Surgical Anatomy of the Jugular Foramen

Anatomia Cirúrgica do Forâmen Jugular

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ABSTRACT

The jugular foramen is one of the most complex regions in the entire human body. The transition between the cranial and cervical compartment is occupied by many critical neurovascular structures that need to be accounted for when planning a surgical approach to this region. A thorough understanding of this anatomy is of utmost importance for any skull base surgeon, thus, we present a brief summary of the most relevant anatomical aspects of the jugular foramen in relation to tumors that arise or extend into it.

Key-words: Jugular Foramen; Skull Base; Surgical Anatomy

RESUMO

O forâmen jugular é uma das regiões mais complexas de todo o corpo humano. A transição entre o compartimento craniano e cervical é ocupada por muitas estruturas neurovasculares críticas que precisam ser consideradas ao ser planejada uma abordagem cirúrgica para esta região. Uma compreensão completa desta anatomia é de maior importância para todo cirurgião de base do crânio. Assim, apresentamos um breve resumo dos aspectos anatômicos mais relevantes do forâmen jugular em relação aos tumores que surgem no mesmo ou se estendem a ele.

Palavras-chave: Forâmen jugular; Base do Crânio; Anatomia cirúrgica

INTRODUCTION

The anatomy of the jugular foramen region is complex and important neurovascular structures are involved. These structures are in close relation with the cervical region, ear and brainstem. A precise knowledge of this anatomical relationship is fundamental to properly expose a tumor originating at or involving the jugular foramen. The jugular foramen is located on the medial and inferior surface of the petrous pyramid and is formed by the occipital and temporal bones. It is a depression around the sigmoid sinus, jugular bulb and inferior petrous sinus in close relationship with the magnum foramen, internal auditory canal and the hypoglossal canal (Fig.1-4)\(^1\)\(^2\). In most cases the width of the right jugular foramen is larger than of the left one\(^3\).

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Received Feb 1, 2019
Accepted Feb 20, 2019
Classically the JF is described as having two portions. The nervous portion with the glossopharyngeal nerve, the inferior petrosal sinus and the meningeal branches of ascending pharyngeal artery and the venous portion with the sigmoid sinus, vagal and accessory nerves (Fig. 5).

The vascular structures within the jugular foramen are: the sigmoid sinus, the jugular bulb, the inferior petrous sinus and branches of the ascending pharyngeal and occipital arteries. The jugular bulb connects the sigmoid sinus and the internal jugular vein. It is located under the floor of the middle ear and its upper portion lies in the jugular fossa (Fig. 6).
The jugular bulb has a size of approximately 15 mm wide and 20 mm high. Large jugular bulbs enter into the middle ear. In these cases the floor of the middle ear may be dehiscent and this anatomic variation may cause pulsatile tinnitus.

The cranial nerves IX, X and XI are located anterior and medial to the jugular bulb. These nerves cross a connective tissue septum that is in continuity with the pericranium and dura mater. The position of these cranial nerves is an important anatomical parameter because it allows a posterior surgical approach to the jugular bulb with preservation of the nerves. The lower cranial nerves present a multifascicular histoarchitecture (particularly the X cranial nerve). The tympanic branch of the glossopharyngeal nerve (Jacobson’s nerve) and the auricular branch of the vagal nerve (Arnold’s nerve) arise from inside the jugular foramen, and may be the site of origin of paragangliomas (Fig. 7).

In 1997, Katsuta and Rhoton divided the jugular foramen in three portions: two venous and one nervous (intrajugular) with the nerves IX, X and XI, between the two venous. Anatomical variations are described in the course of the cranial nerves through the jugular foramen. The vagal nerve is usually formed by multiple fascicles, the glossopharyngeal nerve by one, and the accessory nerve is formed by two fascicles, one spinal and one cranial.

Intradurally, the jugular foramen is related to the cranial nerves IX, X and XI (with its spinal portion) (Fig. 8), superiorly with the VII and VIII cranial nerves, with the vertebral, posterior inferior and anterior inferior cerebellar arteries, the medulla oblongata, pons and upper cervical cord (Fig. 9). The internal carotid artery is located anterior to the jugular bulb and enters the skull through the carotid canal (Figs. 10-11). The glossopharyngeal, vagus, accessory, and hypoglossal nerves run between the internal carotid artery and the internal jugular vein (Fig. 12). The petrous segment of the internal carotid artery (C2) lays inside the petrous portion of the temporal bone. This segment has three portions: an ascending (vertical), the genu and the horizontal portion (Fig. 13). The internal carotid artery is located anterior to the tympanic cavity, Eustachian tube and cochlea (Fig. 14). Anatomical vascular variations within the temporal bone as aberrant internal carotid artery, high jugular bulb, dehiscent carotid canal, stapedial artery and high jugular bulb may mimic glomus tumors. These are rare but very important anomalies because misdiagnosing them may lead to massive hemorrhage. The caroticotympanic branches of the petrous segment of the internal carotid artery may feed the ear portion of a jugular tumor (Fig. 15). The lacerum segment (C3) of the internal carotid artery passes through the superior part of the foramen lacerum, is surrounded by periosteum and gives the vidian artery.

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Figure 9. Intradural view of the jugular foramen with the cranial nerves IX, X and XI.

Figure 10A. Common carotid artery (CCA), external carotid artery (ECA) and Internal carotid artery (ICA) in the neck.

Figure 10B. ICA before entering the skull. MT: mastoid tip.

Figure 11. Internal carotid artery (ICA) at its entrance in the skull (arrow). VII: facial nerve; IJV: internal jugular vein.

