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Article

The Superior Trajectory of the Lingual Artery over the Hypoglossal Nerve: A Morphological Case Report and Focused Review of Neurovascular Inversion in the Carotid Triangle

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Abstract

Introduction: Accurate knowledge of the external carotid artery (ECA) anatomy is essential for head and neck surgery, interventional procedures, and imaging interpretation. Although its branching pattern is classically described as relatively constant, clinically relevant anatomical variations are frequently encountered. Cadaveric dissection remains fundamental for identifying rare vascular configurations. **Materials and Methods**: During an anatomical teaching dissection of a 72-year-old male cadaver, a right-sided lateral cervicotomy was performed to expose the carotid sheath. After mobilisation of the sternocleidomastoid muscle, the ECA and its proximal branches were skeletonised, allowing detailed three-dimensional assessment of their origin, calibre, and neurovascular relationships. **Results**: The superior thyroid artery originated from the proximal segment of the external carotid artery, in close proximity to the carotid bifurcation. The main anatomical finding was a lingual artery of relatively small initial calibre exhibiting an atypical superior trajectory: after its origin, it crossed superior to the hypoglossal nerve before continuing toward the tongue. This configuration differs from classical descriptions and modified the anatomical arrangement of Beclard's and Pirogoff's triangles, creating a potential site of close neurovascular contact. **Conclusions**: This cadaveric study describes a rare trajectory-based variant of the external carotid artery characterised by a lingual artery crossing superior to the hypoglossal nerve. Awareness of such rare patterns is essential for improving anatomical interpretation and enhancing surgical safety in the head and neck region.

Keywords: external carotid artery; lingual artery; hypoglossal nerve; cadaveric dissection; anatomical variation; arterial trajectory; Beclard's triangle; Pirogoff's triangle

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1. Introduction

Accurate knowledge of the external carotid artery (ECA) anatomy is essential for head and neck surgery, vascular procedures, interventional practice, and imaging interpretation.

While classical descriptions portray the branching pattern of the ECA as relatively consistent, numerous studies have documented variability in the origin and configuration of its anterior branches.

Rarely, the spatial relationship between the lingual artery and the hypoglossal nerve may deviate from the expected arrangement within the submandibular region, potentially affecting surgical landmarks traditionally described through Beclard's and Pirogoff's triangles. Although such variants have been sporadically mentioned in the literature, detailed topographic documentation and clinically oriented anatomical interpretation remain limited.

Despite the well-established description of the ECA and its branches in classical anatomical texts [1], numerous studies have emphasised that the vessel exhibits a considerable degree of variability.

Documented variations include differences in the number and origin of its major branches, unusual branching patterns, atypical arterial trunks, and morphologically distinct configurations of the carotid bifurcation [2–5]. Such variations may affect the superior thyroid (SThA), lingual (LA), facial (FA), occipital (OA), maxillary (MA), or superficial temporal (STA) arteries and may also involve uncommon, shared trunks or aberrant anastomoses [6]. From a clinical perspective, unrecognised variants may lead to unexpected bleeding, difficulty in vessel ligation, challenges during lymph node dissection, or misinterpretation of ultrasonographic, computed tomography (CT) angiographic, and magnetic resonance (MR) angiographic studies. In addition, specific variants may be relevant to targeted embolisation procedures or to planning extracranial-to-intracranial bypass surgery.

Cadaveric dissection remains one of the most powerful tools for enriching our understanding of vascular variability. Unlike imaging, dissection allows for direct visualisation of fine arterial relationships and for precise documentation of variants that might otherwise go unnoticed. Teaching dissections provides repeated opportunities to examine anatomical structures in detail, often revealing rare vascular configurations that have not yet been documented in the literature [4,5].

During a recent anatomical teaching course, a previously unreported variant of the external carotid artery was identified. The observed configuration differed from canonical descriptions and from variants documented in existing anatomical and radiological studies. Its distinct morphological features and unusual relational anatomy prompted a detailed investigation.

The present report provides a detailed morphological description of a cadaveric specimen in which the LA courses superior to the hypoglossal nerve (XII), producing a neurovascular inversion in the carotid triangle/submandibular space. We describe the local anatomy, clarify the implications for classical surgical triangles, and discuss potential relevance for open and minimally invasive procedures in the head and neck, including vascular and transoral approaches.

