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ORIGINAL ARTICLE

A detailed anatomical assessment of the lateral tongue extrinsic musculature, and proximity to the tongue mucosal surface. Does this confirm the current TNM T4a muscular subclassification?

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Abstract
Purpose The current T4a subclassification of the TNM staging system for oral malignancies has been criticised as based almost exclusively on anatomical data. The aim of this study was to provide anatomical confirmation of the muscular constraints of T4a classification of oral tongue tumours.
Methods A detailed anatomical study describing and measuring the adjacency of the named extrinsic tongue muscles to the lateral tongue surface was completed on the Visible Human Female (VHF). The distance of styloglossus and hyoglossus to the over lying mucosa were determined.
Results The appearance, position, orientation and anatomical relationships of the lateral tongue extrinsic muscles, with comparison to their classical descriptions are described. The right VHF styloglossus was 1.3 mm (0.33–1.48) and left 2.91 mm (0.66–7.68) from the mucosal surface in the axial plane. The right VHF hyoglossus was 2.93 mm (1.48–4.96) and left 4.33 (1.68–8.71) from the mucosal surface in the axial line.
Conclusions In the lateral tongue, styloglossus and hyoglossus are very superficial. The inclusion criteria of hyoglossus and styloglossus in the T4a staging does not appear justified based upon their anatomical position.

Keywords Tumour staging · Tongue · Oral carcinoma · TNM staging · Styloglossus · Hyoglossus · Genioglossus · Palatoglossus

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Background

The staging of head and neck malignancies are universally described using the TNM classification of the Union Internationale Control le Cancer (UICC), and the American Joint Committee on Cancer (AJCC) [1]. There has been prolonged criticism of the anatomical parameters as they do not predict outcome or occult nodal disease with any accuracy [2–5]. Within the oral cavity (ICD-10 C02-C06), current staging criteria for tongue tumours are defined as

T1	Tumour 2 cm or less in greatest dimension
T2	Tumour >2 cm but <4 cm in greatest dimension
T3	Tumour >4 cm in greatest diameter
T4a (oral cavity)	Tumour invades through cortical bone into deep/extrinsic muscle of tongue (genioglossus, hyoglossus, palatoglossus and styloglossus), maxillary sinus, or skin of the face

There have been few fundamental changes to the T staging criteria, despite significant advances in the management of oral cancer, since Denoix began his work in 1943 [6–8]. Criticism of the TNM system has resulted from several studies showing that size-based T criteria failed to demonstrate a significant relationship with patient survival [9, 10]. Lenz et al. and Boland et al. found that clinical T stage (cT) of oral cancer predicted the pathological T stage (pT) <47 % of the time [11, 12]. There are several reasons for this discrepancy: first, the current TNM system and its predecessors have been almost exclusively based on unidimensional measurements, with complex anatomical confines for T4 disease difficult to accurately define. Clinical measurements of oral tumours in their greatest dimension are inaccurate, with superficial tumour size not necessarily related to prognosis. Finally, the majority of oral and oropharyngeal malignancies fall into the T2 category (2–4 cm), with tumours >4 cm usually invading surrounding structures upstaging them to T4, thus leaving a paucity of T3 tumours [13].

The criterion for T4a includes extension into "deep" muscles. The descriptor "deep" does not accurately describe the relationship of styloglossus, hyoglossus, genioglossus and palatoglossus throughout their relationship within the oral cavity, indeed all of these muscles have superficial and deep components. Styloglossus and hyoglossus muscles lie anatomically in the lateral tongue, the oral cavity subsite most frequently involved with squamous cell carcinomas, and at this site these muscles are relatively superficial. There is difficulty in assessing tumour ingress into specific muscles of the lateral tongue.

A previous MRI study had difficulty in fully delineating the styloglossus and hyoglossus muscle detail within the lateral tongue [19].

The aim of this study was to provide anatomical confirmation of the muscular constraints of the T4a classification of oral tongue tumours, with regard to specific extrinsic tongue muscles, defining the exact location of where the "deep" aspects relate to the lateral border of the tongue (where the majority of oral tongue squamous carcinomas arise).

