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**BEYOND THE BOUNDARIES OF COMPARTMENTAL HEMIGLOSSECTOMY: A
PROPOSAL FOR AN ANATOMICALLY BASED CLASSIFICATION OF SURGICAL
APPROACHES TO ADVANCED ORAL TONGUE SQUAMOUS CELL CARCINOMA**

Luca Gazzini MD¹, Enrico Fazio MD¹, Virginia Dallari MD², Luca Spirito MD³, Monir Abousiam MD¹, Riccardo Nocini MD², Aurel Nebiaj MD¹, Giovanni Giorgetti MD¹, Luca Calabrese MD¹

- 1 Division of Otorhinolaryngology Head and Neck Surgery, “San Maurizio” Hospital, Bolzano, Italy
- 2 Otolaryngology-Head and Neck Surgery Department, University Hospital of Verona, Verona, Italy
- 3 Otolaryngology-Head and Neck Surgery Department, University Hospital of Varese Insubria, Varese, Italy

Corresponding author

Virginia Dallari

Unit of Otorhinolaryngology, Head & Neck Department, University of Verona, Piazzale L.A.

Scuro 10, 37134, Verona, Italy

Phone: +39 0458128333

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**BEYOND THE BOUNDARIES OF COMPARTMENTAL HEMIGLOSSECTOMY: A
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1 **ABSTRACT**

2 In the last decade, compartmental surgery (CTS) has been the surgical approach of choice
3 for advanced tumors of the tongue and oral floor.

4 Advanced tumors (cT3-T4) oral tongue squamous cell carcinoma (OTSCC) may extend
5 beyond the lingual septum and involve the contralateral hemitongue, developing along the
6 intrinsic transverse muscle. The disease may then involve the genioglossus muscle and,
7 more laterally, the hyoglossus muscle.

8 The surgical approach to the contralateral tongue must be guided by anatomic and
9 anatomopathological principles to achieve a safe oncological resection based on the
10 principles of CTS. We propose a schematic classification of glossectomies that extend to
11 the contralateral hemitongue based on the anatomy and pathways of tumor spread.

12

13 **1. INTRODUCTION**

14 Oral squamous cell carcinoma is the eighth most common cancer worldwide. It has a poor
15 prognosis, with less than 60% of patients surviving more than 5 years¹. The most common
16 subsite of occurrence is the tongue. Historically the oral tongue squamous cell carcinoma
17 (OTSCC) is related to risk factors such as smoking, alcohol consumption and betel nut
18 chewing. However, in recent years we are witnessing a change in the epidemiology of
19 OTSCC. Indeed, cases of OTSCC unrelated to known risk factors have been reported in
20 young patients or in women. These trends call for further understanding regarding tumour
21 biology, genetic aetiology and pathogenesis of OTSCC¹.

22 In the last decade, compartmental tongue surgery (CTS) has emerged as a promising
23 approach for the treatment of locally advanced cancers of the tongue and floor of the mouth².

24 The aim of CTS is to remove the entire oncological compartment with the pathways of tumor
25 spread, which therefore include the tumor-affected hemitongue, neck lymph nodes, and
26 “tumor-nodes” tract (TNT)²⁻⁵.

27 According to this perspective, the oral tongue is considered to be a paired symmetric organ
28 that acts as the union of two compartments^{2,6}. The lingual septum does not represent a
29 barrier to tumor spread into the contralateral hemitongue but divides the two compartments.
30 In advanced tumors (cT3-T4), the tumor may extend beyond the lingual septum and involve
31 the contralateral hemitongue, developing along the intrinsic transverse muscle. The disease
32 may then involve the contralateral genioglossus muscle and, more laterally, the contralateral
33 hyoglossus muscle⁷. In these cases, the main challenge of surgery is to obtain oncological
34 radicality while simultaneously guaranteeing acceptable functional results.
35 Therefore, the surgical approach to the contralateral tongue must be guided by anatomic
36 and anatomopathological principles that allow oncologically safe resections based on the
37 principles of CTS.

38 This article aimed to illustrate the surgical approach to advanced cT3 cT4a tumors that
39 extend beyond the boundaries of hemiglossectomy, in order to propose a integration of the
40 current classification of glossectomies⁸. The indications for different surgical approaches to
41 the contralateral tongue are outlined, and the procedures are described step-by-step to
42 provide a comprehensive decision-making algorithm for each possible scenario.

