Surg Radiol Anat (2013) 35:3–10
DOI 10.1007/s00276-012-0983-2

ORIGINAL ARTICLE

Anatomical landmarks for transoral robotic tongue base surgery: comparison between endoscopic, external and radiological perspectives

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Received: 25 November 2011 / Accepted: 11 May 2012 / Published online: 29 May 2012

Abstract

Purpose To describe the transoral viewpoint of the tongue base anatomy, focusing on a superior to inferior perspective, which is less familiar to the head and neck surgeon but, at the same time, worthy to be known given the expanding interest and diffusion of the transoral robotic technique.

Methods Seven heads were dissected, two with the Da Vinci® robotic system, three by means of a transoral endoscopic approach and another two by means of a lateral "traditional" external approach. Ten normal patients, with normal oral cavity and oropharynx, were studied as control samples by means of a 3-T MRI scanner.

Results Major neurovascular elements are placed laterally and deeply within the tongue base. Dissection within intrinsic and genioglossus muscles is safe because the main trunk of the lingual artery lies on the lateral surface of genioglossus muscle, covered by the hyoglossus muscle. The hypoglossal nerve, with its comitant vein, is more lateral, lying on the external surface of the hyoglossus muscle. Radiological evaluation can visualize important details of this complex anatomy. The position of the vessels can be directly identified, whereas major nerves are more difficult to be visualized unless they are surrounded by fibro-fatty tissue.

Conclusions A medial to lateral dissection of the tongue base can be considered safe. A strict collaboration with the radiologist is helpful in approaching these cases by means of a robotic technique and in improving a true 3D understanding of this complex anatomy.

Keywords Tongue base surgery · Transoral robotic surgery · Lingual artery · Hypoglossal nerve · Tongue base anatomy

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Introduction

The tongue base is defined as the posterior part of the tongue, behind the lingual V. It mainly presents a vertical orientation and is a hidden region, not immediately accessible through the oral cavity.

The ideal surgical approach for the tongue base should be both the widest, to completely manage the region under vision, and the safest, to reduce the damage to the surrounding critical structures to a minimum. It also should be the most functionally conservative because of the critical role the tongue base has in determining the quality of life of the patient. In fact, it is well known that resection of the tongue base alone is associated with not-negligible morbidity related to impaired speech, compromised deglutition and possibly chronic aspiration.

Traditional external approaches for the management of the tongue base include anterior suprahyoid pharyngotomy, lateral pharyngotomy and transmandibular approaches. A transoral tongue-splitting approach has also been described for selected median located lesions [5]. With the purpose of progressively reducing the invasiveness of the surgical procedures, transoral laser-assisted techniques have been proposed [7, 8]. More recently, robotic procedures have gained popularity [6, 10, 13, 15].

Based on the growing experience and interest regarding this topic and considering the lack of a dedicated anatomical study, we planned and performed an anatomical study with the scope of describing the anatomy of the tongue base through this new perspective. A comparison with radiological evaluation pointing out opportunities and limitations is given.

Materials and methods

The anatomical part of this study was conducted at the Department of Systematic Anatomy of the University of Vienna. A total of seven specimens was studied, two of which by means of a DaVinci robotic system, three by means of a transoral endoscopic dissection to reproduce a superior to inferior perspective of the anatomy of the tongue base, and the latter two by means of a lateral external approach. The external procedures were performed with the aid of loupes (×5).

The MRI radiological evaluation of the tongue base and surrounding regions was performed in ten patients referred for MRI of the nasal sinuses with no known pathological conditions of the oral cavity. MRI examinations were carried out on a 3-T MRI system (General Electric, Milwaukee, WI, USA) using a neurovascular N-channel phased-array coil. Axial T1- and T2-weighted images without fat suppression were generated with 4-mm slice thickness and 0.8 mm spacing, and were compared with anatomical specimens obtained at the same levels.

Robotic dissections were performed using the DaVinci surgical system (Intuitive®, Sunnyvale). The robot is set up on the right side of the specimen. After the insertion of a mouth gag, the robotic arms are placed in the oral cavity. Visualization is achieved with a 30°, high magnification, three-dimensional endoscope. Procedure begins with the visualization of the epiglottis to orientate the surgeon. Then a piece-meal resection of the tongue base and tonsillar region is performed using a step-by-step approach.

Endoscopic transoral procedures were conducted with a 70° downward scope and cold instruments. In another specimen, this approach was conducted after an external one, to better define the anatomical landmarks.

