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A new landmark for lingual artery identification during transoral surgery: Anatomic-radiologic study

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Abstract

Background: A landmark for the identification of the lingual artery (LA) through a transoral perspective can provide surgeons with an easy method to prevent and manage intraoperative bleeding during transoral approach to the base of tongue (BOT).

Methods: Thirteen tongue and five head and neck specimens were dissected to identify and assess the reliability of the lingual point (LP) as a new landmark for the LA at BOT. The pathway of 42 LAs was radiologically evaluated; axial depth and vertical offset were measured for each LA.

Results: Dissection study: a description of LP is provided; the LA was easily identified in all specimens (36/36 sides) using LP as a landmark. Radiologic study: the mean depth of the LA was 4.2 mm, the mean vertical offset was 1.3 mm.

Conclusions: LP is a simple and reliable landmark for identification of the LA, potentially helping surgeons to prevent and manage intraoperative bleeding.

KEYWORDS

base of tongue, bleeding, landmark, lingual artery, transoral robotic surgery

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1 | INTRODUCTION

Since first gaining FDA approval in 2009 for application in the head and neck, the popularity of transoral robotic surgery (TORS) for treatment of oro- and para-pharyngeal tumors and obstructive sleep apnea/hypopnea syndrome (OSAHS) has progressively increased. TORS is associated with lower mean operating time, avoids disfiguring incisions, minimizes long-term speech and swallowing dysfunction, and reduces postoperative complications and hospital stay compared to open surgery.[1,2]

Head and neck surgeons during TORS must face the complexity of oropharyngeal and parapharyngeal anatomy as seen through an inside-out perspective.[3] This change of perspective, compared to traditional surgical anatomy, requires specific training which includes focus on previously unnoticed anatomical relationships.[4-6]

Despite its functional and oncologic efficacy, TORS can be associated with serious complications. One of the most concerning is oropharyngeal hemorrhage in the early postoperative period, which can be potentially life-threatening, especially in absence of a tracheostomy. Likewise, accurate hemostasis and avoidance of massive bleeding are essential to preserve adequate vision of the surgical field during the procedure. Consequently, prevention and management of bleeding represent critical issues in this surgery. Knowledge of the inside-out vascular anatomy of the oropharynx is of paramount importance to achieve an oncologically adequate resection while minimizing the life-threatening consequences of a postoperative blowout of the lingual artery (LA).[7,8]

The oropharyngeal vasculature is composed of a complex network of vessels of the external carotid artery system. The base of tongue (BOT) receives its blood supply primarily from the LA, and secondarily from the tonsillar branch of the facial artery and the ascending pharyngeal artery. The LA is therefore the most important arterial structure to deal with when performing TORS at this level.[9]

To date, few relevant surgical and radiologic studies have focused on landmarks guiding the identification of the LA during TORS or, more generally, during transoral approaches.[10] Most anatomical studies on the LA have been conducted with the tongue in its resting position[11] and/or analyzed the anatomy of the vessel with respect to the surrounding structures.[12] Moreover, previously published dissection studies were most frequently based on alcohol/formaldehyde-fixed specimens, which are associated with some shrinkage of tissues and modification of mutual anatomical relationships. One should also consider that the location of anatomical structures relative to specific landmarks may be considerably modified when using retractors for transoral surgery and TORS (e.g., Feyh-Kastenbauer [FK] or Crowe-Davis retractor).

This study was aimed at defining a reliable landmark to identify the LA through a transoral perspective, with tongue in both the resting and exposed-retracted positions. This landmark is potentially applicable in different types of transoral surgery in addition to TORS, such as transoral laser microsurgery (TLM) and transoral endoscopic ultrasonic surgery (TOUSS). However, since TORS is nowadays the most applied transoral approach in BOT surgery, our study is mainly focused on this procedure.

2 | MATERIALS AND METHODS

2.1 | Anatomical specimens

From January to November 2020, 13 tongues and five head and neck specimens from 18 fresh-frozen cadavers (all whites; 10 males, eight females; mean age at death, 67 years; range, 51–84) provided by Medcure® (Portland, USA) were dissected at the Laboratory of Endoscopic Anatomy of the University of Brescia, Italy. The arterial system of cadavers was injected through common carotid arteries with a bicomponent red silicone (Xiameter RTV, DOWN CORING, Midland, Michigan, USA). The specimens were stored at −20°C and kept at 15°C for about 24 h before dissection.

2.2 | Dissection study

2.2.1 | Identification phase

The preliminary phase of the study was focused on the identification of a specific anatomical landmark for the main trunk of the LA. During previous cadaveric dissections on several head and neck specimens (which were being employed for different educational and research purposes), the course of the LA was analyzed. The BOT mucosal area closest to the main trunk of LA was identified and defined as a "LA mucosal projection" (LAMP). We then studied the geometrical relationships of LAMP with respect to the surrounding mucosal anatomical landmarks. The point identifiable through the surrounding mucosal structures that most closely marked the position of LAMP was defined as the "lingual point" (LP).

