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Landmarks for the Hypoglossal Nerve within the Anterior Cervical Triangle

Topografía del Nervio Hipogloso en el Triángulo Cervical Anterior

Alejandra Mansilla[1]; Alejandro Russo[1,2]; Sofía Mansilla[1]; Joaquín Calisto[1] & Eduardo Olivera[1]

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SUMMARY: Cranial nerve injury is one of the neurologic complications following carotid endarterectomy. The hypoglossal nerve is one of the most frequently injured nerves during carotid endarterectomy. Guidelines suggest that proper anatomic knowledge is crucial to avoid cranial nerve injury. The aim of the present study is to provide landmarks for the localization of the hypoglossal nerve during carotid endarterectomy. 33 anterior cervical triangles of formalin-fixed adult cadavers were dissected. The "carotid axis" was defined and measured, the level of the carotid bifurcation within the carotid axis was registered. "High carotid bifurcation" was considered for those carotid bifurcation found in the upper 25 mm of the carotid axis. The distance between the hypoglossal nerve and the carotid bifurcation was measured (length 1). The relationship between the hypoglossal nerve and the posterior belly of the digastric muscle was registered. For caudal positions, the distance between hypoglossal nerve and posterior belly of the digastric muscle was determined (length 2). Carotid axis range 88.3 mm-155.4 mm, average 125.8 mm. Level of the carotid bifurcation within the carotid axis range 75.3 mm-126.5 mm, mean 102.5 mm. High carotid bifurcation was found in 19 cases (57 %). Length 1 ranged from 1.6 mm to 38.1, mean 17.5. Finally, in 29 specimens (87.8 %) the hypoglossal nerve was caudal to posterior belly of the digastric muscle, whereas in 4 cases (12.2 %) it was posterior. Length 2 ranged from 1 mm to 17.0 mm, mean 6.9 mm. Distances between the hypoglossal nerve and nearby structures were determined. These findings may aid the surgeon in identifying the hypoglossal nerve during carotid endarterectomy and thus prevent its injury.

KEY WORDS: Anatomy; Neck; Hypoglossal nerve; Cranial nerve injury; Carotid endarterectomy.

INTRODUCTION

Current guidelines recommend carotid endarterectomy (CEA) over carotid stenting (CAS) in symptomatic patients with severe carotid stenosis (Naylor *et al*., 2018). CEA has less stroke rate reported (minor or disabling) than CAS (Doig *et al*., 2014), thus CEA is still the preferred carotid revascularization method when feasible. Other complications of CEA include: myocardial infarction, death, wound infection, hematoma and cranial nerve injury (CNI) among others (Kakisis *et al*., 2017). The latter has received considerably less attention, despite the fact that they are quite frequent and potentially serious; they may even be life threatening when they present bilaterally (Gutrecht *et al*., 1988; Kakisis *et al*.).

Although it has been over 40 years since CNI following CEA was described, its incidence ranges widely, from 2 % to over 50 % according to various researchers (Hertzer *et al*., 1980; Dehn & Taylor, 1983). This variation depends mostly on the method used for the evaluation and on the fact that these types of injuries are frequently transient (Kakisis *et al*.).

CNI during CEA is due to surgical dissection, traction, electrocautery, transection, clamp injury or compression by a postoperative hematoma (Bennett *et al*., 2015; Hye *et al*., 2015). The most commonly injured nerves are the hypoglossal nerve (HN), the recurrent and the superior laryngeal branches of the vagus nerve, the marginal mandibular branch of the facial nerve and the glossopharyngeal nerve (Rutherford, 1993; Fokkema *et al*., 2014; Goller *et al*., 2014). The symptoms depend on the nerve that is injured and the deficit varies from being a minor

[1] Departamento de Anatomía, Faculty of Medicine, Universidad de la República, Montevideo, Uruguay.
[2] Vascular surgery unit, Hospital Pasteur, ASSE, Montevideo, Uruguay.

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nuisance to a severe disability which may require a feeding tube and/or tracheostomy (Hye *et al*.) or worse, as previously stated. Since there is no specific and effective therapy for CNI, prevention is the best measure. In fact, the ESVS guidelines on the treatment of carotid stenosis clearly state that CNI can be avoided by proper anatomic knowledge (Naylor *et al*.).