Results

Transoral procedures

The dissection starts with the removal of the mucosa and lymphoid tissue of the tongue base; we consider the amygdalo-glossus sulcus the lateral boundary for dissection. If present, the palatine tonsil is removed on a sub-capsular plane. The inferior tonsillar arteries, branch of the facial artery and the ascending palatine artery, are usually visualized. Superiorly, the superior tonsillar arteries, coming from the ascending pharyngeal artery and the descending palatine artery, are visualized. The superior constrictor muscle is seen on the lateral surface of the tonsillar fossa. Under the mucosa of the tongue base, a rich-vascular arteriolar network given by the dorsal lingual arteries is clearly evident (Fig. 1), and a further amount of lymphoid tissue can be removed piece by piece until tongue muscles are identified. The hyoid bone can be easily identified at the level of the glosso-epiglottic space. The hyoid bone is gently freed from its surrounding connections: medially from the genio-hyoid muscle and, inferiorly from the mylohyoid muscle. It is not easy to identify the genioglossus muscle within the tongue base, of which it represents the medial portion. More laterally the lingual artery is visualized, covered by the hyoglossus muscle (the vessel is medial to it) while the hypoglossal nerve and its comitant vein are identified more laterally. Extending the dissection at the level of the upper laterocervical region allows the identification of the lingual portion of the submandibular gland, and, once the gland is removed, the identification of the posterior belly of the digastric muscle and the hypoglossal nerve is possible. The posterior belly is easily identifiable given its posterior to anterior and lateral to medial direction. Its typical tendon is evident on the superior border of the hyoid bone. At this level, the posterior belly is crossed by the hypoglossal nerve that lies on a more superficial plane and has a lateral to medial and posterior to anterior course. (Fig. 2).

Lateral procedures

The identification of the anterior and posterior bellies of the digastric muscle delineates the submandibular space. The mylohyoid muscle is evident in the anterior portion of the submandibular triangle. The hypoglossal nerve runs in the inferior portion of the triangle, lying on the lateral