2.2.2 | Validation phase

Dissection started with the identification of the aforementioned LP on the BOT. All specimens were bilaterally dissected.

Thirteen specimens composed of the tongue, base of tongue, oropharynx, hypopharynx, and larynx were placed in a simulated resting position. Mucosa was incised in an anterior-to-posterior fashion on the LP and blunt dissection was performed along a mediocranial-to-laterocaudal plane oriented at roughly 45° with respect to an axial plane (i.e., parallel to the direction of LA) until the LA was identified.

2.2.3 | Transoral surgery simulation

Transoral endoscopic dissection was bilaterally performed on five head and neck specimens to simulate the TORS perspective. The surgical setting consisted of an FK retractor for adequate BOT exposure, an Olympus (Tokyo, Japan) 4 K camera with 45° scope to appreciate the "inside-out" anatomy perspective, and a Med-Engineering (Munich, Germany) Robotic Surgical System that allowed working with two hands and the camera at the same time (Figure 1).[13] In order to reach and transorally operate at the BOT, a surgical set for endoscopic surgery (Explorent ENT Instruments, Olympus, Tokyo, Japan) was used. Dissection was performed as for the tongue specimens; first the LP was identified, then the LA was exposed, and after that an open neck dissection was performed to verify that the identified vessel was indeed the LA and to assess the relationship between the LA, LP and surrounding structures.

Pictures of the BOT were taken with a digital 4 K 45° endoscope (Olympus, Tokyo, Japan) placed in the same sagittal plane of the median glosso-epiglottic fold (MGF) from a fixed distance of roughly 3 cm. Pictures were analyzed using Photoshop CC (Adobe Systems, San Jose, California, USA). The angle of intersection between the LA and stylohyoid ligament was measured.

2.3 | Radiologic study

A radiologic evaluation of the path of LAs was made to objectively assess the tridimensional relationship between LP and LA. To this end, computed tomography angiograms (CTA) of 21 adult subjects (42 LAs) were randomly selected from our institutional radiologic database; the only exclusion criterion was previous surgery of the oral cavity and/or oropharynx. In all cases, CTA images were acquired because of neurologic stroke.

With reference to LP, the pathway of the LA was assessed extracting four parameters:

FIGURE 1 Simulated transoral robotic surgery scenario at the laboratory of endoscopic anatomy, University of Brescia [Color figure can be viewed at wileyonlinelibrary.com]

a. LA depth: the distance on an axial plane between LA and LP;
b. Vertical offset: the vertical distance between LA and LP, measured on a coronal image passing through the LP;
c. Distance between LA and the MGF on the coronal plane passing through LP;
d. Distance between LAs on the coronal plane passing through both LPs.

A statistical analysis through the Mann–Whitney test was performed to analyze the difference in terms of a), b), and c) measurements when comparing one to other side.

Moreover, 21 magnetic resonance (MRI) studies of subjects with unaltered oral and neck anatomy were analyzed to evaluate the relationship between the LA and stylohyoid ligament.

2.4 | Concordance between radiologic and cadaver measurements

With the same technique, LA depth, vertical offset, distance between LA and the MGF, and distance between LAs were radiologically measured on CTs of 3/5 (60.0%) head and neck specimens prior to performing the transoral identification of LAs. To evaluate the concordance between radiologic and cadaver measurements, after LAs were identified, the same parameters were measured with a mm- ruler placed in the surgical field. Due to the technical difficulty in measuring the vertical offset on the specimens, this parameter was evaluated as surgeon's subjective evaluation on the need to move the dissection into a more cranial or caudal plane with respect to the LP.

The correlation between radiologic and cadaver measurement of the LA axial depth, distance between LA and MGF, and distance between LAs was evaluated through Pearson and Spearman correlation tests.

3 | RESULTS

3.1 | Dissection study

3.1.1 | Identification phase

We observed that LAMP was constantly located in the lateral portion of the interface between BOT and glosso-epiglottic valleculae. Thus, LP was defined through the following lines:

1. LGFL: a line following the free edge of the lateral glosso-epiglottic fold (LGF);
2. MGFL: a line following the free edge of the MGF;
3. BOT line (BTL): the horizontal line perpendicularly crossing the MGFL at the point where it meets the BOT.

The LP was located where the BTL crossed the ipsilateral LGFL (Figure 2).

3.1.2 | Validation phase

The LP led to the identification of the LA bilaterally in all specimens (26/26, 100%). No anatomical variation preventing identification of the LA at the level of the LP was encountered (Figure 2).