According to a meta-analysis HN is the second most injured cranial nerve during CEA, with a total injury rate of 3.79 % and a permanent injury rate of 0.15 % (Kakisis *et al*.). The HN gives off motor branches to all the intrinsic and the vast majority of the extrinsic muscles of the tongue, with the exception of the palatoglossal muscle. In the infrahyoid region, through its descending branch, it supplies the infrahyoid muscles.

The hypoglossal nerve can be divided in four segments: intra-axial, cisternal, skull base and extracranial segment which can be damaged by different pathological processes (Alves, 2010). The extracranial segment can be divided in two portions: descending and horizontal segments. Our study focuses on the horizontal segment. Its origin lays in the medulla oblongata at the level of the hypoglossal triangle within the floor of the fourth ventricle. It passes through the anterior collaterall skull and along the hypoglossal canal to reach the retrostyloid space. From this point on, it takes an oblique downward between the internal carotid and the jugular vein and forward path following the direction of the posterior belly of the digastric muscle (PBDM). In this area the HN runs through the carotid triangle, whose boundaries are: the anterior margin of the sternocleidomastoid muscle (ABSM) posteriorly, the superior belly of the omohyoid muscle antero-inferiorly and the PBDM superiorly. The contents of this triangle, besides the HN, are the carotid bifurcation (CB) and its branches, the internal carotid artery (ICA) and external carotid artery (EC), the internal jugular vein and the vagus nerve among others. All of these structures, both limits and contents of the carotid triangle, are usually encountered during ECA (Iaconetta *et al*., 2018).

The present study aims to provide landmarks for a more precise localization of the HN in the anterior cervical triangle during CEA.

MATERIAL AND METHOD

This is a descriptive, observational, cross-sectional and cadaveric study. 33 anterior cervical triangles of formalin-fixed adult cadavers were dissected, 18 right sided and 15 left sided. Previous scars caused by surgery were not observed in the dissected areas of any specimen. All of the dissections were carried out within the laboratories of the Anatomy Department, Faculty of Medicine, Universidad de la República, exclusively by the authors. The data was collected during the corresponding period of time from February 2017 to July 2019.

In each case the dissection consisted of a cervical midline skin incision and lateral retraction of the platysma skin flap, dissection of the middle cervical fascia and careful blunt dissection of the carotid bundle and the nearby structures.

Anatomic structures that are found during ECA were identified: ABSM, common carotid artery (CCA), the CB and its branches ICA and EA, HN and the PBDM (Fig. 1).

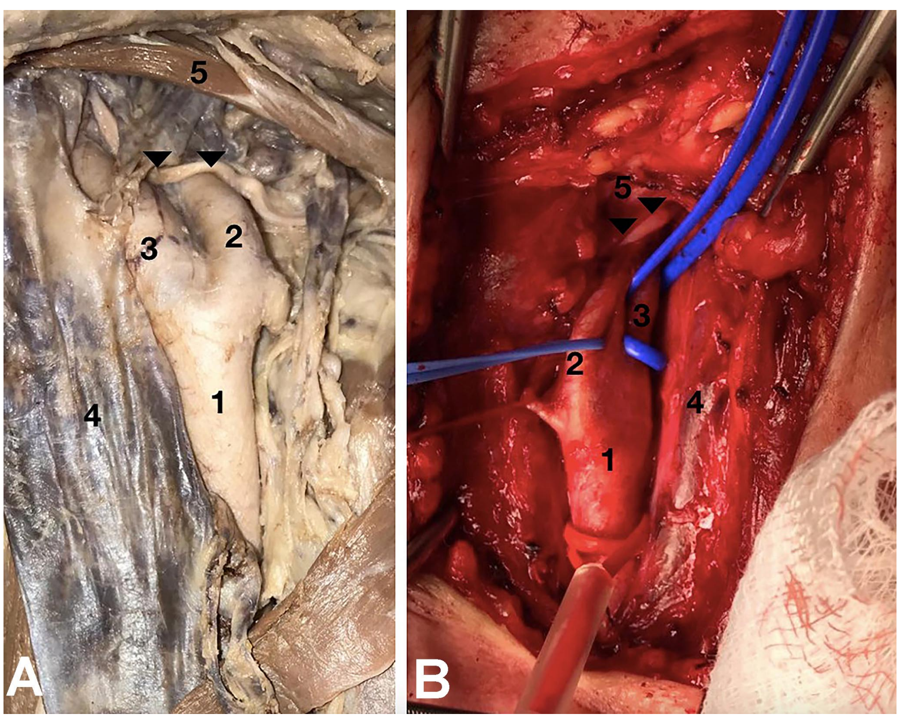

Fig. 1. A. Photograph showing the right side of the neck of a cadaveric specimen. B. Surgical exposure of a left carotid triangle during ECA. Arrow heads: HN. 1: CCA; 2: EA; 3: ICA; 4: Internal Jugular Vein; 5: PBDM. See full text for further references