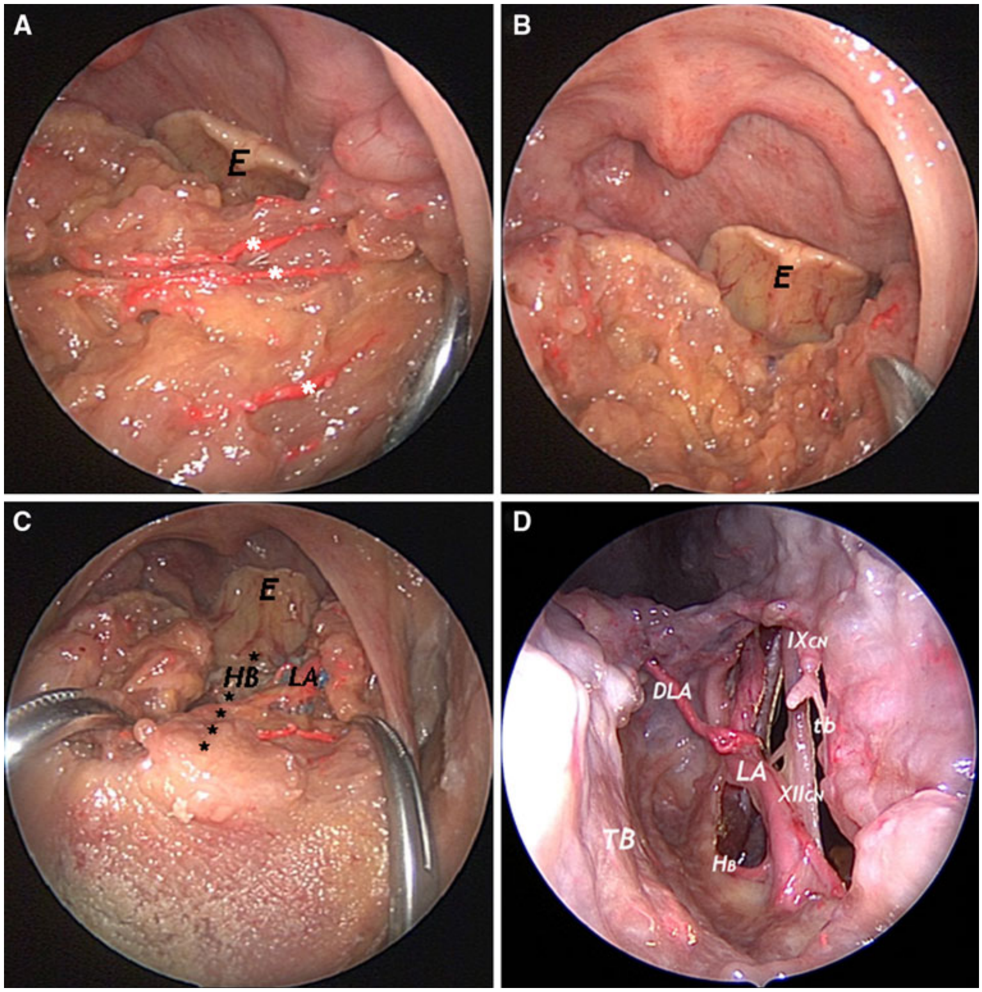

Fig. 1 Tongue base dissection: endoscopic transoral view. **a** superficial arteriolar network given by dorsal lingual branches, reaching the midline. **b** Progression of the dissection showing the absence of major critical structure in the superior aspect of the tongue base. **c** Exposition of the lingual artery and the hyoid bone. Note the lateral and deep position of the main trunk of the lingual artery. **d** Detailed vision of the lateral tongue base and amygdalo-glossal regions. The hyoglossal muscle has been removed to expose the hypoglossal nerve. *E* epiglottis, *TB* tongue base, *HB* hyoid bone, *LA* lingual artery, *black asterisks* indicate the midline, *white asterisks* indicate the dorsal lingual branches, *DLA* dorsal lingual artery, *HB* hyoid branch, *IXcn* glossopharyngeal nerve, *tb* tonsillar branch, *XIIcn* hypoglossal nerve

surface of the hyoglossus muscle, while the lingual nerve is evident in the superior portion, on the lateral surface of the styloglossus muscle. The hyoglossus muscle connects the hyoid bone and the lateral portion of the body of the tongue while the styloglossus muscle runs into the hyoglossus muscle, in its superior portion. Slightly more laterally and inferiorly, it is possible to visualize the stylopharyngeus muscle with the glossopharyngeal nerve lying on its lateral surface (Fig. 3). This nerve, at the level of the tongue base, splits into various branches for the tongue base itself and for the tonsillar region. The lingual artery, coming from the external carotid artery, runs in close proximity to the greater cornu of the hyoid bone for a short distance before passing below the hyoglossus muscle. Underneath this muscle, the artery gives off different branches for the tongue base (dorsal lingual arteries) and for the body of the tongue. At this level the artery lies on the lateral surface of the genioglossus muscle. More anteriorly in the submandibular triangle, the hypoglossal nerve and the lingual nerve run closely to each other at the level of the sublingual gland and usually present a communicating branch.

Anatomo-radiological considerations

The bodies of the genioglossus muscle can be well appreciated as the root of the tongue in axial planes. Also the hyoglossus and mylohyoid muscles are easily recognizable. Lateral to the genioglossus muscle the lingual artery can be visualized. The intrinsic muscles of the tongue can be visualized. In some slices, in T1-weighted sequences, when surrounded by fibro-fatty tissue, the lingual nerve can be identified on the lateral surface of the

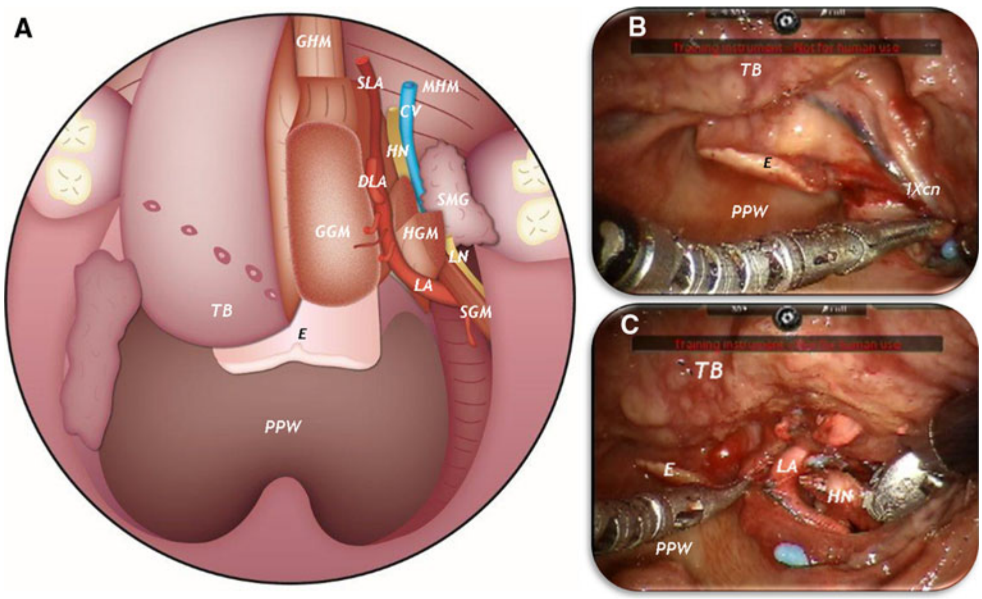

Fig. 2 **a** Three-dimensional reconstruction of the tongue base and surrounding regions with a "robotic" perspective. **b**, **c** Transoral robotic dissection of the tongue base and surrounding regions. *TB* tongue base, *GGM* genioglossus muscle, *HGM* hyoglossus muscle, *MHM* mylohyoideus muscle, *GHM* geniohyoideus muscle, *SGM* styloglossus muscle, *SMG* submandibular gland, *LN* lingual nerve, *IXcn* glossopharyngeal nerve, *HN* hypoglossal nerve, *CV* comitant vein, *LA* lingual artery, *DLA* dorsal lingual artery, *SLA* sublingual artery, *E* epiglottis, *PPW* posterior pharyngeal wall

hyoglossus muscle and in close proximity of the sublingual gland (Fig. 4). It is not actually possible to identify the hypoglossal nerve within the tongue base.