43

44 **2. THE RATIONALE BEHIND THE PROPOSED NEW CLASSIFICATION**

45 The gold standard imaging technique used to plan further surgical steps is magnetic
46 resonance imaging (MRI) with gadolinium. MRI is a key decision-making tool for the
47 treatment of cT3 and cT4 OTSCC.

48 When a neoplasm crosses the lingual septum and invades the contralateral tongue, the
49 objective of MRI is to assess the extent to which the contralateral compartment is involved
50 as the tumor may cross the intrinsic musculature and move inferiorly to invade the
51 genioglossus muscle or laterally into the hyoglossus muscle.

52 Recently Gawryszuk et al described the functional swallowing units (FSUs), defined as
53 groups of swallowing muscles sharing their function, that are in close proximity to each other,
54 from a radiotherapy perspective^{9,10}. Their paper provide detailed CT-based delineation
55 guidelines for all FSUs, which are required for implementation of a functional approach in
56 radiotherapy practice¹⁰. They identify seven FSUs, among them there is the
57 hyoglossus/styloglossus muscles complex (HSG). These two muscles co-operate with each
58 other facilitating the tongue base retraction and thus, sufficient pressure building in the
59 hypopharynx⁹. In the wake of this scientific evidence, we introduce the minimal functional
60 unit that must be preserved surgically, if not involved by the tumor, and allows an acceptable
61 swallowing result. It is the so-called functional unit of the base of the tongue, which includes
62 the hyoglossus and styloglossus muscles innervated by the hypoglossal nerve (hyoglossus-
63 styloglossus unit-HSU, **Figure 1**).

64 Three distinct scenarios can be schematically described based on involvement of the
65 musculature of the contralateral tongue:

- 66 – SCENARIO A: Involvement of only the contralateral intrinsic musculature without
67 extrinsic musculature invasion.
- 68 – SCENARIO B: Partial involvement of the contralateral extrinsic musculature
69 (genioglossus muscle), preserving the HSU.
- 70 – SCENARIO C: Invasion of the entire contralateral compartment.

71 Furthermore, in addition to invasion of the contralateral tongue, the surrounding anatomic
72 structures outside the oncological compartment of the tongue, may also be involved
73 including the palatine tonsil, vallecula, supraglottic larynx, mandible, cheek mucosa, and
74 retromandibular trigone. These can be associated with the three aforementioned scenarios
75 and are described as extracompartmental approaches.

76

77

78 **3. SURGICAL TECHNIQUE**

79 We describe only the adjunctive steps that involve the contralateral compartment of the
80 tongue, assuming that a standard surgical approach to the origin of the tumor in the
81 ipsilateral compartment has been followed as described in the literature⁵.

82

83 **3.1 Extended Glossectomy Type A**

84 The OTSCC extends out of the compartment through the intrinsic musculature without
85 infiltration of the contralateral extrinsic musculature. In this case, the spread of OTSCC is
86 by extending past the lingual septum without invading it. The tumor follows the direction of
87 the intrinsic muscle fibers in the following order: superior longitudinal muscle, vertical
88 muscle, transverse muscle, and inferior longitudinal muscle (**Figure 2A,B**). In this case, the
89 contralateral compartment is not involved, and the risk of invasion of the contralateral
90 anatomic spreading routes (extrinsic musculature, TNT, and vasculoneural structures) is
91 low, enabling only ipsilateral CTS to be performed with contralateral wedge resection
92 (**Figure 2C,D**).

93

94 *Surgical steps*

- 95 – An ipsilateral CTS procedure is performed. At this point, the contralateral
96 genioglossus muscle is viewed directly, and the absence of invasion of the
97 contralateral extrinsic musculature can be confirmed.
- 98 – Along the dorsal lingual surface, the midline is highlighted with a skin marker. Using
99 a monopolar scalpel, the tongue mucosa is dissected forming a wedge where the
100 tumor goes beyond the midline, with macroscopic safety margins of at least 1.5–2
101 cm.
- 102 – The intrinsic muscle fibers are dissected from top to bottom. Wedge resection is
103 performed under the direct control of the deep margin and genioglossus muscle,

104 which is already evident after the compartmental approach and dissection of the
105 lingual septum.