3.1.3 | Transoral surgery simulation

In the head and neck specimens, the LA was identified in all cases (10/10 sides, 100%). Furthermore, the stylohyoid ligament

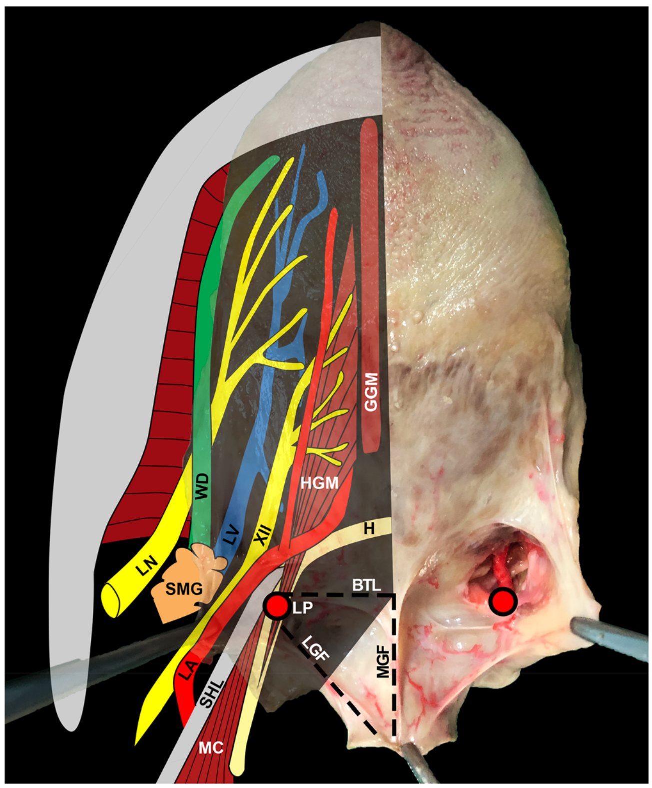

FIGURE 2 Tongue specimen in simulated resting position with a diagram of the main anatomical structures and localization of LP. GGM, genioglossus muscle; H, hyoid bone; HGM, hyoglossus muscle; LA, lingual artery; LGF, lateral glosso-epiglottic fold; LN, lingual nerve; LP, lingual point; LV, lingual vein; MC, medial pharyngeal constrictor muscle; MGF, median glosso-epiglottic fold; SHL, stylohyoid ligament; SMG, submandibular gland; WD, Wharton duct; XII, hypoglossal nerve [Color figure can be viewed at wileyonlinelibrary.com]