Figure 12. Internal jugular vein (IJV) in close relationship with the internal carotid artery at its entrance in the skull.
The facial nerve is frequently involved in cases of jugular foramen tumors. This nerve emerges from the brainstem and enters the internal auditory canal with the VIII cranial nerve. The facial nerve has the following portions: cisternal, meatal, labyrinthine, tympanic, mastoid and extratemporal (stylomastoid, parotid and peripheral) (Fig. 16). Jugular foramen tumors may involve the facial nerve from the brainstem to the parotid gland. The anatomical parameters to expose the facial nerve at the stylomastoid foramen region are: the mastoid tip, the cartilage of the external ear canal ("pointer") and the posterior belly of the digastric muscle (Fig. 17). In the mastoid cavity the facial nerve runs downwards to the stylomastoid foramen anterior and medial to the sigmoid sinus and digastic ridge. In these cases, a radical mastoidectomy is performed to expose the tumor in this region, the jugular bulb and hypotympanum (Figs. 18-19). After opening the mastoid antrum, the short process of the incus is identified. It points to the Fallopian canal medial to the lateral semicircular canal (Fig. 20).
Figure 17A. Drawing representing the course of the facial nerve in the Fallopian canal. Art: Erasmo Barros da Silva Jr.

Figure 17B. Anatomical parameters used to identify the facial nerve (VII). Pointer, digastric muscle; mastoid tip; parotid.

Figure 17C. Anatomical parameters used to identify the facial nerve (VII). Pointer, digastric muscle (DM); mastoid tip (MT). PG: parotid gland.

Figure 17D. Extracranial portion of the facial nerve (arrows).

Figure 18A. Mastoidectomy with exposition of the antrum.

Figure 18B. Mastoidectomy and the planned craniotomy.
The jugular foramen has relationship with anatomical structures of the neck. Neck dissection is indicated to approach tumors extending to this region. The surgical anatomy of the neck region related to the jugular foramen is complex and includes different muscles, vessels and nerves. The muscles are: sternocleidomastoid (SCM), digastric, splenius capitis, Obliquus capitis superior and inferior, Rectus capitis posterior major and splenius cervicis. The arteries are: common carotid, external carotid and its branches, internal carotid, vertebral artery at the craniocervical junction. The veins are: common facial, external and internal jugular veins. The nerves are: great auricular nerve, cranial nerves X, XI and XII and the pericarotid sympathetic trunk (Fig. 21).

The common carotid artery, as well as the external and internal carotid artery, runs medial to the internal jugular vein. The vagus nerve courses between the internal jugular vein and the common carotid artery and before its entrance into the skull lateral to the internal carotid artery (Fig. 22). The common carotid artery is covered by the superficial cervical fascia, platysma muscle, deep cervical fascia, and the anterior margin of the SCM. In the carotid triangle of the neck, bounded posteriorly by the SCM and superiorly by the stylohyoideus and digastric muscle, the internal carotid artery (ICA) is posterolateral to the external carotid artery (ECA). The internal jugular vein is lateral to both (Fig. 22). The ICA has no branches in the neck. The hypoglossal nerve crosses the ICA and the ECA cranially to their bifurcation (Fig. 9). The vagus nerve is located in a plane posterior to the ICA (Fig. 19). The second segment of the vertebral artery (VA) ascends through...
the transverse foramina of the upper six cervical vertebrae. The cervical roots are posterior to the VA. The VA is covered with a venous plexus. This plexus is larger in the region of C1-C2 joint. After its exit from the transverse foramen of C3, the VA makes a loop close to the articular facet and courses through the transverse foramen of C2, anterior to the two roots of the C2 ganglion. Small branches (muscular and a small artery along the C2 ganglion) arise in this portion. Posteriorly, the muscles related to the C1/C2 segment of the VA in the suboccipital triangle are: semispinalis cervicis from the C2 to C5 to the transverse process of the upper thoracic vertebrae, the superior oblique from the transverse process of C1 to the inferior nuchal line, the inferior oblique, the rectus capitis posterior major (medial limit of the suboccipital triangle), rectus capitis minor, scalenus medius and the elevator scapulae (Fig. 23). Anteriorly, the muscles involved are: anterior and lateral rectus capitis, longus capitis, longus colli and longus capitis. Exiting the transverse process foramen of C1 the VA makes a right angle loop medially along the groove on the superior surface of the arch of the C1 and turns anteriorly to enter the spinal canal in front of the ligamentum denticulatum (Fig. 24). Then, it bends upwards in relation with the first cervical nerve, the spinal branch of the accessory nerve and the hypoglossal nerve. Figure 25 shows the entire surgical exposure (neck dissection, mastoidectomy, meatotomy, craniotomy, ICA dissection and intradural) for jugular foramen involving the high cervical region, ear, internal carotid artery and intradural region.

**Figure 22.** Neck dissection showing the course of the vagal nerve (arrows), the Internal Jugular vein (IJV), the internal carotid artery (ICA) and the XI cranial nerve.

**Figure 23.** Muscles related to the C1/C2 vertebral artery segment. Superior and inferior Obliquis muscles. Rectus capitis posterior major (RCPM) and minor (RCPMi) muscles.

**Figure 24A.** Drawing showing the vertebral artery at the C1/C2 junction and the vertebral groove at C1 lamina before entering the skull (arrow). Art: Erasmo Barros da Silva Jr.
CONCLUSION

The jugular foramen remains a challenging region where few skull base surgeons are prepared to conquer. Profound anatomical knowledge of this region, as well as its myriad of variations are the key to safely approach the jugular foramen.

REFERENCES


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