2. Materials and Methods

The observations in this case report were performed at the University of Siena in the Head and Neck Anatomy Research Laboratory (H.A.R.L., managed by Dr Fagni Niccolò). The anatomical preparation was sent by the ICLO Teaching and Research Centre (Verona, Italy), an authorised institution for cadaveric studies, in November 2024. The dissection of a human Caucasian male cadaver aged 72 years, injected with synthetic resins (acrylic polymers) colored red for arteries and blue for veins, was performed for teaching purposes.

The resin injection provided adequate distension and visual contrast of the arterial and venous trees without evident over-distension or leakage. Although it did not allow formal haemodynamic assessment, it facilitated reliable comparison of vessel calibre within the same specimen, supporting the qualitative identification of relatively small-calibre arterial segments.

Access to the carotid vessels was achieved through a lateral cervicotomy running parallel to the anterior margin of the sternocleidomastoid muscle (SCM). Following the skin incision, the subcutaneous layers and platysma were sectioned in a layered fashion. Superior and inferior myocutaneous flaps were then elevated, providing broad, stable exposure of the deep planes of the carotid triangle and enabling precise identification of fascial landmarks.

The SCM was subsequently mobilised, dissected free, and retracted laterally. Dissection proceeded along the natural cleavage plane of the superficial cervical fascia, following the medial border of the muscle until the carotid sheath was exposed along its longitudinal extent. This approach preserved the integrity of anatomical planes and minimised traction on deeper vascular structures.

Once the carotid sheath was fully exposed, it was opened with a precise longitudinal incision, progressively revealing the three main components of the cervical neurovascular bundle: the common carotid artery (CCA), the internal jugular vein, and the vagus nerve. Opening the sheath allowed controlled separation of these structures, enabling selective dissection and a clear definition of their reciprocal anatomical relationships.

The CCA was then followed cranially to its bifurcation, located at the level of the hyoid bone. After identification of the division into the internal carotid artery (ICA) and ECA, the proximal segment of the ECA was isolated. Dissection continued with systematic skeletonisation of its proximal collateral branches by removing surrounding connective tissue and fascial septa, while preserving the spatial relationships with adjacent nerves, satellite veins, and muscular structures.

Morphometric measurements were obtained using a calibrated ruler/digital caliper, including the distance from the carotid bifurcation to the origin of the superior thyroid and lingual arteries and the external diameter of the proximal lingual artery. Collateral pathways were assessed by inspection of the facial artery and its submental branch within the exposed field.

The lingual artery measured approximately 1.8 mm in diameter, the external carotid artery approximately 4.8 mm, and the common carotid artery approximately 7.0 mm. The hypoglossal nerve measured approximately 2.8 mm in diameter. These values are consistent with normal adult anatomy and confirm the relatively small calibre of the lingual artery observed in this specimen.

This technique provided a complete three-dimensional visualisation of the ECA and its branches, enabling accurate documentation of the anatomical variant encountered, with particular attention to the origin, course, and topographic relationships of the involved vascular structures.

Only the right side of the neck was dissected and analysed; therefore, the possible bilateral occurrence of this vascular configuration could not be assessed.

3. Results

The anatomical dissection of the right cervical region allowed complete exposure of the carotid bifurcation and the proximal branches of the ECA. The superior thyroid artery originated from the proximal ECA, in close proximity to the carotid bifurcation, compared with commonly described configurations. The distinction between the ICA and the ECA was evident in both calibre and course.

In the posterior compartment of the ECA, the emergence of the posterior auricular artery (PAA) was clearly visible along its initial course; the OA, however, was outside the exposed dissection field, as its origin lies more cranially than the exposed field allowed.

Proceeding cranially along the ECA, the FA and the continuation of the ECA trunk were identified before the division into terminal branches (STA and maxillary arteries). Anteriorly and cranial to the SThA, the LA and FA were identified in their proximal courses, before the emergence of the submental artery, typically emerging from the facial branch. The intermediate tendon of the digastric muscle marked the superior limit of the distal skeletonisation of the ECA.