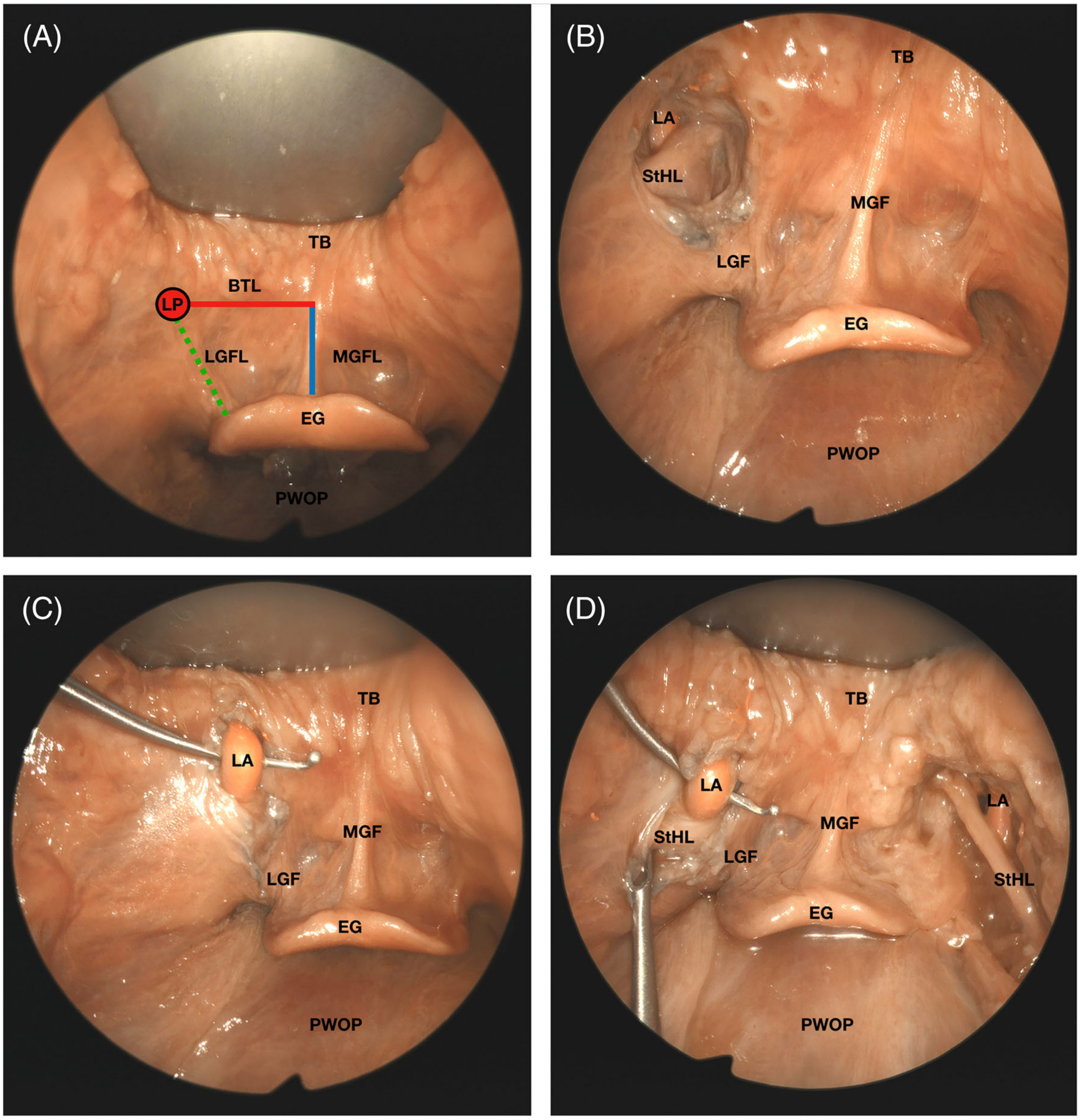

FIGURE 3 Lingual point. Transoral view of the tongue base. (A) Identification of the LP by means intersection of the BTL and LGFL. (B–D) Anatomical relations between LA and surrounding structures. BTL, base of tongue line; EG, epiglottis; LA, lingual artery; LGF, lateral glosso-epiglottic fold; LGFL, lateral glosso-epiglottic fold line; MGF, median glosso-epiglottic fold; MGFL, median glosso-epiglottic fold line; PWOP, posterior wall of the oropharynx; StHL, stylo-hyoid ligament; TB, tongue base [Color figure can be viewed at wileyonlinelibrary.com]

was identified immediately medial and superficial to the LA in all dissections (Figure 3; Video S1). The mean angle between LA and the stylohyoid ligament was 36.1° (range 31.5°-40.0°).

3.2 | Radiologic study

The LP, similar to the dissection study, was identified in CTA images as follows:

1. Thin slice CTA images were analyzed in a multiplanar-reformation-images (MPR) software (PACS — Philips, Amsterdam, The Netherlands) and axial, coronal, and sagittal reformations were obtained with respect to the hard palate;
2. LGFL and MGFL were drawn on the axial image where the visibility of LGF and MGF was optimal, in order to minimize the error in the identification of the glosso-epiglottic folds;
3. Subsequently, the LGFL and MGFL were transposed to a more cranial axial plane at the level of the free edge of the glosso-epiglottic folds, and there, by drawing the BTL, the LP was identified where the BTL crosses LGFL.

The results of radiologic evaluation on the CTA in 21 adult subjects regarding LA depth (Figure 4), LA