Materials and methods

The anatomy of the extrinsic tongue muscles were mapped in three dimensions using images from the Visible Human Project (VHP) [14]. The VHP obtained high-resolution CT and MRI imaging prior to freezing, sectioning and photographing of two human cadavers (male 1994; female 1995). This produced 3D datasets of complete human anatomy, available free to the scientific community. Of the two datasets making up the VHP, the VHF is the more comprehensive. This dataset has a slice resolution of 2048 × 1216 pixels, pixel size 0.33 mm × 0.33 mm, with 24-bit colour, and slice thickness of 0.33 mm, thus creating isometric voxels. In total, there are 5,189 images comprising a database of about 40 GB [14]. The VHF produced very detailed anatomy of the lingual myostructure, with the thin slices photographed in high resolution resulting in unrivalled anatomical imaging. By arranging a stack of images, the viewer is able to navigate from slice to slice in similar fashion to viewing sectional images of CT/MRI scans. The isometric dimensions of the VHF voxels make the data ideal for multiplanar reformatting (MPR) and 3D rendering. The VHF offers detailed inspection of the tongue and oral cavity in situ without the distortion effects and shrinkage of formalinised tissues, permitting comparison with classical dissection descriptions.

Axial and coronal images of the VHF were downloaded as JPEG files (Joint Photographic Experts Group) from the Visible Human Browser website [15]. The images were imported into Adobe Lightroom (v2.5, Adobe Systems, San Jose, CA) and cropped to include only the structures necessary for the investigation. Cropped images were imported into ImageJ (v1.42q, National Institutes of Health, USA) as image stacks, permitting easy navigation and tracking. The extrinsic muscles of the tongue were identified from their bony attachment to lingual insertion. Measurements were taken using the ImageJ ruler, first calibrated to the 0.33 mm × 0.33 mm pixel dimension, being subsequently exported into Microsoft Excel 2007 (Microsoft Corporation) for analysis.

The distance relative to the lingual mucosal surface was measured for styloglossus and hyoglossus, defined as the length of a line drawn perpendicular to the mucosal surface to the most superficial muscle fibres. Palatoglossus could not be visualised throughout its complete course, and was therefore excluded from further investigation.

As the slice thickness of the VHF was 0.33 mm, measurements taken on every 5th axial and coronal image were deemed to provide sufficient accuracy. Measurements were completed by a single reviewer (PB) on three occasions, and a mean result obtained. Where the lingual mucosa was contiguous or indistinguishable from the mucosa of other structures (e.g. lingual sulcus), the combined thickness of the mucosal surfaces was included. For each slice, five measurements were taken of the muscle adjacent to the overlying mucosa of the lateral tongue (Fig. 1). In the axial plane, the distance from the mucosal surface to the superior border of the styloglossus was measured on seven consecutive slices. The same series of slices were used for measurements of both left and right muscles.

Results

The appearance, position, orientation and anatomical relationships of the extrinsic muscles, with comparison to their classical descriptions are given below.