The main anatomical novelty observed concerns the LA, which presented a relatively small calibre in its initial segment compared with the adjacent ECA branches and exhibited an unusual course: after its origin, it ran superiorly over the hypoglossal nerve, crossing it before continuing towards its lingual territory. This atypical superior trajectory of the LA, with a close neurovascular relationship to the XII nerve, is not previously reported in classical descriptions or documented variants.

Indeed, this arrangement significantly alters the architecture of Beclard's and Pirogoff's triangles.

Beclard's and Pirogoff's triangles are two anatomically and surgically significant regions within the submandibular and suprahyoid spaces, serving as key landmarks for identifying the lingual artery and its relationships with surrounding neurovascular structures [7].

- Beclard's triangle is classically defined by three anatomical boundaries:
  - Superiorly, the posterior belly of the digastric muscle (PBDM);
  - Inferiorly, the greater horn of the hyoid bone (HB);
  - Posteriorly, the posterior border of the hyoglossus muscle (HM).

The floor of the triangle is formed by the hyoglossus muscle, while its roof is constituted by the mylohyoid muscle and the overlying soft tissues of the floor of the mouth. Within this anatomical space, the lingual artery is typically encountered as it courses deep to the HM after arising from the ECA. In its classical configuration, the artery lies inferior and deep to the XII, which traverses the region in a more superficial and superior plane.

- Pirogoff's triangle is a deeper and more medially located anatomical space, classically defined by the following boundaries:
  - Superiorly, the hypoglossal nerve (XII);
  - Inferiorly, the intermediate tendon of the digastric muscle (IT);
  - Anteriorly, the posterior border of the mylohyoid muscle (MM).

The floor of the triangle is formed by the HM. Within this space, the LA runs deep to the HM, making the triangle a key surgical landmark for vascular control during procedures involving the floor of the mouth or the submandibular region.

In standard anatomical descriptions, the XII nerve forms the superior boundary of Pirogoff's triangle, while the lingual artery lies inferior and medial to it. This predictable spatial relationship facilitates safe identification of both structures during surgical dissection (Figure 1).

In the present specimen, the anatomical configuration of both Beclard's and Pirogoff's triangles was significantly modified by the atypical superior trajectory of the LA in relation to the XII nerve.

Beclard's triangle: although the muscular boundaries of Beclard's triangle were preserved, its internal neurovascular arrangement was markedly altered. The LA originated from the ECA and ascended superiorly, crossing above the hypoglossal nerve before entering the lingual region. As a result, the artery occupied a more cranial position than expected, partially redefining the functional anatomy of the triangle. This superior displacement reduced the reliability of Beclard's triangle as a landmark for locating the LA based on its classical anatomical description.