Using calipers, several measurements were made. Firstly, the "carotid axis" (CA) was defined. It consisted of a line that originated on the upper aspect of the medial clavicle (0 marker), it traced a cephalic path through the longitudinal axis of both CCA and ICA to reach its end point at the superior margin of the PBDM (Fig. 2). Secondly, the level of the CB within the CA was registered (LCB). "High CB" was considered for those CB found at the upper 25 mm of the CA. Thirdly, the distance between the HN's crossing the CA to the CB was measured (L1). Finally, the relationship between the HN and the PBDM was determined (caudal or posterior). For caudal positions, the distance between HN and PBDM within the CA (L2) was measured.

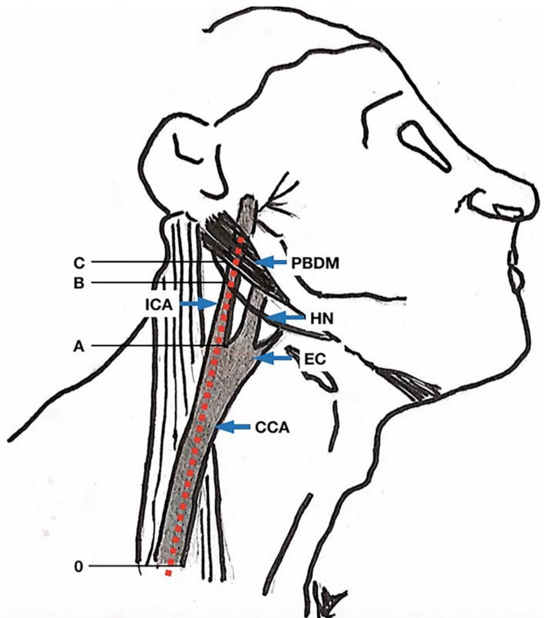

Fig. 2. Schematic drawing of the right side of the neck. Red dotted line: CA with its 0 marker (0). Markers through the CA: A: CB, B: HN, C: PBDM. Distance between 0 to A represents HCB, distance between A-B represents L1 while L2 was measured between B-C. See full text for further references

Ethical approval: All procedures performed in this study involving human bodies are endorsed by the ethics committee of the Universidad de la República, in accordance with the national laws and the ethical standards of the national research committees, as well as with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

List of abbreviations: CEA: Carotid endarterectomy. CAS: Carotid stenting. CNI: Cranial nerve injury. HN: Hypoglossal nerve. ABSM: anterior margin of the sternocleidomastoid muscle.CCA: common carotid artery. CB: carotid bifurcation. ICA: internal carotid artery. EA: external carotid artery. PBDM: posterior belly of the digastric muscle. CA: Carotid axis. LCB: Level of the carotid bifurcation within the carotid axis was. L1: Length 1. The distance between the hypoglossal nerve and the carotid bifurcation. L2: Length 2. The distance between hypoglossal nerve and posterior belly of the digastric muscle.

RESULTS

HN within the anterior cervical triangle was found in every specimen. The total length of the CA ranged from 88.3 mm to 155.4 mm, mean 125.8 mm. LCB ranged from 75.3 mm to 126.5 mm, mean 102.5 mm. According to our definition of "High CB", 19 specimens (57.5 %) were found in the upper 25 mm of the CA while the remaining 42.5 % cases (14) were located below this point within the CA. L1 ranged from 1.6 mm to 38.1 mm, mean 17.5 mm. However, when L1 was segregated in two different groups, High CB versus Low CB, the mean distance was 13.2 mm and 23.7 mm respectively. Finally, in 29 specimens (87.8 %) HN was found caudal to the DMPB, whereas in 4 cases (12.2 %) HN lied posterior to the DMPB (Fig. 3). For those HN caudal to the DMPB, L2 ranged from 1 mm to 17.0 mm, mean 6.9 mm.