Discussion

Tongue base surgery is a challenge for both surgeons and patients. Especially in oncologic cases, it can be associated with severe morbidity given the need of a radical and often mutilating resection. With this consideration, chemoradiation has gained increasing acceptance in tongue base cancers in recent years. However, it must be underlined that also this treatment modality can be associated with severe morbidity, namely severe acute toxicities in the majority of patients, treatment-related mortality, swallowing dysfunction and late toxic effects such as pharyngeal fibrosis and severe xerostomia, necessitating non oral feeding [2]. In the sleep apnea syndrome field, there are only a few reports about open surgical management of huge tongue base hypertrophy [3, 18]. Obviously traditional external approaches are associated with not-negligible consequences. So, over the years, many efforts have been made to offer patients a more conservative approach, which is able to reduce the functional impact of surgical procedures, while gaining similar control rates obtained with more radical surgery or chemoradiation.

In cases of small early tumors a transoral approach can be planned, either with an anterior midline glossotomy or by means of a laser-assisted procedure. The first approach can be proposed for small midline lesions [5], but regardless of the good outcome, it cannot be considered a conservative procedure. Laser-assisted procedures have been proposed with good outcomes in oropharyngeal cancers [8] and good results have also been described for tongue base lesions [7, 9, 19]. Transoral laser-assisted resection is a minimally invasive endoscopic surgical technique that offers tumor-targeted treatment, relatively rapid recovery and a low long-term toxicity profile [19]. Notwithstanding, it has been reported that appreciation of tumor boundaries is more difficult with transoral laser and the rate of re-excision demonstrates the difficulty of determining tumor extent visually [9]. Although recently transoral laser procedures have been proposed also for advanced lesions, we maintain that larger tumors need to be approached by means of external approaches: among these, pharyngotomic (suprahyoid or lateral) and transmandibular ones.

Suprahyoid pharyngotomy can be useful for small tumors of the tongue base even in the presence of limited involvement of the supraglottic larynx. This kind of approach, for limited lesions of the tongue base, has been associated with an excellent cure rate, normal speech, good cosmesis and swallowing without aspiration [16]. Different from the aforementioned approach, the lateral pharyngotomy approach allows the management of more lateral located lesions of the tongue base [12] that do not grossly involve the amygdalo-glossal sulcus. For extended lesions, a mandibulotomy approach—a mandibular swing—can be