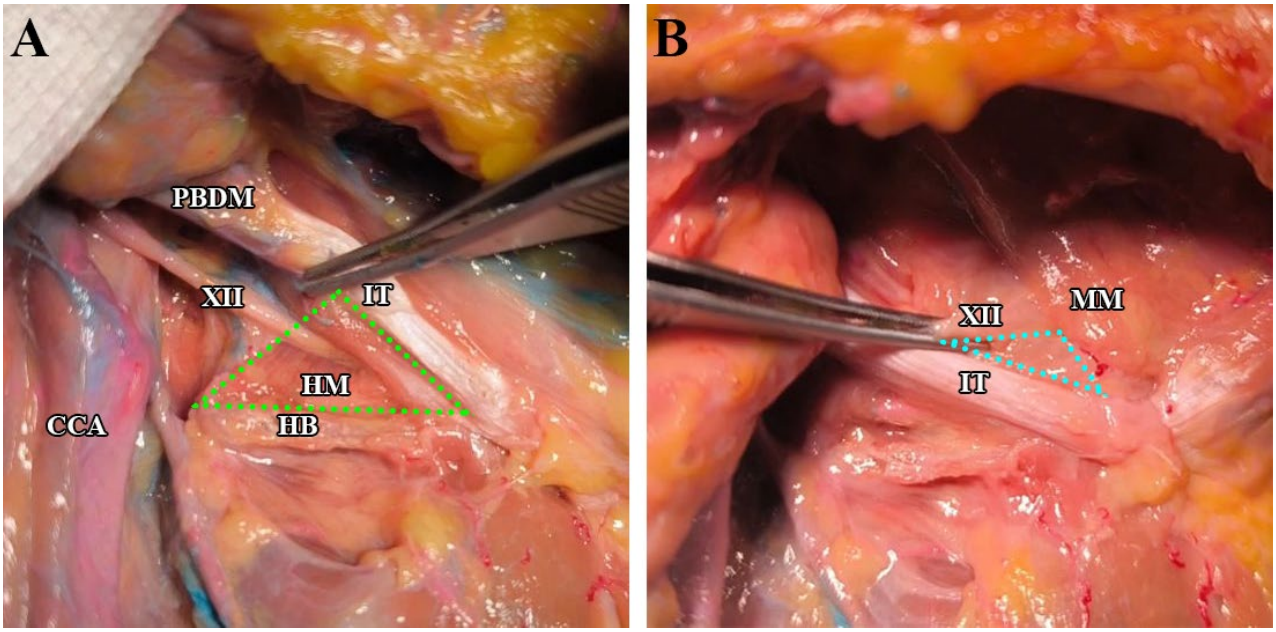

Figure 1. Normal anatomy of Beclard's and Pirogoff's triangles. Panel (**A**) illustrates the normal anatomical configuration of Beclard's triangle (green dotted area), bounded by the posterior border of the hyoglossus muscle (HM), the posterior belly of the digastric muscle (PBMD), and the greater horn of the hyoid bone (HB). The hypoglossal nerve (XII) courses superficially within the region, serving as an important surgical landmark. It also highlights the common carotid artery (CCA) and the intermediate tendon (IT) of the digastric muscle. Panel (**B**) shows the normal anatomy of Pirogoff's triangle (cyan dotted area), superiorly delimited by the hypoglossal nerve (XII), the posterior border of the mylohyoid muscle (MM), and the intermediate tendon (IT) of the digastric muscle.

Pirogoff's triangle: in typical anatomy, the LA courses deep to the HM and inferior to the XII nerve, forming a consistent and surgically useful landmark within this space.

In the present specimen, this relationship was inverted. The lingual artery crossed superior to the XII nerve, thereby modifying the upper boundary of Pirogoff's triangle and disrupting its classical configuration. Consequently, the expected neurovascular arrangement within this region was altered, creating a zone of close spatial proximity between the artery and the nerve. This variation may increase the risk of vascular or neural injury during surgical procedures involving the submandibular region or the floor of the mouth.

This arrangement creates a potential site of close neurovascular interaction between the lingual artery and the hypoglossal nerve, as the artery's superior course over the hypoglossal nerve may create an intimate relationship between the two structures in vivo. However, its clinical significance cannot be assessed in a cadaveric specimen.

The investigation was conducted exclusively on the right side of the neck; the contralateral side was not examined, and therefore, it is not possible to determine whether this configuration represents a unilateral or potentially bilateral variant (Figure 2).