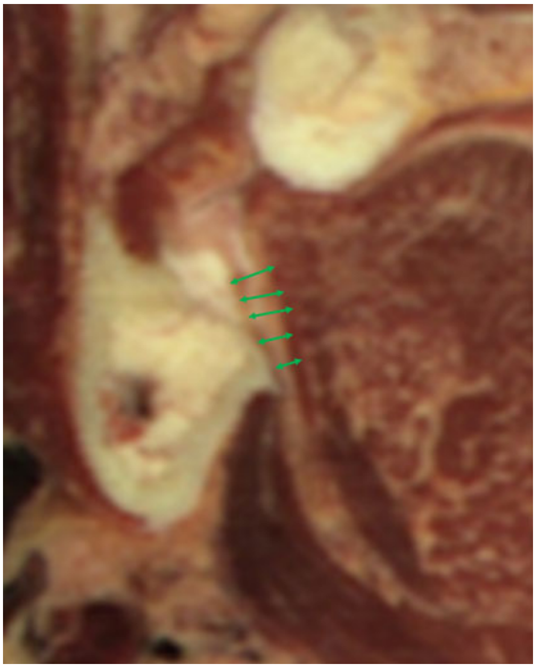

Fig. 1 Measurement of extrinsic muscle distance. Five measurements, indicated by *green lines*, of the distance of the left hyoglossus are shown. A zoomed coronal view of the VHF is shown, located approximately in the middle one-third of the tongue. In this case, the mucosa of the lateral tongue and medial alveolar ridge are juxtaposed. Measurements were taken using the combined width of the mucosal layers (colour figure online)

Extrinsic muscles

Styloglossus

Styloglossus (Fig. 2) arises on the antero-medial surface of the distal styloid process, at the same level of origin as stylohyoid and inferior to stylopharyngeus. The muscle descends antero-medially, its axis oblique to the axial plane, passing between the superior and middle constrictor muscles. At the lateral tongue base, the palatoglossus merges with both the intrinsic muscles (transverses and superior longitudinalis) and styloglossus.

Upon reaching the base of the tongue, the muscles' directional axis enters the axial plane and appears to split into postero-medial and antero-medial fibre groups. Those fibres passing postero-medially appear to merge with the vertically orientated fibres of the hyoglossus muscle and the superior longitudinalis. The antero-medial fibres of the styloglossus follow the infero-lateral tongue from the posterior margin of the hyoglossus to within a few centimetres of the apex, at which point the fibres interdigitate with, and are indistinguishable from, the inferior longitudinalis.

Throughout its course from tongue base to apex, the styloglossus remains superficial and distinct from hyoglossus.

Hyoglossus

Hyoglossus (Fig. 2) arises from the greater cornu and lateral aspect of the hyoid bone. The muscle extends supero-laterally and inserts into the lateral aspect of the posterior half of the tongue. Hyoglossus is rhomboid in shape with the cranio-caudal and anterior-posterior axes slightly skewed relative to the sagittal plane. In the posterior one-third to one half of the tongue, the hyoglossus is seen to extend vertically from the hyoid bone to as much as 80 % of the cranio-caudal length. In the anterior tongue, the vertical extent of hyoglossus is limited to the superficial infero-lateral tongue.

Throughout its course hyoglossus lies deep to styloglossus, except at its posterior edge where the muscles merge.

Genioglossus

Genioglossus (Fig. 2) arises from the superior mental spine on the lingual surface of the mandible at the symphysis menti. Its origin is immediately superior to that of the geniohyoid muscle. Genioglossus spreads from the origin in a fan-like pattern, well demonstrated on the sagittal MPR, until it interdigitates with the transverses and verticalis intrinsic muscles. Genioglossus was noted to have both superficial and deep components, being very superficial to the overlying mucosa in the anterior floor of the mouth especially towards the midline.

Genioglossus, like hyoglossus, is deeper red compared to the adjacent intrinsic muscles. Like hyoglossus the composition of genioglossus is relatively uniform near its origin, but displays increasing amounts of fibrofatty tissue as the distance from the origin increases. This infiltration separates the muscle into increasingly smaller fibre bundles until complete interdigitation with the intrinsic muscles occurs.

In the midline the fibrofatty median raphe is well defined and separates the genioglossi into distinct left and right muscle bellies. Laterally the thin but distinct fibro-fatty paramedian septi become less pronounced as the genioglossi integrates with the intrinsic muscles, not seen in the superior tongue.