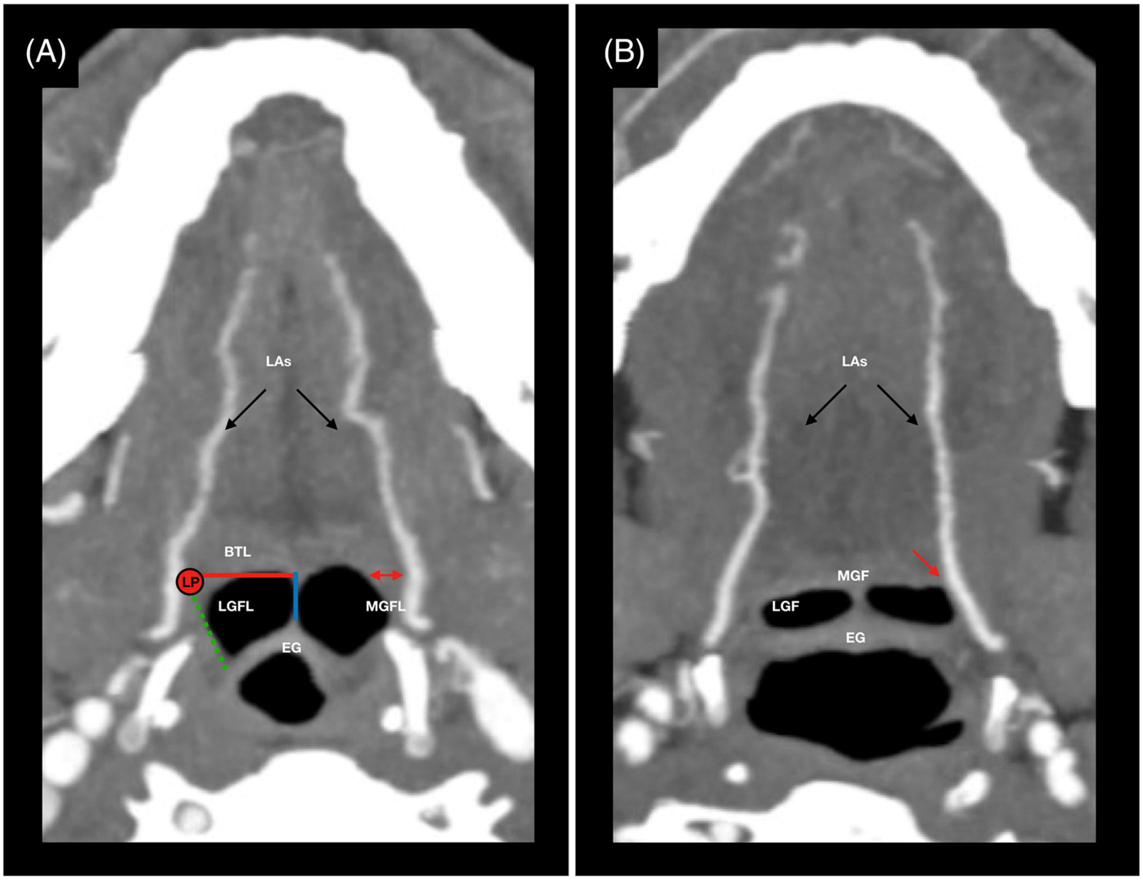

FIGURE 4 Depth variability of the lingual artery at the LP from the overlying mucosa. Curved maximum intensity projection CTA of the lingual arteries in two subjects. Image A shows a regular case, where both lingual arteries pass some millimeters deep to the mucosal surface at the level of the LP point, which is identified at the crossing point between the LGFL (green dotted line) and BTL (red lines). The red double arrow depicts the lingual artery depth. Image B shows a peculiar scenario, where the left lingual artery has a superficial path, almost reaching the mucosal surface (red arrow). BTL, base of tongue line; Eg, epiglottis; LAs, lingual arteries; LGFL, lateral glosso-epiglottic fold; LP, lingual point; MGFL, median glosso-epiglottic fold [Color figure can be viewed at wileyonlinelibrary.com]

vertical offset (Figure 5), distance between LA and the MGF, and distance between LAs are shown in Table 1.

Neither LA depth ($p = 0.356$), LA vertical offset ($p = 0.400$), nor the distance between the MGF and LA ($p = 0.421$) differed significantly when comparing one side to the other.

In all MRIs (42/42 sides, 100%), the LA ran on the lateral aspect of the caudal insertion of the stylohyoid ligament.

3.3 | Concordance between radiologic and cadaver measurements

The radiologic measurements on head and neck specimens are summarized in Table 2.

The same measurements were collected on the specimens after dissection (Table 2). In all cases, the vertical offset was negligible, as the LA was always deemed to run roughly on the same axial plane of the LP.

Radiologic and cadaver measurements of LA depth (Pearson-$p = 0.001$, Spearman-$p = 0.017$; Figure 6), distance between MGF and LA (Pearson-$p = 0.002$, Spearman-$p = 0.033$), and distance between LAs (Pearson-$p = 0.021$, Spearman-$p = 0.333$) were significantly correlated.

4 | DISCUSSION

This study shows that the LP is a simple and reliable landmark for identification of the LA in transoral surgery, which can provide surgeons with an easy method to prevent and manage intraoperative bleeding. The BOT plays a primary role in essential physiological functions such as swallowing and speaking. The surgical interest in this region is mainly related to two clinical entities:

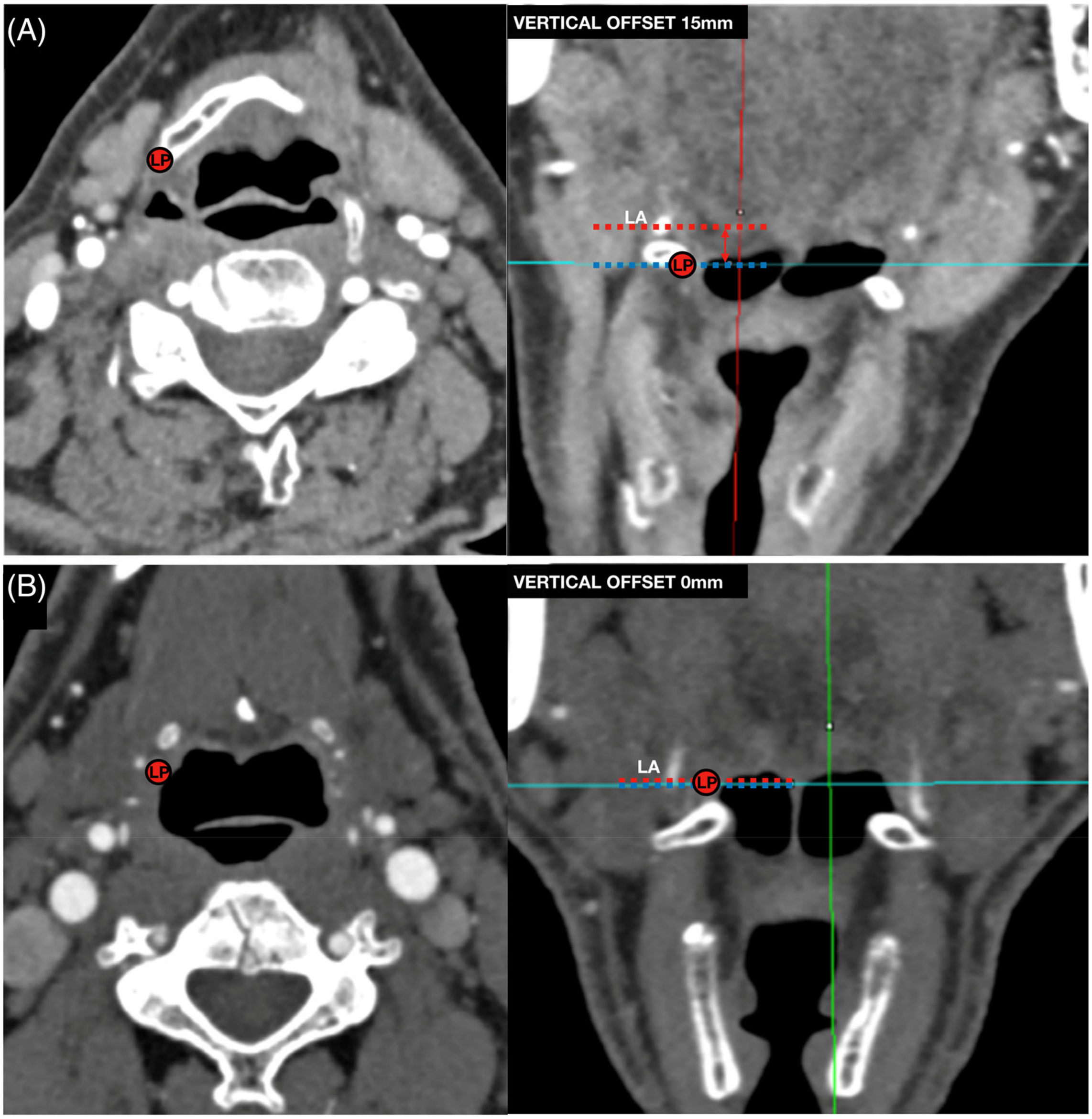

FIGURE 5 Vertical offset variability of the lingual artery at the LP. CTA multiplanar-reformation-images (MPR) of the neck in two different subjects: the image A shows a peculiar case where the LA lies on a more cranial plane with respect to the LP; in this case, the vertical offset between the planes of the LP (blue dotted line) and the LA (red dotted line) was bilaterally 15 mm (as shown by the red double arrow). The image B shows a more common scenario, where the LA (red dotted line) lays on the same axial plane of the LP (blue dotted line) with a vertical offset of 0 mm. LA, lingual artery; LP, lingual point [Color figure can be viewed at wileyonlinelibrary.com]

OSAHS induced by BOT hypertrophy and oropharyngeal tumors. To date, transoral resection, with special reference to TORS, is among the treatment options for early oropharyngeal squamous cell carcinomas[14-16] and other oropharyngeal malignancies such as minor salivary gland carcinomas.[17,18] In this region, vascularization is mostly provided by the lingual artery, with other minor branches arising from the tonsillar artery, ascending palatine artery, and facial artery. Bleeding from the LA is a life-threatening eventuality and therefore represents a major concern during TORS and its postoperative course.[19] This is confirmed by the fact that even in the context of a recent randomized trial by world-leading centers, a case of death due to postoperative bleeding from the LA has been reported.[20] A recent publication reported an overall postoperative bleeding rate after TORS of 13.2%, of which 71.4% of bleedings required a revisit in the operating room; transcervical arterial ligation significantly reduced the incidence of major and severe bleeding events.[21] BOT surgery is considered one of the most challenging TORS procedures due to the lack of anatomical landmarks and change of perspective compared to transcervical approaches.[3] For these reasons, it is paramount to define landmarks that can reliably guide dissection during