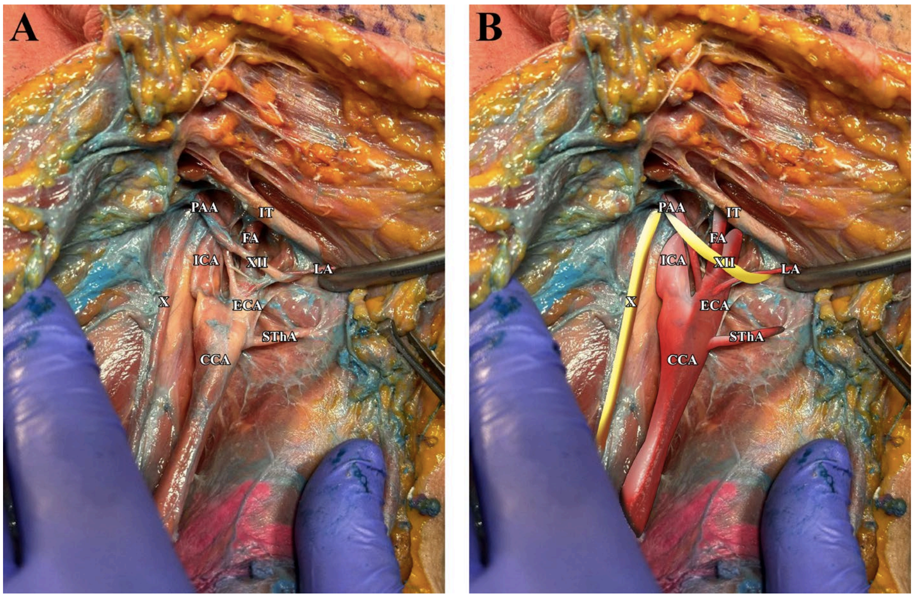

Figure 2. Anatomical variation in the ECA on the right side of the neck. Panel (**A**) shows the vascular architecture on the right side of the neck region (the forceps indicate the lingual artery). Panel (**B**) highlights the relationship between the ECA branches and the nerves. CCA (Common Carotid Artery); ICA (Internal Carotid Artery); ECA (External Carotid Artery); SThA (Superior Thyroid Artery); LA (Lingual Artery); FA (Facial Artery); PAA (Posterior Auricular Artery); IT (Intermediate Tendon (digastric muscle)); X (Vagus Nerve); XII (Hypoglossal Nerve).

4. Discussion

This report describes an unusual anatomical configuration of the external ECA characterised by a low-origin SThA and, most notably, by a LA with a relatively small initial calibre and an atypical superior trajectory crossing above the XII nerve. To our knowledge, this specific spatial arrangement has not been clearly documented in previous anatomical or radiological studies and expands the current spectrum of variants of the ECA and its branches [5,8].

Variations in the superior thyroid, lingual and facial arteries are well documented in classical and contemporary literature, including rare common trunks, atypical origins, and altered branching patterns [2–6]. However, previously published classifications, including those proposed by Zaccheo et al. [3] and by earlier angiographic and cadaveric studies, do not mention a lingual artery coursing superior to the hypoglossal nerve. Similarly, extensive morphological surveys such as the work of Cobiella et al. [9] and the hemi-head dissections analysed by Mata and colleagues [10] did not report a comparable trajectory, reinforcing the novelty of this finding.

Beyond classical descriptions of ECA branching, recent studies have provided more refined insights into the variability of the lingual artery [11–15]. A comprehensive angiographic review by Na et al. [16] summarised morphological and trajectory patterns of the lingual artery, confirming substantial variability in origin and calibre. Sarna et al. [17], through cadaveric analysis supported by imaging correlation, further detailed variant origin patterns and their relationships with consistent anatomical landmarks. Additionally, Triantafyllou et al. [18], in a systematic review and meta-analysis of computed tomography angiography, quantified the prevalence of common trunks between the lingual and facial arteries, underscoring the anatomical diversity of the anterior ECA branches. Notably, all these studies consistently describe the lingual artery coursing inferior to the hypoglossal nerve. The superior trajectory observed in our specimen, therefore, represents a deviation from the established classifications and introduces a trajectory-based variant not yet integrated into current anatomical taxonomies.

The superior course of the lingual artery modifies the classical topography of Beclard's and Pirogoff's triangles, both of which rely on stable relationships among the hyoglossus muscle, the intermediate tendon of the digastric muscle, and the hypoglossal nerve. In the present specimen, the artery occupies a more cranial and anterior position, altering vascular landmarks commonly used during surgical exposure of the floor of the mouth. While the functional implications cannot be evaluated in a cadaver, the close spatial relationship between the artery and the hypoglossal nerve represents a potential site of neurovascular contact that should be recognised in surgical and interventional planning. In vascular surgery practice, awareness of this configuration may be relevant during exposure and preparation of the carotid axis. An atypical relationship between the LA and the XII nerve could increase the risk of inadvertent arterial injury or nerve traction during manoeuvres aimed at identifying and protecting the hypoglossal nerve, a step that may be required during carotid endarterectomy and related carotid procedures.

From a clinical standpoint, this variant may influence several head and neck procedures. During submandibular gland excision, selective neck dissections of levels I–II, and transoral approaches to the tongue base, an unrecognised superior trajectory of the LA could increase the risk of inadvertent arterial injury or unintended traction on the XII nerve. Furthermore, reconstructive microsurgery relying on LA branches may be complicated by an atypical vessel position or reduced calibre. In endovascular practice, selective LA embolization (performed for haemorrhage control or tumour devascularization) may also be affected, as a small-calibre vessel with an unexpected trajectory could be difficult to catheterise or identify on routine angiography.