Palatoglossus

Palatoglossus (Fig. 2) is small in bulk and generally difficult to identify, but best seen in the axial plane. It can be identified at its origin on the anterior surface of the hard palate. The muscle then thickens as it descends infero-laterally, passing anterior to the palatine tonsil to reach the postero-lateral tongue. There palatoglossus merges with the

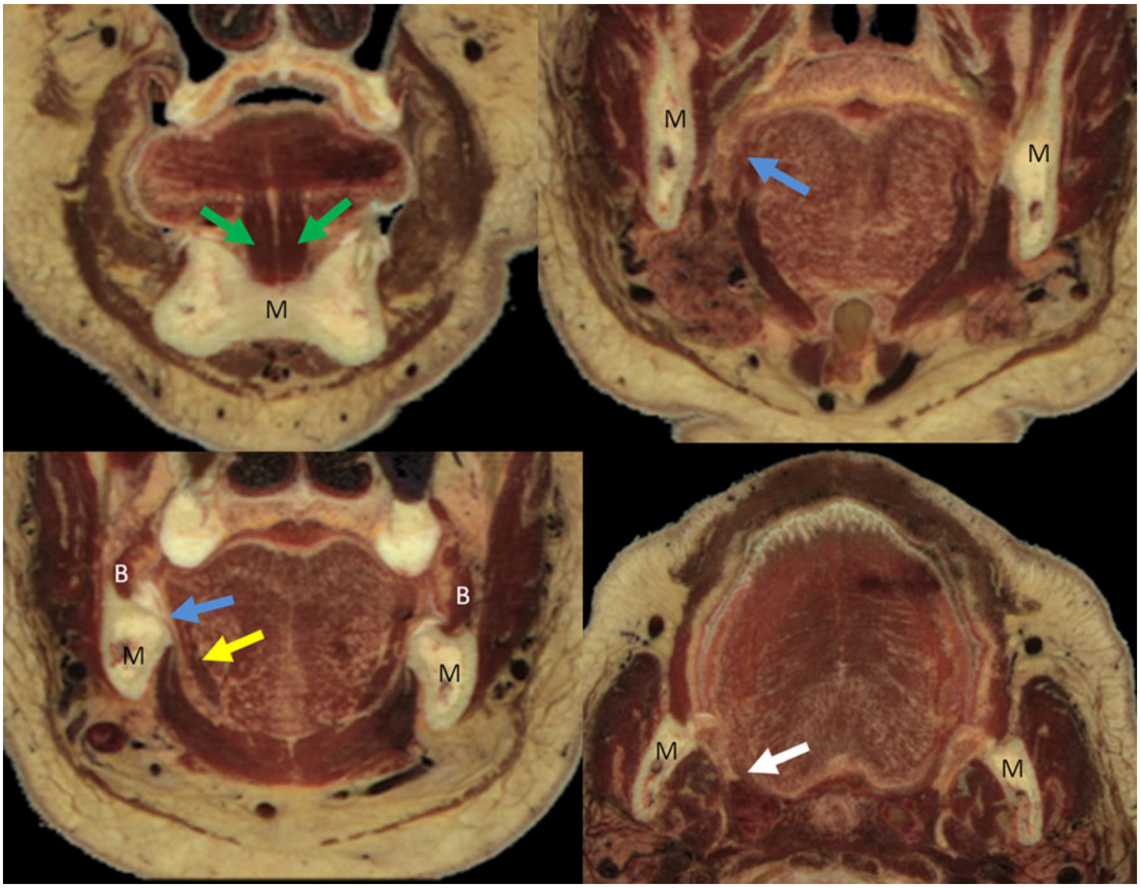

Fig. 2 Coronal and axial VHF view of styloglossus (*blue arrow*), hyoglossus (*yellow arrow*), genioglossus (*green arrows*) and palatoglossus (*white arrow*). The mandible (*M*) and buccinators muscles (*B*) are also highlighted to aid interpretation (colour figure online)

intrinsic muscles (transverses and superior longitudinalis) as well as styloglossus.

Like the other three extrinsic muscles, at its origin and throughout much of its course, palatoglossus is uniformly deep red with minimal fatty infiltration. Upon reaching the lateral tongue, its integration is abrupt. This coupled with the small muscle size means that no further anatomical information is available.