TABLE 1 Single-patient data obtained from the radiologic evaluation

# Patient	LA depth (mm)		Vertical offset (mm)		Distance LA–MGF (mm)		Distance between LAs (mm)
	Left	Right	Left	Right	Left	Right	
1	5	2	0	0	21	18	39
2	11	10	1.4	5	28	27	55
3	6	7	15	15	22	24	46
4	1.5	3.5	0	0	16.5	20.5	37
5	2	2	0	0	17	17	34
6	11	5.5	1	0	28	21.5	49.5
7	1.5	2	0	0	16.5	17	33.5
8	3.5	2.5	0	0	20.5	19.5	40
9	2	2	0	0	18	18	36
10	4.5	4	0	0	17.5	18	35.5
11	4	6	3.5	0	19	22	41
12	3	3	7	0	18	16	34
13	6.5	3	0	0	19.5	16	35.5
14	6	6	0	0	22	22	44
15	10	4	0	2.5	24	17	41
16	2.5	2.5	0	0	20.5	20.5	41
17	4	4	2	0	19	19	38
18	7	3	0	0	23	19	42
19	1.5	2.5	0	0	14.5	15.5	30
20	3	4.5	0	0	21	22.5	43.5
21	3	0.7	0	0	18	15.7	33.7
Mean value	**4.7**	**3.8**	**1.4**	**1.1**	**20.2**	**19.3**	**39.5**
Range	**1.5–11**	**0.7–10**	**0–15**	**0–15**	**14.5–28**	**15.5–27**	**14.5–28**
St. deviation	**3**	**2.1**	**3.5**	**3.4**	**3.5**	**3**	**5.9**
Median value	**4**	**3**	**0**	**0**	**19.5**	**19**	**39**
Total mean value	**4.2**		**1.3**		**19.7**		-
Total st. deviation	**2.6**		**3.4**		**3.3**		-
Total median value	**3.5**		**0**		**19**		-

Abbreviations: LA, lingual artery; MGF, median glosso-epiglottic fold.

transoral procedures. Indeed, a strategy to easily identify the LA from the transoral perspective would facilitate the procedure, enable transoral vessel ligation, and potentially reduce the need for precautionary measures such as temporary tracheostomy, prolonged intubation, transcervical ligation, or flap coverage.[22-24]

To our knowledge, this is the first study defining a surgical landmark to identify the main trunk of the LA at the level of the BOT through a transoral perspective.

Our results demonstrated that the LP was an accurate and reliable landmark that allows the identification of the main trunk of the LA with the tongue in both the resting position and after tongue base exposure with an FK retractor.

The course of the intralingual tract of the LA (i.e., the part of the vessel enclosed by the hyo- and genioglossus muscles) varies considerably when the tongue is extended and retracted for transoral procedures. Wu et al[12] analyzed the depth of the LA beneath the lingual surface and the distance between the two LAs on three coronal planes: the first passing through the foramen cecum, with the second and third passing 1 cm in front and behind the foramen cecum, respectively. They demonstrated that the spatial relationship of the LA with the surrounding structures changes remarkably when passing from a resting to a fully extended position.[12] However, in our study, LA was easily identified in both resting and exposed-retracted positions in all cases. This difference is related

TABLE 2 Comparison between radiologic and cadaver measurements

	Radiologic LA depth (mm)		Radiologic vertical offset (mm)		Radiologic distance LA–MGF (mm)		
# H&N specimen	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Distance between LAs (mm)**
1	6.6	3.4	1.4	0.8	24	23	47
2	14.1	11.3	0	0	16	14	30
3	7.7	6.6	6.6	9.2	23	21	44
Total mean value	**8.3**		**3**		**20.1**		**40.3**
Range	**3.4–14.1**		**0–9.2**		**14–24**		**30–47**
Total st. deviation	**3.8**		**3.9**		**4.2**		**9.1**
Total median value	**7.2**		**1.1**		**22**		**44**
	Cadaver LA depth (mm)		**Cadaver vertical offset (mm)**		**Cadaver distance LA–MGF (mm)**		
# H&N specimen	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Distance between LAs (mm)**
1	7	5	-[a]	-[a]	23	22	45
2	12	11	-[a]	-[a]	15	16	31
3	8	6	-[a]	-[a]	21	22	43
Total mean value	**8.2**		-		**19.8**		**39.7**
Range	**5–12**		-		**15–23**		**31–45**
Total st. deviation	**2.8**		-		**3.4**		**7.6**
Total median value	**7.5**		-		**21.5**		**43**

Abbreviations: MGF, median glosso-epiglottic fold.

[a]In all cases, the vertical offset was negligible, as the lingual artery (LA) was always deemed as running roughly on the same axial plane of the LP.