This case demonstrates the continuing value of cadaveric dissection in identifying subtle yet clinically meaningful vascular variants. Imaging modalities such as CT and MR angiography offer excellent anatomical detail but may not reliably detect fine neurovascular relationships or small-calibre vessels, especially when located in constrained anatomical spaces. Direct dissection, therefore, remains essential for documenting variations that may otherwise go unnoticed.

A limitation of this study is its unilateral nature, as only the right side of the neck was examined. Bilateral dissection or correlation with imaging would be required to determine whether this configuration represents a unilateral variation or a less common bilateral pattern [19]. Additionally, although resin injection provided good visualisation of the vessels, it does not allow formal haemodynamic assessment and therefore limits conclusions regarding functional significance.

Transoral robotic surgery (TORS) and other transoral approaches to the tongue base rely on precise knowledge of deep neurovascular anatomy. In standard configurations, predictable relationships between the LA, XII nerve, and muscular planes allow safe surgical access. However, a superior trajectory of the LA relative to the XII nerve, as observed in this case, may significantly alter these expected landmarks.

Such a variation may place the artery closer to the operative field during tongue base dissection, increasing the risk of unexpected bleeding or vascular injury, particularly in minimally invasive procedures where exposure is limited. Moreover, the close spatial relationship between the artery and the XII nerve may increase the risk of neural injury, potentially affecting postoperative tongue mobility. Awareness of this anatomical configuration is therefore essential for surgical planning, intraoperative orientation, and risk reduction during TORS and related transoral approaches.

From an embryological perspective, variations in the ECA arise from complex remodeling of the ventral pharyngeal arterial system during development. Subtle differences in

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the persistence or regression of embryonic vascular channels supplying the face and tongue may lead to atypical arterial origins or trajectories.

In this context, the superior course of the lingual artery observed in the present case may reflect altered developmental patterning within the arterial plexus of the pharyngeal region. Such variations represent stable anatomical configurations rather than pathological anomalies and help explain uncommon spatial relationships between arterial branches and cranial nerves, including the XII nerve. Recognition of these developmental mechanisms supports a more informed interpretation of vascular variability in surgical anatomy.

In summary, this report documents a previously undescribed anatomical variant in which the LA crosses the hypoglossal nerve superiorly, modifying established landmarks of the floor of the mouth and creating a potential site of neurovascular contact. Recognition of such configurations is crucial for enhancing surgical safety, improving preoperative planning, and refining anatomical interpretation in the head and neck region.

5. Conclusions

This cadaveric study documents a previously undescribed anatomical variant of the ECA, characterised by a low origin of the superior thyroid artery and a relatively small-calibre LA that crosses superior to the hypoglossal nerve. This atypical trajectory modifies the classical relationships of Beclard's and Pirogoff's triangles and creates a potential site of close neurovascular contact in the lingual region.

Recognising such rare configurations is crucial for improving anatomical interpretation and enhancing surgical safety during submandibular gland procedures, selective neck dissections, transoral approaches to the tongue base, and reconstructive or endovascular interventions involving the LA.

This finding expands the current spectrum of ECA variants and highlights the continued value of cadaveric dissection in identifying subtle yet clinically relevant anatomical patterns [20,21]. Further studies incorporating bilateral dissections and imaging modalities are warranted to clarify the prevalence and potential clinical implications of this and similar variants.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki. Regarding ethical approval, an Institutional Review Board or Ethics Committee approval was not required, as the dissection was performed in a private institute that operates in full compliance with current national legislation governing anatomical dissection. The procedure was conducted according to all applicable legal and ethical regulations.

Informed Consent Statement: Informed consent was obtained from all study participants before their death.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CCA	Common Carotid Artery
ECA	External Carotid Artery
ICA	Internal Carotid Artery
OA	Occipital Artery
LA	Lingual Artery
FA	Facial Artery
SThA	Superior Thyroid Artery
STA	Superficial Temporal Artery
PAA	Posterior auricular artery
IT	Intermediate Tendon of digastric muscle
SCM	Sternocleidomastoid muscle
CT	Computed Tomography
MR	Magnetic Resonance
X	Vagus Nerve
XII	Hypoglossal Nerve
PBDM	Posterior Belly of Digastric Muscle
HM	Hyoglossus Muscle
MM	Mylohyoid Muscle
HB	Hyoid Bone

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