Measurements of the VHF styloglossus and hyoglossus muscles from the lateral tongue mucosal surfaces (Table 1):

Styloglossus

On the right, styloglossus was 1.33 mm (0.33–1.48) from the overlying mucosa and 2.91 mm (0.66–7.68) on the left. The left side measurements were influenced by the differing position of the sublingual salivary tissue extending superiorly (Fig. 3). It seems this anatomical variation may be the result of previous inflammatory reactions resulting in the tissues being distorted by scarring.

Similar results were found in the coronal plane, utilising 16 consecutive slices. On the right, the distance of styloglossus from the mucosal surface was 0.84 mm (0.33–1.68), and on the left 2.30 mm (0.66–4.87).

Hyoglossus

On the right, 8 consecutive axial slices were measured and on the left, 7 slices. On the right side, the mean distance was 2.93 mm (1.48–4.96), and on the left 4.33 mm (1.68–8.71). Similarly, in the coronal plane 12 consecutive slices were measured on both left and right sides. On the right side the mean was 1.85 mm (0.74–3.69), and left 1.64 mm (0.99–3.04).

The extrinsic muscles are demonstrated graphically in Fig. 4.

Discussion

The VHF displays remarkable symmetry in both position and dimension of the extrinsic muscles. The most notable

Table 1 Proximity of styloglossus and hyoglossus to the overlying lingual mucosa in the axial and coronal planes

	Styloglossus	Hyoglossus
Axial		
Right	1.33 mm (0.33–1.48)	2.93 mm (1.48–4.96)
Left	2.91 mm (0.66–7.68)	4.33 mm (1.68–8.71)
Coronal		
Right	0.84 mm (0.33–1.68)	1.85 mm (0.74–3.69)
Left	2.30 mm (0.66–4.87)	1.63 mm (0.99–3.04)

The distance was defined as the length of a line drawn perpendicular to the mucosal surface to the most superficial muscle fibres. Results are displayed as the mean (mm) [range]

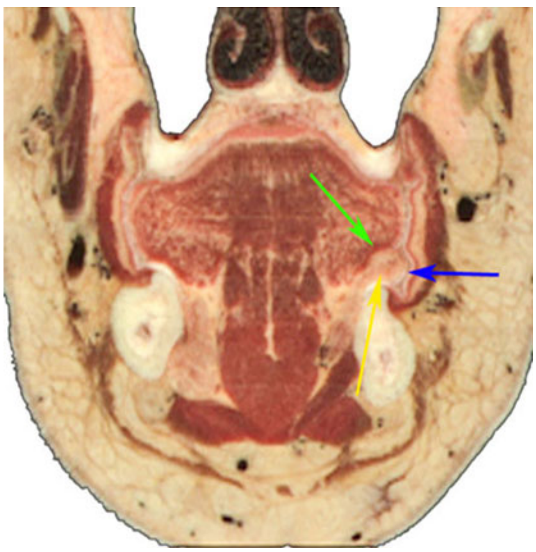

Fig. 3 Coronal VHF view confirming asymmetry of the sublingual salivary gland tissue position. The *green arrow* highlights styloglossus, *blue arrow* lingual sulcus, *yellow arrow*, inferior extension of sublingual gland (colour figure online)

exception is the morphology of the sublingual salivary glands. On the left side, the gland was far more superior and posterior than the right. In its superior extent, the left gland is found in the lateral tongue, superficial to the styloglossus muscle, thus increasing the apparent distance from the mucosal surface.

The VHF lingual myoarchitecture was in keeping with the classical anatomical descriptions and, therefore, suitable for morphologic study of the relative distance of the lateral extrinsic muscles from the lingual mucosal surface. Styloglossus has been confirmed to be anatomically very close to the overlying oral mucosa throughout the length of the lateral oral tongue. Hyoglossus is also close to the lateral mucosa, but slightly deeper than styloglossus. Based on these measurements, it could be argued that styloglossus is within a couple of millimetres of the lateral lingual mucosal surface throughout much of its course. However,