106 – The resection is completed by proceeding from the bottom upwards, checking the
107 transition point between the genioglossus muscle and the last intrinsic muscle fibers.
108 This is a crucial step; here, it is essential to collect frozen sections along the resection
109 margins to exclude genioglossus infiltration. A cuff of genioglossus muscle can also
110 be included in the specimen as an additional safety margin.

111

112 **3.2 Extended Glossectomy Type B**

113 In this case, the tumor spreads from the intrinsic musculature to invade the contralateral
114 genioglossus muscle (**Figure 3A,B**). Extended CTS is then performed on the contralateral
115 genioglossus muscle, which is removed in radical compartmental terms (**Figure 3C,D**).

116

117 *Surgical steps*

118 – Ipsilateral CTS is performed without dissecting the lingual septum. At this point, the
119 contralateral genioglossus muscle is under direct view, and its involvement with the
120 primary tumor can be confirmed.

121 – The contralateral genioglossus is detached from the mental symphysis.

122 – The genioglossus is used as the dissection plane to locate the contralateral lingual
123 artery. This artery is a fundamental landmark for identifying the hyoglossus and
124 styloglossus muscles, which are located in a plane superficial to the artery and
125 vascular space. The hyoglossus muscle is identified in this plane in an anterior
126 position, and the fibers of the styloglossus muscle are identified posteriorly. These
127 two structures, together with the terminal branches of the hypoglossal nerve directed
128 to them, are carefully dissected and preserved to maintain the function of the HSU.

- 129 – Inferiorly, the sublingual gland and the lingual and hypoglossal nerves are identified
130 in the sublingual region, and their terminal branches directed to the genioglossus
131 muscle are dissected.
- 132 – Finally, detachment of the genioglossus from the hyoid bone and dorsal resection
133 with a monopolar scalpel are carried out.

134

135 **3.3 Extended Glossectomy Type C**

136 This represents the most advanced case of direct infiltration of the genioglossus,
137 hyoglossus, or styloglossus muscles (**Figure 4A,B**), and both compartments must be
138 removed (**Figure 4C,D**). In this case, both HSUs are involved in the disease; therefore, it
139 is not possible to preserve one of them.

140

141 *Surgical steps*

- 142 – Homolateral CTS is performed without septal dissection. At this point, the
143 contralateral genioglossus muscle is view directly and invasion of the contralateral
144 extrinsic musculature can be confirmed. Moreover, infiltration of the contralateral
145 hyoglossus muscle is also observed.
- 146 – Hyoid insertions of the mylohyoid, hyoglossus, and genioglossus muscles are
147 sectioned.
- 148 – The lingual artery, lingual vein, lingual nerve, and hypoglossal nerve are sectioned
149 after detachment of the descending ansa.
- 150 – The sublingual area of the sublingual gland is fully resected. Posteriorly, the
151 styloglossus muscle is sectioned as cranially as possible.
- 152 – The resection is completed on the dorsal surface with removal of the entire lingual
153 body together with the tongue base bilaterally, with the glossoepiglottic valleculae as
154 the posterior limit of resection.

155

156 **4. DISCUSSION**

157 The gold standard treatment is surgical resection with clean margins. Advanced (cT3-
158 T4) OTSCC may extend beyond the lingual septum and involve the contralateral
159 hemitongue, developing along the intrinsic transverse muscle. The disease may
160 then involve the genioglossus muscle and, more laterally, the hyoglossus muscle. In
161 cases of macroscopic infiltration of the extrinsic musculature of the tongue, CTS has
162 shown good survival results in terms of both long-term survival and locoregional control of
163 the disease, particularly when used as a primary treatment modality^{6,11}.

164 The main objective of CTS is to remove the entire oncological compartment with the
165 pathways of tumor spread, which include the tumor-affected hemitongue, neck lymph nodes,
166 and TNT. In this case, the content of the TNT is removed entirely with its connective tissue
167 and fat content, together with all the nervous vascular structures contained therein: the
168 hypoglossal nerve, lingual artery, and lingual vein, and the mylohyoid, hyoglossus, and
169 ipsilateral genioglossus muscles^{4,12-14}.

170 Generally, after infiltrating the intrinsic musculature, the tumor follows the direction of muscle
171 fibers⁷. An anterior or middle third OTSCC tends to involve the intrinsic musculature first,
172 followed by the genioglossus muscle fibers. A posterior third OTSCC may involve the more
173 superficial hyoglossus and styloglossus muscles at an earlier stage¹⁵.

