 (100%)</td>
<td></td>
</tr>
<tr>
<td>Additional communications</td>
<td>0.5 (11%)</td>
<td></td>
</tr>
<tr>
<td>with the Vagus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathetic trunk</td>
<td>21 (46%)</td>
<td></td>
</tr>
<tr>
<td>Ansa hypoglossi</td>
<td>3 (7%)</td>
<td></td>
</tr>
<tr>
<td>Lingual nerve</td>
<td>11 (24%)</td>
<td></td>
</tr>
<tr>
<td>Spinal accessory nerve</td>
<td>1 (2%)</td>
<td></td>
</tr>
</tbody>
</table>
neck. In a series reported by Weiss et al. (1987), the HN was the most commonly injured nerve during carotid endarterectomy, with an incidence of 8.6%. Iatrogenic damage of the HN usually results from extensive retraction rather than direct section of the nerve.

The area bordered superiorly by the HN, posteriorly by the digastric tendon and the posterior belly of the digastric muscle, and anteriorly by the mylohyoid muscle is referred to as the lingual (Pirogoff’s) triangle. The area bounded superiorly by the HN and anteroinferiorly and posteroinferiorly by the anterior and posterior bellies of the digastric muscle, respectively, has been termed Lesser’s triangle. These triangles, however, can be defined only when the HN lies superior to the digastic tendon, a finding in only 45.7% of the specimens in the present work. In a study by Homze et al. (1997), the HN was superior to the upper border of the digastic tendon in 58.2% of the cases and inferior to the superior border of the tendon in 41.8% of cases. They reported that the HN was at a distance of 9.4 mm superior to the hyoid bone, and this correlates well with our results (9.7 ± 3.3 mm).

In the present study, the diameter of the HN immediately at its entrance into the submandibular triangle was 2.96 mm. This gives a cross sectional area of 6.88 mm². The diameter of the FN as measured on its emergence through the stylomastoid foramen was 2.66 mm, yielding a cross sectional area of 5.56 mm². Asaoka et al. (1999) reported cross sectional areas of 0.948 mm² for the FN and 1.541 mm² for the HN. They measured the cross sectional area of the FN as it left the external genu and that of the HN at the level of the atlas. This may explain the difference between their results and ours because the diameter of a cranial nerve increases as it distances itself from the brainstem due to an increase in the thickness of the myelin sheath. Another reason for the discrepancy may be the use of different techniques for measurement.

In classical hypoglossal facial neurorrhaphy, the HN is divided upon its entrance into the submandibular triangle, whereas the FN is sectioned immediately after its emergence from the stylomastoid foramen, and the two nerves are then connected with fine sutures. At these points, the cross sectional area of the HN is larger than that of the FN. This allows performing anastomosis of the FN to only part of the HN, whereas the remaining part is left for innervation of the ipsilateral tongue muscles in an attempt to prevent hemiparalysis and atrophy of its muscles. Several authors have reported different techniques of hemi-hypoglossal facial nerve neurorrhaphy with favorable outcome (May et al., 1991; Cusimano and Sekhar, 1994). It has been suggested that the HN be incised at its posterior part, which contains fibers from the communicating branch of the first cervical spinal nerve. Dividing these fibers would not affect glossal movements because they go to the ansa hypoglossi without contributing motor innervation to the tongue muscles (Asaoka et al., 1999).

The length of the segments of the nerves that are available for neurorrhaphy must be adequate so as to enable tension-free neurorrhaphy. Asaoka et al. (1999) reported that the distance between the HN and the bifurcation of the FN (pes anserinus) was 17.3 ± 2.5 mm. In the present study, this distance was 16.1 ± 3.3 mm (13.3–20.4 mm). Those authors also found that the length of the FN from the external genu to the pes anserinus was 30.5 ± 4.4 mm. We found that the length of the FN trunk from the SMF to the bifurcation was 16.44 mm (Salame et al., 2002).

According to the results of our dissections, an adequate segment of the FN to allow performing a tension-free neurorrhaphy can be exposed and mobilized without mastoidectomy. Drilling of the mastoid carries the risks of opening the mastoid air cells, leak of cerebrospinal fluid, infection, air embolism and injury to the horizontal semicircular canal. In cases where the length of the available segments of the nerves are not sufficient for performing a tension-free neurorrhaphy, we prefer to release and mobilize the HN. We found that this is usually possible, and that it can be further facilitated by division of the ansa hypoglossi and the occipital artery which can usually be sacrificed without significant sequels.

In the present study, the HN received blood supply directly from the ECA in 100% of cases with additional contribution from the occipital artery in 91% of the dissections. In a study on cadavers arterially injected with latex, Brown et al. (2000) found that a rich network of small arterial twigs originating from the large branches of the ECA surrounds the lower four cranial nerves from their exit through the skull to the carotid bifurcation, but further specifications were not provided.

The HN supplies all the intrinsic and extrinsic muscles of the tongue except the palatoglossus, which is innervated by the spinal accessory nerve. Koizumi et al. (1993) reported a case of anomalous innervation from the HN to the sternocleidomastoid muscle. Other branches may also arise from the HN before it enters the tongue muscles, the most consistent being the branch to the geniohyoid muscle fol-
lowed by the nerve to the thyrohyoid muscle. Both branches are formed by fibers that originate from the ventral rami of the high cervical nerves and join the HN at a higher level in the neck.

The HN may also carry afferent fibers from the lingual nerve to the second cervical nerve. During sharp rotation of the neck, these fibers may be compressed at the atlanto axial interval, before joining the HN. This may cause the rare clinical syndrome of pain and paresthesias in the occipital and upper nuchal area with numbness of the tongue on the same side (Lance and Anthony, 1980). We identified an anastomosis between the HN and the lingual nerve in 24% of our cases, but we were not able to identify the relation of these communications with the cervical nerves.

Fibers from the ventral rami of the upper cervical nerves join the HN at a high cervical level and contribute to the ansa hypoglossi, but do not participate in the motor supply of the tongue muscles. The ansa hypoglossi was identified in 96% of our dissections and seen to descend anterior to the carotid vessels, remaining outside the carotid sheath, in all of them. Some researchers have reported that the ansa may pass inside the carotid sheath (Jones, 1995), but this variation was not encountered in the present work. When the HN is used as a donor for repair of the facial or recurrent laryngeal nerve, the ansa may be anastomosed to the distal stump of the HN in an attempt to prevent atrophy of the ipsilateral half of the tongue.

CONCLUSION

The HN exited the skull through the hypoglossal canal in all the dissections and has intimate relationships with important vascular and neural structures in the neck. There were no significant variations in the course or relationships of the HN between its exit from the skull and its entrance into the tongue. Surgical exposure and mobilization of the HN can be carried out safely if the surgeon has adequate knowledge of the anatomy. It is feasible to split the fibers of the HN longitudinally and to use only part of them for reanimation of other nerves, while leaving the other part for innervation of the ipsilateral tongue muscles.

REFERENCES