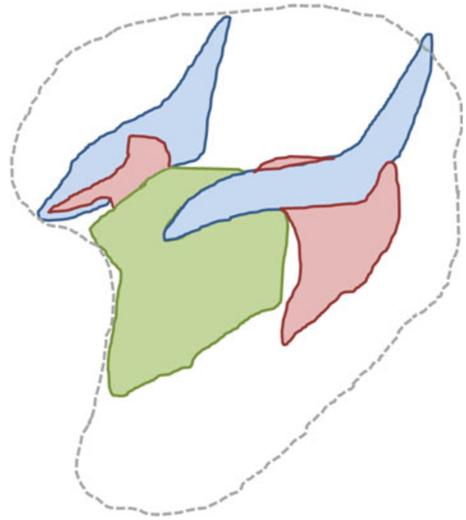

Fig. 4 Diagrammatic representation of the tongue extrinsic muscles shown from the left semi-lateral position. Genioglossus is depicted in *green*, Styloglossus in *pink* and Hyoglossus in *blue* (colour figure online)

the critical measurement is the minimum distance, which confirms styloglossus and hyoglossus lie within 3 mm of the lateral tongue mucosal surface throughout the majority of the tongue edge. Although this anatomical confirmation was derived from the single VHF, it serves to demonstrate close approximation to the classical anatomical texts of Abd-El-Malek (1939) and Miyawaki (1974) [16, 17].

Further, Diffusion Tensor Imaging with Tractography demonstrates the superficial course of the styloglossus may extend from lateral tongue base to apex [18]. The extrinsic muscles have bony origins outside the tongue body and the insertions are not discrete structures, but an interdigitation of muscle fibres with the intrinsic muscles and other extrinsic muscles. External skeletal attachments permit movement and some change in shape, and can be described as "deep".

Notably the styloglossus and hyoglossus muscles appear to be distinct in the superficial lateral tongue, being separated by a thin fascial plane. This is contrary to the view of Golding et al. that interdigitation of styloglossus and hyoglossus occurs in the antero-lateral tongue forming a combined lateral extrinsic group [19]. While anatomically separate, it is likely their close proximity makes them appear as a single unit on MRI.

Despite the inclusion of specific extrinsic muscle invasion in the TNM criteria since its inception, it is difficult to determine why they should represent such a poor prognostic indictor. Could these muscles act as a conduit for tumour spread to the oral floor or deeper structures? If true, then this predictable tumour spread should present regularly with similar specific patterns of growth. Lateral tongue tumours should with this hypothesis follow the course of the styloglossus, anteriorly and posteriorly. Posterior extension along the styloglossus would extend to structures near the skull base.

Following the hyoglossus muscle, tumour would theoretically track inferiorly to invade the floor of the mouth. Lingual carcinomas that invade to reach genioglossus could follow the muscle anteriorly to reach the symphysis menti, posteriorly to reach the tongue base, or inferiorly to reach the mouth floor. However, clinical and histological experience confirms that tumour spread is by direct tissue invasion, intravascular, lymphatic and perineural ingress and rarely if, at all, along muscle bellies.

For small tumours invading styloglossus, it seems unlikely that a T4a designation is justified, even if the conduit theory exists. Certainly a T4a designation is inappropriate for superficial, low volume tumours of the lateral tongue. Similarly, tumours invading only 1–3 mm may invade hyoglossus, making a T4a designation inappropriate, despite the potential to spread to floor of the mouth.

The drawback with this study is that the VHF is based on a single tongue musculature, which may not be representative of the most prevalent anatomy in the population. However, agreement with classical descriptions is reassuring. VHF anatomy is one of the few studies of the relative position of the extrinsic tongue muscle, being untainted by formalin or dissection. It must be looked upon as a useful guide to confirm the detailed anatomy of the extrinsic muscles. Correlation with archived MRI staging and outcome measures would seem justifiable to confirm the influence this extrinsic muscle invasion has on tongue staging.

In conclusion, the styloglossus and hyoglossus muscles within the lateral tongue are very superficial. Based on their superficial anatomical positions these muscles cannot justify the descriptor "deep" and we question the rationale for automatic upstaging to T4a.

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