174 The lingual septum divides the tongue into two compartments, and in advanced cases, the
175 tumor (cT3-cT4a) may extend beyond it and invade the contralateral tongue⁷.

176 The search for a reproducible and modular systematization of surgical approaches to
177 OTSCC has recently been superseded by the classification of glossectomies proposed by
178 Ansarin et al⁸. Although this classification is precise and facilitates shared communication
179 between surgeons, it does not describe in detail all the possible approaches in advanced
180 tumors based on the OTSCC spreading routes. Indeed, the anatomic characteristics of the

181 lingual musculature influence tumor progression in the contralateral compartment. The
182 neoplasm can exceed the midline only above the lingual septum, and spreading along the
183 intrinsic transverse course of the muscle fibers. Subsequently, there may be infiltration of
184 the contralateral genioglossus musculature⁷. This implies that, in the first case, a median-
185 based wedge resection of the intrinsic musculature is necessary, and when the neoplasm
186 begins to infiltrate the extrinsic musculature, a subtotal glossectomy is performed, which
187 includes removal of the contralateral genioglossus, leaving only a functional unit including
188 the tongue base and the hyoglossus and styloglossus muscles.

189 As stated by Gawryszuk et al and also in authors' experience, there is a minimal functional
190 unit that allows an acceptable swallowing result and which we have named the HSU, the
191 functional unit of the base of the tongue, which includes the hyoglossus and styloglossus
192 muscles innervated by the hypoglossal nerve^{9,10}. This unit must only be sacrificed if there is
193 direct bilateral invasion of the hyoglossus muscle, so in this case, the surgical approach
194 should be converted to total glossectomy.

195 The anatomically based classification proposed in the present work can be a useful tool in
196 decision making, providing a complete decision algorithm based on preoperative CT and
197 MRI, and intraoperative findings. CT and MRI are widely used to depict tumor extensions
198 and to perform radiological diagnostic outpatient imaging (r-DOI) for staging of OTSCC.
199 Radiological imaging findings are an important resource for both planning surgical treatment
200 on the tumor and predicting cervical lymph node metastases^{16,17}.

201 An anatomic step-by-step procedure based on preoperative imaging and intraoperative
202 findings makes it possible to tailor the surgical approach, extend the resection to precise
203 anatomic structures that could represent a potential spreading pathway for the tumor, and
204 preserve structures that are not involved in the disease.

205 As extended glossectomies involve the "en bloc" removal of the tumor and its pathways of
206 spread, the residual volumetric defect is large, so the reconstructive flap of choice is the

207 anterolateral thigh flap (ALTF). ALTF harvesting permits to reduce incidence of donor area
208 dysfunction and complications. It can be closed and sutured directly without the need for
209 skin grafting and without obvious effects on shape and function, unlike radial forearm free
210 flap (RFFF) which is indicated in patients with tongue defects less than half of tongue
211 tissue¹⁸⁻¹⁹. Moreover the donor area of the ALTF can be operated on at the same time,
212 shortening the surgical time, that in this surgery could be long due to the complexity of the
213 technical steps.

214 The ALTF provides sufficient tissue volume to cover the functional defect and it can also be
215 harvested with part of the vastus lateralis muscle if necessary. In type B and C
216 extended glossectomies, the resection is large and a voluminous flap is required to fill the
217 defect. In these cases, it may be necessary to set up a chimeric ALTF with the vastus
218 lateralis muscle. This can be very useful in patients with poor subcutaneous tissue or
219 who will undergo radiotherapy and thus greater loss of flap volume.

220 Other free flaps that can be used in extended glossectomies are: the Gracilis Flap, the
221 Rectus Abdominis flap and the Latissimus dorsi flap²⁰.

222 In patients with a high comorbidity profile, the pedicled locoregional flap is the flap of
223 choice²¹. The workhorse flap in these patients is the major pectoralis flap.

224 Flap reconstruction is necessary for the restoration of tongue volume and better functional
225 outcomes in patients who underwent extended resection of the tongue.

226 Indeed the challenge in treating advanced OTSCC is to achieve a safe oncological result
227 while preserving an acceptable quality of life. Patients should be appropriately counseled of
228 the risks involved in this radical surgery to remove an extensive tumor with emphasis on
229 intensive swallowing rehabilitation in the post-treatment setting²²⁻²⁴.