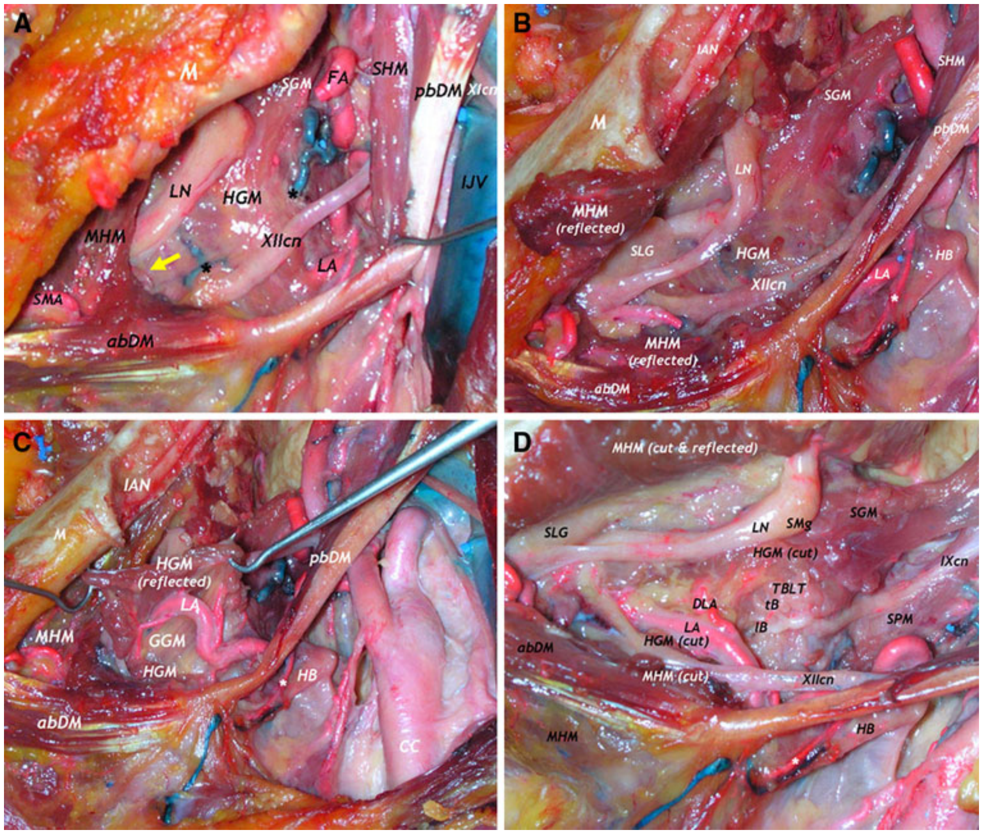

Fig. 3 External lateral views of the submandibular, tongue and floor of the mouth regions. **a** The submandibular gland has been removed and the facial artery transected. **b** The mylohyoideus muscle has been cut and reflected superiorly and inferiorly. The gross part of the course of the hypoglossal and lingual nerve is evident on the lateral surface of the hyoglossus muscle. **c** The hyoglossus muscle has been cut and reflected superiorly and inferiorly. The course of the lingual artery with its branches is evident on the lateral surface of the genioglossus muscle. **d** Final visual with exposition of the tongue base region. Different neurovascular structures are clearly evident. *SMA* submental artery, *FA* facial artery, *LA* lingual artery, *DLA* dorsal lingual artery, *IXcn* glossopharyngeal nerve, *tB* tonsillar branch, *lB* lingual branch, *XIIcn* hypoglossal nerve, *HGM* hyoglossus muscle, *MHM* mylohyoideus muscle, *SHM* stylohyoideus muscle, *SGM* styloglossus muscle, *SPM* stylopharyngeus muscle, *pbDM* posterior belly of the digastric muscle, *abDM* anterior belly of the digastric muscle, *IJV* internal jugular vein, *XIcn* accessory nerve, *black asterisks* comitant vein, *LN* lingual nerve, *yellow arrow* Wharton's duct, *M* mandible, *IAN* inferior alveolar nerve, *HB* hyoid bone, *white asterisk* hyoid branch, *SLG* sublingual gland, *SMg* submandibular ganglion, *TBLT* tongue base lymphoid tissue

proposed. Whenever possible, osteotomy must be performed anteriorly to the mental foramen. Notwithstanding, regardless of the position of the osteotomy, the mandibulotomy itself plus the disruption of the muscles of the floor of the mouth is associated with significant morbidity. In this context, major procedures require the surgeon to dismantle and repair normal musculoskeletal structures of the neck and the maxillofacial skeleton for access [17].

In this scenario, robotic-assisted techniques seem to offer significant advantages in tongue base surgery. By means of a multiplanar tissue transection at any angle, it enhances the ability of the surgeon in managing this complex region [13] and seems to be very well tolerated [10, 15, 21]. Our clinical experience in transoral tongue base robotic surgery for sleep apnea [21] demonstrates that post-op pain is extremely low. And to strengthen the good impression of this technique, oncological results in oropharyngeal cancer management are encouraging too [4, 22, 23].

Typical advantages of robotic techniques are well known [15]. Among these, we maintain that 3D visualization is one of the most important, given the fact that it offers a superb vision of the surgical field, thus increasing the orientation of the surgeon and safety of surgery. With respect to external approaches, there is little, if any, risk of post-op fistulas and, not of minor interest, robotic procedures are not associated with any bony work. In comparison to transoral laser-assisted approaches, surgical procedures are less disorienting, because the tissues need no severe distortion.

In this respect, it is critical to underline that transoral approaches require the surgeon not only to be familiar with this anatomy, but also particularly with the superior to inferior perspective. In this context, traditional surgical