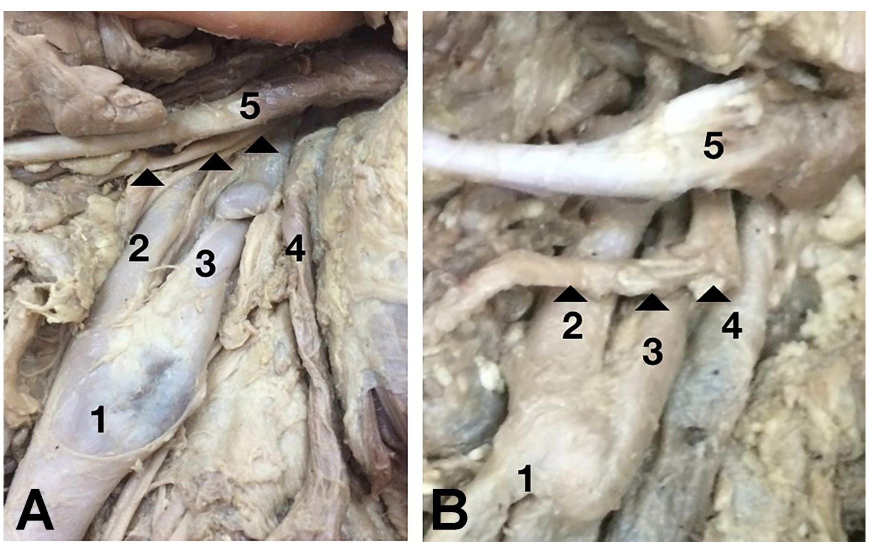

Fig. 3. A and B. Photographs of dissections of the left side of the neck illustrating the relationship of the HN (arrow heads) and the PBDM (5). In a the HN travels posterior to the PBDM which had to be retracted slightly upwards in order to see the HN. In b the HN (arrow heads) clearly runs below the PBDM (5). 1: CCA. 2: EA. 3: ICA. 4: internal jugular vein

DISCUSSION

Injury to the NH may produce alterations in spoken language expression, mastication and swallowing. A typical clinical finding is a lateral deviation of the tongue towards the side of the lesion, due to the action of the contralateral genioglossus muscle (Goller *et al.*). Lesions to the NH may occur either by compression, traction or vascular clamping, most of these being temporary injuries due to neuropraxia (Rutherford; Fokkema *et al.*; Goller *et al.*). The injury by nervous section is extremely rare, presenting the same clinical manifestations, but permanently (Mojumder *et al.*, 2016; Kakisis *et al.*). The injury of both HN is an infrequent event, but possible in the context of bilateral CEA, being a cause of obstruction of the upper airway by descent of the toneless tongue backwards (Gutrecht *et al.*; Goller *et al.*).

Unlike the arterial system, which can be examined radiologically prior to the surgery, we lack radiologic tests that can evaluate nervous anatomy. Thus, the surgeon must be well aware of the anatomy of the region and its variants during CEA to avoid CNI. We believe that anatomic structures surrounding the HN may play a role as landmarks to help identify the location of the nerve during CEA and thus prevent its lesion.

One of the recommendations to avoid CNI during CEA is to maintain the dissection plane as close as possible to the arterial wall (Naylor *et al.*). Taking this into account we defined the CA, which serves as a longitudinal path through the tar get vessels during CEA. Along the CA we set markers for important structures during the surgical act: CB, HN, PBDM. Knowledge of the mean distances between these structures may be beneficial for the surgeon, especially when dissecting on the upper part of the surgical field (close to the PBDM) or when placing a clamp on the distal ICA.

According to our findings, the average length of the CA was 125.8 mm and the CB was found on average, at 102.5 mm of the CA. We did not compare the level of the CB with any surrounding structure (bony landmark or the larynx) because they are usually not seen during surgery. We arbitrarily set the high-low CB point on the upper most 25 mm of the CA. Following this definition, the majority of the specimens studied had high CB (19 cases vs. 14 cases). L1 had a mean length of 17.5 mm. Bademci & Yasargil (2006) found the HN 12–25 mm (mean 19 mm) superior to the CB, comparable to our findings.

Also, interestingly, we found that the HN was 1cm closer to the CB on average in those specimens with high CB, when compared to the ones with lower CB. This finding should inform the surgeon that patients with high CB will present closer HN. However, Bademci & Yasargil found that if the CB is located more distally, the distance between the bifurcation and the horizontal part of the HN increases.