230 One of the most debilitating symptoms complained of by patients undergoing surgery is
231 postoperative swallowing difficulty, followed by reduced speech intelligibility.

232 Recent literature focuses on assessing the psychological well-being of patients undergoing
233 total or subtotal glossectomy. It is necessary for patients to be supported in the postoperative
234 period by both psychological and psychiatric professionals.

235 Some of the questionnaires that can be used in both the pre and postoperative period are:
236 general health and social functioning scores of the SF-8 (Short Form 8-Item Health
237 Survey) and the depression scores of the HADS (Hospital Anxiety and Depression
238 Scale). Overall quality of life can be measured using the European Organization for
239 Research and Treatment of Cancer (EORTC) H&N35 questionnaire²⁵.

240 Improving quality of life should be recognized as an ultimate goal of treatment, as head
241 and neck cancers cause more somatic and psychological distress than other types of
242 cancer.

243

244 **CONCLUSION**

245 The anatomically based classification proposed in the present work provides a complete
246 decision algorithm for advanced OTSCCs, that allows the optimum approach to be
247 chosen on the basis of contralateral tongue involvement. The surgical approach to the
248 contralateral tongue must be guided by anatomic and anatomopathological
249 principles that permit oncologically safe resections based on the principles of
compartment surgery, and at the same time, which preserve the HSU to guarantee the
best possible quality of life for patients.

FIGURES

Figure 1: Drawing of the HSU (hyoglossus-styloglossus unit). HGM, hyoglossus muscle; STM, styloglossus muscle; HB, hyoid bone; LA, lingual artery.

Figure 2A,B: Coronal and axial contrast-enhanced T1-weighted head and neck MRIs. The dotted line indicates the medial limit of the tumor, which encompasses and extends beyond the lingual septum and reaches the contralateral intrinsic musculature.

Figure 2C,D: Extended glossectomy type A. Coronal and axial views. The tumor invades the contralateral intrinsic musculature; therefore, it is necessary to perform CTS ipsilateral to the lesion with contralateral wedge resection.

Figure 3A,B: Coronal and axial contrast-enhanced T1-weighted head and neck MRIs. The red dotted line indicates genioglossus muscles. The tumor, following the muscle fibers of the genioglossus muscle, extends to the contralateral extrinsic musculature.

Figure 3C,D: Extended glossectomy type B. Coronal and axial views. The tumor partially invades the contralateral extrinsic musculature; therefore, it is necessary to perform CTS extending to the contralateral genioglossus muscle and preserving the HSU.

Figure 4A,B: Coronal and axial contrast-enhanced T1-weighted head and neck MRIs. In this case, both HSUs are involved in the tumor; therefore, it is not possible to preserve one of them.

Figure 4C,D: Extended glossectomy type C. Coronal and axial views. The tumor invades the entire contralateral compartment; therefore, total glossectomy must be performed.

Figure 5: Extracompartmental approaches: the anatomically oriented algorithm. HSU, hyoglossus-styloglossus unit; OTSCC, oral tongue squamous cell carcinoma.