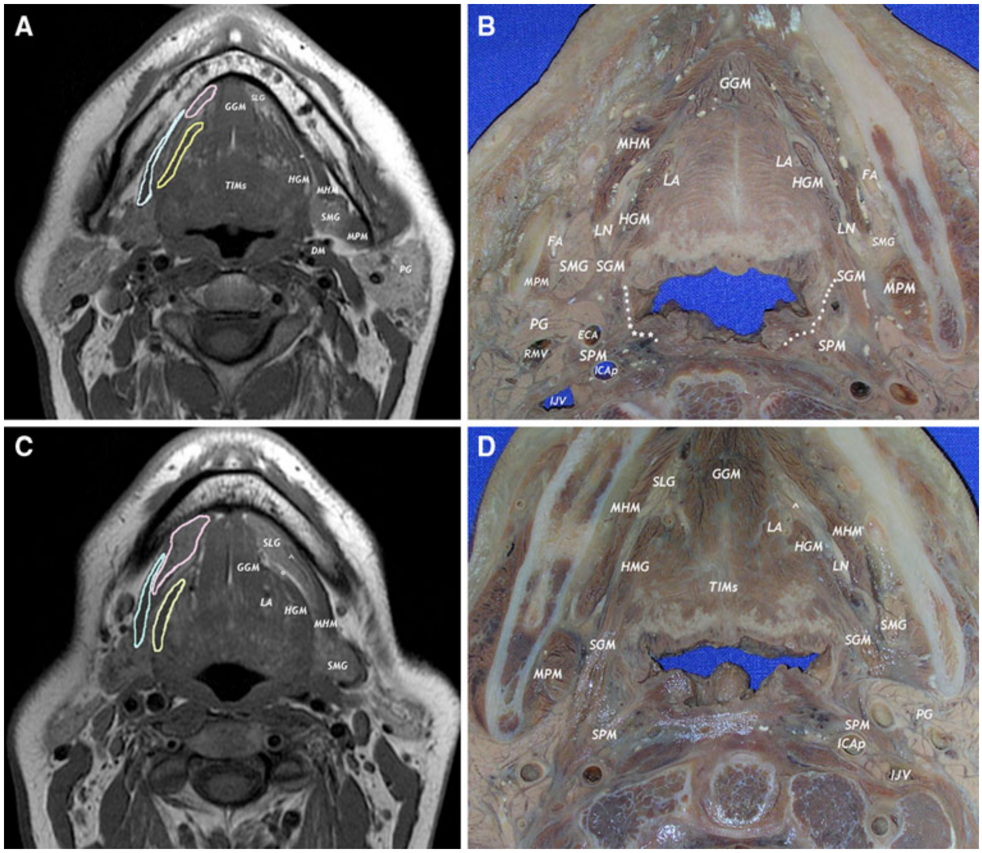

Fig. 4 Anatomo-radiological correlation of the tongue base-floor of the mouth, submandibular regions. Axial views. **a** T1-weighted MRI, axial view. **b** Anatomical slice, axial view. **c** T1-weighted MRI, axial view. **d** Anatomical slice, axial view. *SLG* sublingual gland, *SMG* submandibular gland, *PG* parotid gland, *GGM* genioglossus muscle, *HGM* hyoglossus muscle, *SGM* styloglossus muscle, *SPM* stylopharyngeus muscle, *MPM* medial pterygoid muscle, *MHM* mylohyoid muscle, *white asterisks* superior constrictor muscle, *TIMs* tongue intrinsic muscles, *DM* digastric muscle, *white circle* lingual nerve, *white arrowhead* hypoglossal nerve, *yellow bordered drawing* hyoglossus muscle, *pink bordered drawing* sublingual gland, *sky-blue bordered drawing* mylohyoideus muscle, *LA* lingual artery, *LN* lingual nerve, *ICAp* parapharyngeal portion of the internal carotid artery, *FA* facial artery, *ECA* external carotid artery, *IJV* internal jugular vein, *RMV* retromandibular vein