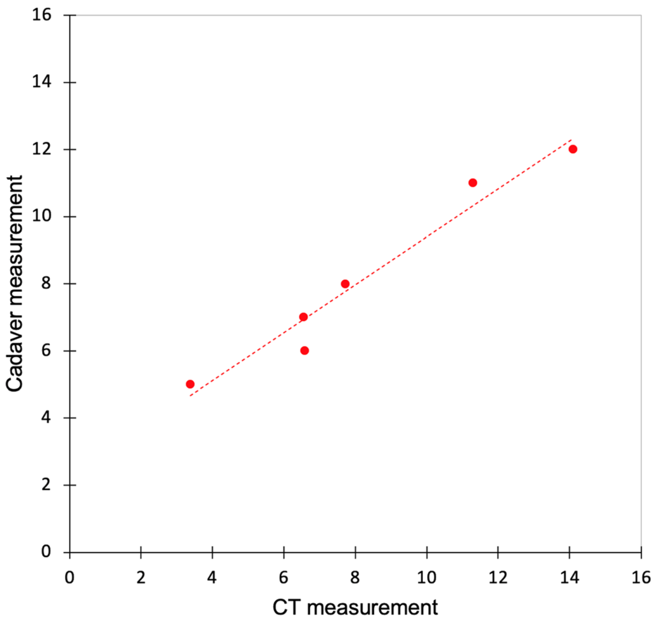

FIGURE 6 Scatter plot showing the correlation between radiologic and cadaver measurements [Color figure can be viewed at wileyonlinelibrary.com]

to the fact that the LP guides to a more proximal tract of the lingual artery, which is minimally affected by tissue retraction when the BOT is the target of surgery. Furthermore, it is reasonable to hypothesize that the proximal portion of the LA and LP maintains their mutual relationship when the oral portion of the tongue is pulled and suspended, also because during traction the lines providing the landmarks for the LP also concordantly stretch such that the LP remains reliable with respect to the position of the LA. This was confirmed by Cohen et al[25] who analyzed the position variability of eight points along the LA passing from resting to FK-retracted situation, showing that only the position of the dorsal branch of the LA was affected by retraction.

In our series, we evaluated the concordance between radiologic and cadaver measurements, finding that LA depth is maintained from the preoperative resting position to the FK-retracted situation. This result endorses our thesis, confirming that the LP can serve as a reliable landmark even in the surgical setting (i.e., in retracted position). During the dissection on whole head and neck specimens, the LA was always found lateral and deep to the stylohyoid ligament, which was recognized thanks to its white color and firm consistency. We therefore analyzed 21 MRIs of patients with unaltered head and neck anatomy, showing that the relationship between the LA and stylohyoid ligament was constant. In this light, the stylohyoid ligament can be considered as a second landmark to guide LA identification (Figures 2 and 3).

The radiologic study showed that presurgical-targeted evaluation of the LA course can provide valuable information to minimize the risk of accidental intraoperative injury. It has been shown that the mean depth of the LA from the overlying mucosa of the BOT was 4.2 mm, but ranged considerably between 0.7 and 11.0 mm. Interestingly, in four of 42 cases (9.5%) undergoing radiologic analysis, the LA was found at less than 2 mm from the mucosal plane. This anatomical situation increases the risk of an unintentional injury to the vessel even during mucosectomy (Figure 4). Moreover, the vertical offset of the LA, that is, the accuracy of the LP to predict the position of the LA in a craniocaudal perspective, was evaluated (Figure 5). This analysis showed that in almost 80% of cases the LP laid on the same axial plane of the LA (Figure 5(B)). An average vertical offset of 3 mm was found in almost 17% of cases. However, during a surgical procedure this millimetric distance can be considered as negligible, as demonstrated by the fact that LA was deemed to be approximately on the same axial plane of the LP during dissection of head and neck specimens with preoperative CT available. In our transoral-simulated approach, radiologic measurements proved to be useful in identifying the LA; by knowing the depth of the LA, the surgeon can build a mental map of the vessel's position, thus resulting in a safer resection. For the abovementioned reasons, we recommend the evaluation of the LA relative to BOT mucosa as part of preoperative imaging, since it can provide the surgeon with a mental representation of the LA course in relation with an easily replicable landmark such as the LP.

Finally, the following study limitations should be analyzed. Firstly, this is a preclinical anatomical study reproducing a simulated TORS setting on fresh frozen injected specimens, thus leading to unavoidable approximations compared to surgery on living patients. Moreover, during cancer resection, the presence of the tumor, or previous treatments, may cause anatomical and vascular alterations and reduce the reliability of the LP. Accordingly, the clinical applicability of the LP still needs to be verified. Lastly, the limited sample size does not allow for sound statistical analysis.

5 | CONCLUSION

The present anatomical and radiologic study describes, for the first time, an anatomical landmark to identify the main trunk of the LA in the BOT through a transoral perspective. We believe that this can be a simple and replicable tool for the transoral surgeon to prevent and manage intraoperative bleeding. The planning of transoral surgery should include radiologic preoperative evaluation of the LA, in order to assess its course and its relations with the abovementioned landmark. Translation of this landmark from a pre-clinical to a clinical setting represents the next proposed step.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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