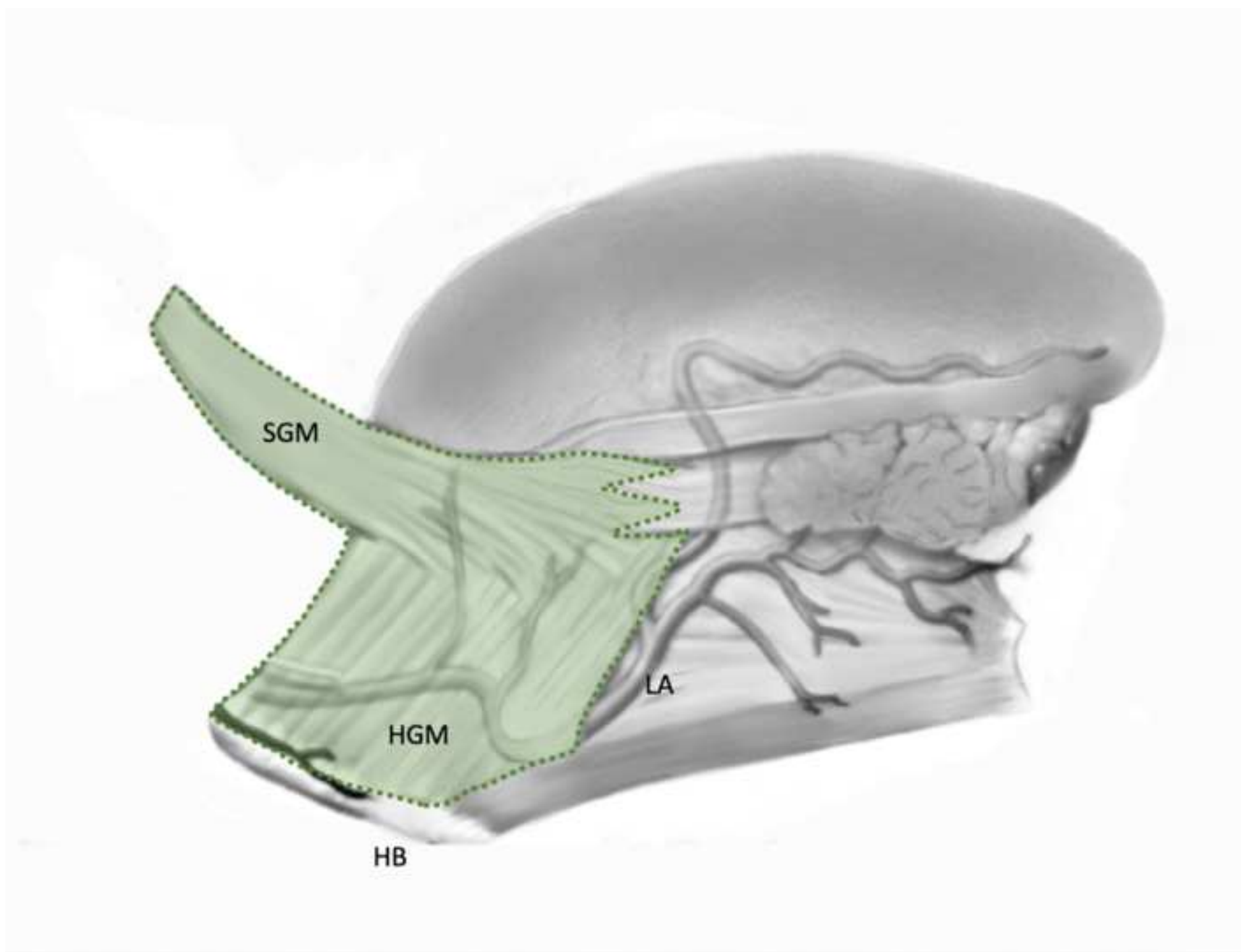
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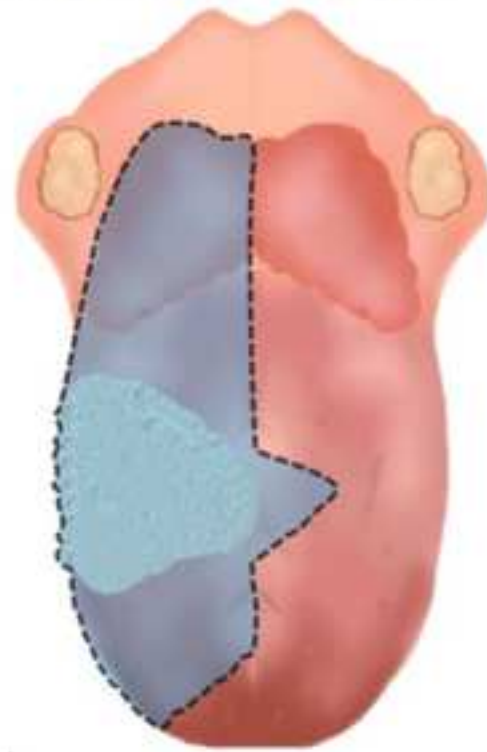