landmarks are useless in transoral surgery, and a detailed anatomical dissection is mandatory to understand the 3-dimensionality of this complex region. By combining the external perspective and the endoscopic one, the surgeon should be able to create in his/her mind a geometrical reconstruction of the tongue base region. More in detail, the critical problem in addressing the tongue base from above is the difficulty in the management of the neurovascular structures. In fact, external approaches are safer given the different and constant landmarks they offer. From a transoral viewpoint, the intrinsic anatomy of the tongue base offers poor anatomical orientation. In most cases, under the mucosa, a variable amount of lymphoid tissue is evident. Within this tissue, a sort of vascular network given by small arteries (dorsal lingual arteries) reaching the midline can be visualized, but this "plane" is surgically meaningless. This side-to-side tongue base anastomotic plexus has been well emphasized by Lopez et al. [14]. Dissection in the midline region is safe and leads to the identification of the hyoid bone. The lingual septum can easily be visualized in the anatomical and radiological setting. In the medial region, no major neurovascular structures are present and by moving laterally the main trunk of the lingual artery, covered by the hyoglossus muscle, can be identified. More laterally, on the lateral surface of this muscle, the hypoglossal nerve with its comitant vein(s) can be visualized as well. So we can assume that dissection within intrinsic muscles of the tongue is safe, because the main trunk of the lingual artery lies on the lateral surface of the genioglossus muscle. Detailed description of the lingual arterial system and arborisation has been previously reported [14]. On the contrary, the identification of the glossopharyngeal nerve is by far less easy. This nerve splits before entering the tongue base in the tonsillar and tongue base branches; the lingual branch goes into the tongue base and runs within this portion. So, in all the procedures necessitating a tongue base resection this branch is cut. On the other hand, the tonsillar branch lies within the lateral wall of the pharynx and is usually spared unless the dissection is extended in the lateral-tonsillar regions. In real conditions, we underline that a strict collaboration with the radiologist is mandatory and a careful discussion, case by case, is advisable. Several imaging modalities can be used for morphological evaluation of the tongue base, including ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI). Among them, US allows an accurate depiction of the salivary glands, salivary ducts and tongue base muscles, with the advantage of low cost, wide availability and an absence of exposure to ionizing radiation and contrast material. However, it is strongly operator dependent and is deficient in terms of vision if compared to cross-sectional imaging techniques, such as CT and MRI. Modern CT scanners provide excellent spatial resolution in all directions with voxel isotropy with an extremely short imaging time, but at the expense of a substantial radiation burden, although the latter can be minimized using dedicated dose-saving techniques. Moreover, soft tissue contrast resolution of CT is poor unless iodinated contrast material is administered i.v. Contrast-enhanced CT is the first level imaging modality for the non-invasive evaluation of vascular anatomy, owing its ability to depict vessels sized less than 1 mm. Nevertheless, compared with CT, MRI has a superior inherent soft tissue contrast resolution, enabling accurate differentiation of non-bony structures even without i.v. injection of paramagnetic contrast medium. And with the advent of very high field MRI scanners (up to 3 T) equipped with dedicated phased array coils, it is possible to achieve high resolution of the tongue base with very fast acquisition times (less than 1 min). In this respect, with MRI, it is possible to identify the muscular bellies, and, with the aid of a contrast medium and dedicated sequences, the vascular architecture of the lingual artery. The hyoglossus muscle can be easily visualized in the axial and coronal section, medial to the mylohyoid muscle. On its medial surface, the lingual artery is visualized. Especially with 3-T MRI scanners, the soft tissues of the tongue base can be accurately depicted, including muscles, salivary glands, adipose layers, and neurovascular bundles. With this aim, conventional T1- and T2-weighted images, with and without fat suppression, can be used provided that slice thickness is sufficiently narrow (3 mm or less, for lingual vessels and nerves). Blood vessels (especially the tiniest ones) can be more easily appreciated by means of a contrast-enhanced MR angiography without the superimposition of bones, which is a typical potential limitation of CT angiography. Visualization of the hypoglossal and lingual nerves is more difficult and can be performed using high resolution heavily T1-weighted or steady-state sequences, where they are seen as hypointense structures surrounded by their hyperintense perineural fat. Nerve depiction can also be improved using high-resolution T1-weighted images obtained after i.v. injection of gadolinium chelates, as the position of nerves can usually be inferred from their spatial relationships with neighboring vessels [1, 11, 20]. At the moment, identification of the neural structures within muscles is not possible. Maybe in the future a labelling system will solve this problem in radiological and clinical settings. A preclinical study seems to be encouraging [24].

Globally, we are strongly convinced that the fusion of dedicated anatomical studies with radiological imaging is the basis for a sound anatomical understanding of particularly complex regions, like the tongue base. This 3D knowledge is necessary for a safe and effective surgery.

Conclusion

Transoral tongue base surgery needs a sound knowledge of the pertinent anatomy with particular focus on the endoscopic perspective. A strict collaboration with the radiologist will increase the ability of the surgeon to understand this complex anatomy and to better orientate the surgical work.

Acknowledgments We thank Mrs. Diana Hearn for help in translation and revision of the manuscript.

Conflict of interest The authors certify that they have no potential conflicts of interest with any entity mentioned in this manuscript and that they received no financial support for this work.

References

1. Alves P (2010) Imaging the hypoglossal nerve. Eur J Radiol 74:368–377
2. Calais G, Alfonsi M, Bardet E, Sire C, Germain T, Bergerot P, Rhein B, Tortochaux J, Oudinot P, Bertrand P (1999) Randomized trial of radiation therapy versus concomitant chemotherapy and radiation therapy for advanced stage oropharynx carcinoma. J Natl Cancer Inst 91:2081–2086
3. Chabolle F, Wagner I, Blumen MB, Sequert C, Fleury B, De Dieuleveult T (1999) Tongue base reduction with hyoepiglottoplasty: a treatment for severe obstructive sleep apnea. Laryngoscope 109:1273–1280
4. Dean NR, Rosenthal EL, Carroll WR, Kostrzewa JP, Jones VL, Desmond RA, Clemons L, Magnuson JS (2010) Robotic assisted surgery for primary or recurrent oropharyngeal carcinoma. Arch Otolaryngol Head Neck Surg 136(4):380–384
5. Dwivedi RC, Rhys Evans PH, Patel SG (2009) Tumors of the oropharynx. In: Montgomery PQ, Rhys Evans PH, Gullane PJ (eds) Principles and practice of head and neck surgery and oncology, 2nd edn. Informa Healthcare, London, pp 192–232
6. Garfein ES, Greaney PJ Jr, Easterlin B, Schiff B, Smith RV (2011) Transoral robotic reconstructive surgery reconstruction of a tongue base defect with a radial forearm flap. Plast Reconstr Surg 127(6):2352–2354