During CEA, when the patients have a high CB or when there is a plaque extended cranially within the ICA, the HN must be mobilized in cranial direction. Improper retraction or mobilization can result in nerve dysfunction or paralysis, which as mentioned, is temporary in most cases (Kakisis *et al.*). To minimize injury to the HN in these cases, the surgeon can divide the sternocleidomastoid artery which tethers the nerve. Also, the HN can then be indirectly retracted by applying a tie to the divided ansa cervicalis (Naylor *et al.*). At this point, if still further upward exposure is needed, the PBDM can be divided (Rutherford).

Regarding the relationship between the HN and the PBDM, in the vast majority of the cases studied the HN lied below the PBDM (29 cases, 87.8 %). The mean distance between these structures was on average 6.9 mm within the CA. Bademci & Yasargil found the HN mostly inferior to the PBDM tendon as well, about 3 to 7 mm (mean 4.5 mm) from it. Comparing both L1 and L2, regardless of the type of CB, we found that on average, the HN is closer to the PBDM than to the CB (6.9 mm vs 17.5 mm). The latter may aid the surgeon when trying to identify the HN, according to our findings the PBDM is the closest landmark to the HN. Although infrequent in our series (4 cases (12.2 %)) the HN may lie posterior to the PBDM. The surgeon should take into account this scenario, especially when dividing the PBDM is required, as previously stated.

Finally, we must acknowledge that by using formalin-fixed cadavers the measurements may be modified by both post mortem modifications and retractions secondary to formaldehyde use.

CONCLUSION

Although infrequent, CNI is one of the most common complications of CEA. Proper anatomic knowledge is crucial to avoid nervous lesion. We hope that the anatomical landmarks mentioned within the surgical field may be helpful to identify the HN and prevent its injury. From our findings, we point out that the closest landmark to the HN was the PBDM, and in cases of high CB, the HN may lie closer to the CB than expected.

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RESUMEN: La lesión de pares craneales es una de las complicaciones neurológicas posteriores a la endarterectomía carotídea. El nervio hipogloso es uno de los nervios lesionados más frecuentemente durante la endarterectomía carotídea. Las guías de actuación clínica sugieren que el conocimiento anatómico adecuado es crucial para evitar lesiones de los nervios craneales. El objetivo del presente estudio fue proporcionar puntos de referencia para la ubicación del nervio hipogloso durante la endarterectomía carotídea. Se disecaron 33 triángulos cervicales anteriores de cadáveres adultos fijados en solución a base de formaldehído. Se definió y midió el "eje carotídeo", se registró el nivel de la bifurcación carotídea dentro del eje carotídeo. Se consideró una "bifurcación carotídea alta" para aquellas bifurcaciones carotídeas encontradas en los 25 mm superiores del eje carotídeo. Se midió la distancia entre el nervio hipogloso y la bifurcación carotídea (longitud 1). Se registró la relación entre el nervio hipogloso y el vientre posterior del músculo digástrico. Para las posiciones caudales, se determinó la distancia entre el nervio hipogloso y el vientre posterior del músculo digástrico (longitud 2). Rango del eje carotídeo 88,3 mm-155,4 mm, media 125,8 mm. Rango del nivel de la bifurcación carotídea dentro del eje carotídeo 75,3 mm-126,5 mm, media 102,5 mm. Se encontró una bifurcación carotídea alta en 19 casos (57 %). La longitud 1 osciló entre 1,6 mm y 38,1, con una media de 17,5. Finalmente, en 29 muestras (87,8 %) el nervio hipogloso fue caudal al vientre posterior del músculo digástrico, mientras que en 4 casos (12,2 %) fue posterior. La longitud 2 osciló entre 1 mm y 17,0 mm, con una media de 6,9 mm. Se determinaron las distancias entre el nervio hipogloso y las estructuras cercanas. Estos hallazgos pueden ayudar al cirujano a identificar el nervio hipogloso durante la endarterectomía carotídea y así prevenir su lesión.

PALABRAS CLAVE: Anatomía; Cuello; Nervio hipogloso; Nervio craneal; Endarterectomía carotídea.

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Corresponding author:
Dr. Alejandro Russo
Canning 2505/306
Vascular surgery unit
Hospital Pasteur
ASSE
Montevideo
URUGUAY

Email: aleru86@gmail.com