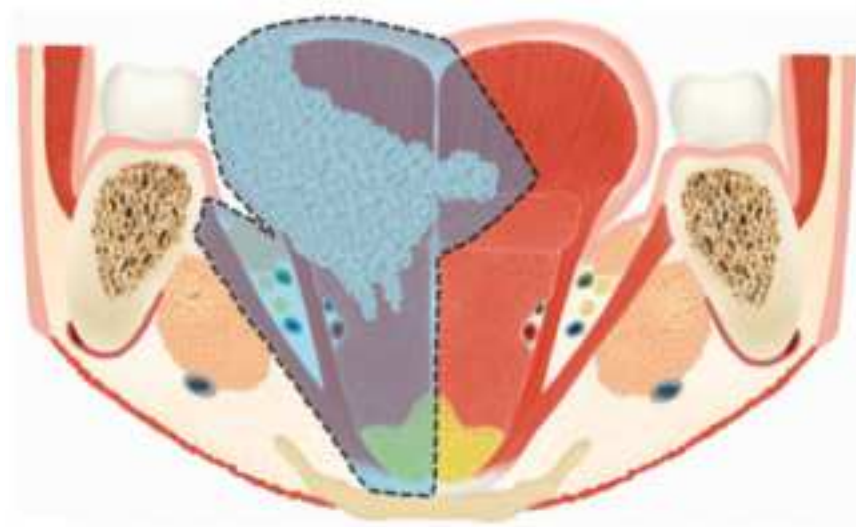
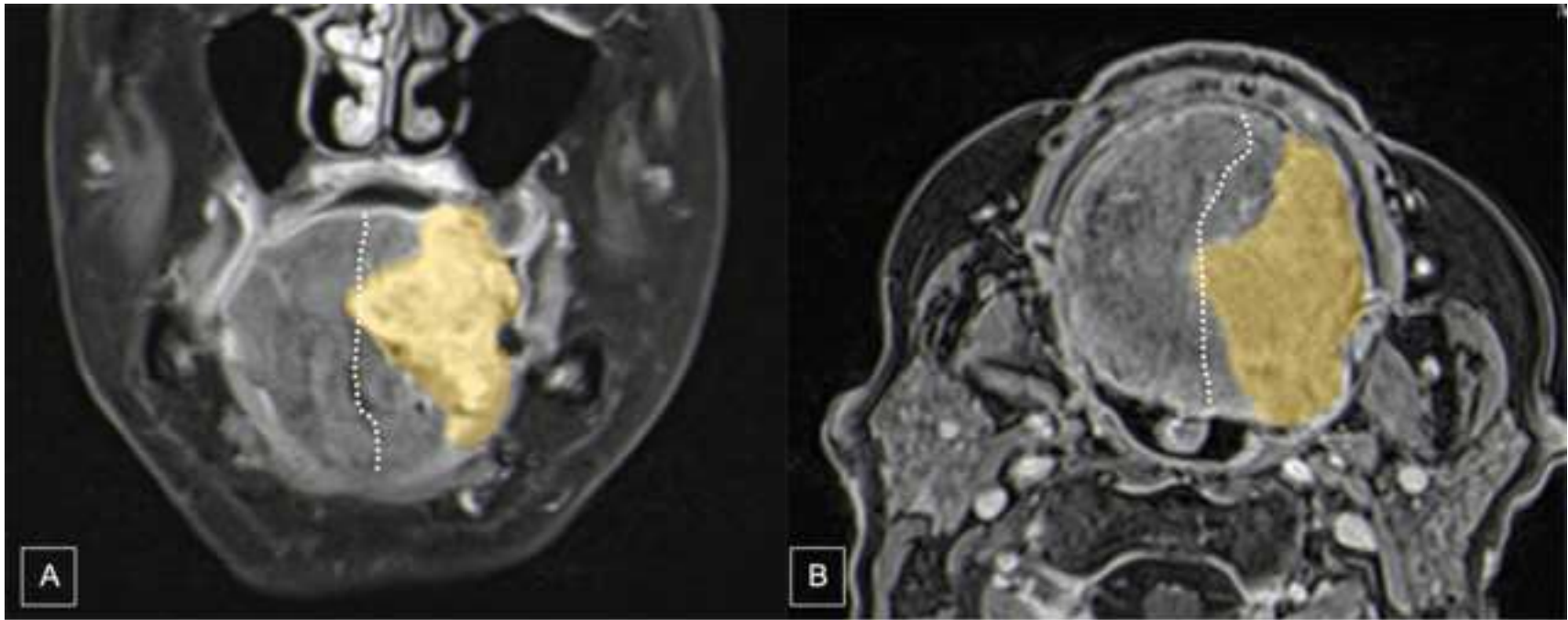
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