7. Grant DG, Salassa JR, Hinni ML, Pearson BW, Perry WC (2006) Carcinoma of the tongue base treated by transoral laser microsurgery. Part I: untreated tumors, a prospective analysis of oncologic and functional outcomes. Laryngoscope 116:2150–2155
8. Haughey BH, Hinni ML, Salassa JR, Hayden RE, Grant DG, Rich JT, Milov S, Lewis JS, Krishna M (2011) Transoral laser microsurgery as primary treatment for advanced stage oropharngeal cancer: a United States multicenter study. Head Neck. doi:10.1002/hed.21669
9. Henstrom DK, Moore EJ, Olsen KD, Kasperbaeur JL, McGree ME (2009) Transoral resection for squamous cell carcinoma of the base of the tongue. Arch Otolaryngol Head Neck Surg 135(12):1231–1238
10. Hockstein NG, O'Malley BW Jr (2008) Transoral robotic surgery. Oper Tech Otolaryngol 19:67–71
11. La'porte SJ, Juttla JK, Lingam RK (2011) Imaging the floor of the mouth and the sublingual space. Radiographics 31(5):1215–1230
12. Laccourreye O, Seccia V, Menard M, Garcia D, Vacher C, Holsinger FC (2007) Extended lateral pharyngotomy for selected squamous cell carcinomas of the lateral tongue base. Ann Otol Rhinol Laryngol 118(6):428–434
13. Leonhardt FD, Quon H, Abrahao M, O'Malley BW Jr, Weinstein GS (2011) Transoral robotic surgery for oropharyngeal carcinoma and its impact on patient-reported quality of life and function. Head Neck. doi:10.1002/hed.21688
14. Lopez R, Lauwers F, Paoli JR, Boutault F, Guitard J (2007) Vascular territories of the tongue: anatomical study and clinical applications. Surg Radiol Anat 29:239–244
15. O'Malley BW Jr, Weinstein GS, Snyder W, Hockstein NG (2006) Transoral robotic surgery (TORS) for base of tongue neoplasms. Laryngoscope 116(8):1465–1472
16. Rodrigo JP, Diaz-Molina JP, Moreno C, Suarez C (2011) Oncologic and functional results after transhyoid surgical approach for cancer of the tongue base. Head Neck 121(7):1449–1454
17. Seikaly H, Rieger J, Wolfaardt J, Moysa G, Harris MD, Naresh J (2003) Functional outocomes after primary oropharyngeal cancer resection and reconstruction with the radial forearm free flap. Laryngoscope 113:897–904
18. Sorrenti G, Piccin O, Mondini S, Ceroni AR (2006) One-phase management of severe obstructive sleep apnea: tongue base reduction with hyoepiglottoplasty plus uvulopalatopharyngoplasty. Otolaryngol Head Neck Surg 135:906–910
19. Steiner W, Fierek O, Ambrosch P, Hommerich CP, Kron M (2003) Transoral laser microsurgery for squamous cell carcinoma of the base of tongue. Arch Otolaryngol Head Neck Surg 129:36–43
20. Thompson EO, Smoker WR (1994) Hypoglossal nerve palsy: a segmental approach. Radiograhics 14(5):939–958
21. Vicini C, Dallan I, Canzi P, Frassineti S, Nacci A, Seccia V, Panicucci E, La Pietra MG, Montevecchi F, Tschabitscher M (2012) Transoral Robotic surgery of the tongue base in Obstructive Sleep Apnoea–Hypopnoea Syndrome: anatomic considerations and clinical experience. Head Neck 34(1):15–22
22. Weinstein GS, O'Malley BW Jr, Cohen MA, Quon H (2010) Transoral robotic surgery for advanced oropharyngeal carcinoma. Arch Otolaryngol Head Neck Surg 136(11):1079–1085
23. Weinstein GS, O'Malley BW Jr, Snyder W, Sherman E, Quon H (2007) Transoral Robotic surgery. Radical tonsillectomy. Arch Otolaryngol Head Neck Surg 133(12):1220–1226
24. Wu AP, Whitney MA, Crisp JL, Friedman B, Tsien RY, Nguyen QT (2011) Improved facial nerve identification with novel fluorescently labeled probe. Laryngoscope 121(4):805–810