**TECHNICAL NOTE**

# Compartmental surgery in tongue tumours: description of a new surgical technique

## *Chirurgia compartimentale nei tumori della lingua: descrizione di una nuova tecnica chirurgica*

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SUMMARY

The aim of curative surgical oncology is to remove the primary tumour with a wide margin of normal tissue. What constitutes a sufficiently wide margin particularly in oral cancer is fundamentally unclear. The currently accepted standard is to remove the primary lesion with a 1.5-2 cm circumferential macroscopic margin. In the last ten years, anatomical considerations in the approach to primary, advanced and untreated tumours of the tongue led us to develop and improve a new surgical approach to their demolition and reconstruction. From July 1999 to July 2009, at the European Institute of Oncology in Milano, Italy, 155 patients were treated, while defining and refining the concept of compartmental tongue surgery (CTS) and its main components: 1) anatomical approach to the disease that requires removal of the primary lesion and all of the potential pathways of progression – muscular, lymphatic and vascular; 2) identification of a distinct territory at risk of metastatic representation of the disease: the parenchymal structures between the primary tumour and the cervical lymphatic chain that include the muscular (mylohyoid), neuro-vascular (lingual nerve and vein) and glandular (sublingual and submandibular) tissues; 3) preparation for a rational reconstruction in consideration of a functional defect resulting from this anatomical demolition.

KEY WORDS: Tongue • Malignant Tumours • Squamous Cell Carcinoma • Surgery • Technique • Compartment

RIASSUNTO

*Lo scopo della chirurgia oncologica curativa è quello di rimuovere il tumore primario con un ampio margine di tessuto sano. In cosa consista un margine sufficientemente ampio, sopratutto nei tumori del cavo orale, rimane fondamentalmente poco chiaro. Lo standard corrente è di rimuovere la lesione primaria con un margine macroscopico circonferenziale di 1,5-2 cm. Negli ultimi 10 anni alcune considerazioni anatomiche nell'approccio ai tumori primari della lingua avanzati e non trattati precedentemente ci ha spinto a sviluppare e perfezionare un nuovo approccio chirurgico. Dal luglio 1999 al luglio 2009 presso l'Istituto Europeo di Oncologia, Milano, abbiamo trattato 155 pazienti, definendo e perfezionando il concetto della chirurgia compartimentale della lingua e le sue componenti principali: 1) un approccio anatomico alla malattia che richiede l'asportazione della lesione primaria e di tutte le potenziali vie di progressione – muscolari, linfatiche e vascolari; 2) identificazione di un territorio a se stante ad alto rischio metastatico: le strutture parenchimali comprese tra il tumore primario e la catena linfatica cervicale che comprende i tessuti muscolari (miloioideo), neuro-vascolare (nervo e vena linguale) e ghiandolari (sottolinguale e sottomandibolare); 3) preparazione ad una ricostruzione razionale tenendo presente il difetto funzionale risultante da questa demolizione anatomica.*

PAROLE CHIAVE: *Lingua • Tumori maligni • Carcinoma squamo cellulare • Chirurgia • Tecnica • Compartimento*

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## Introduction

The aim of curative surgical oncology is to remove the primary tumour with a wide margin of normal tissue. What constitutes a sufficiently wide margin, particularly in oral cancer, is fundamentally unclear [1], with regional (country) and surgeon-dependent variability [2]. The currently accepted standard is to remove the primary lesion with a 1.5-2 cm circumferential macroscopic margin [3]. With this approach the portion of the tongue musculature (intrinsic and/or extrinsic) that needs to be removed cannot be well defined pre-operatively with obvious implications for organ and function preservation, reconstruction as well as rehabilitation.

Several gross anatomical considerations underestimate the difficulties related to the surgical treatment of malignancies of the tongue. The tongue is a symmetrically paired organ consisting of two halves, or compartments, the extreme boundaries of which are represented by the periosteum (lateral, inferior, anterior) and the midline lingual septum.

Clinical evidence shows what, so far, has only been suggested in the literature [1 4] and adequately described only in the musculoskeletal system: tumour cells can migrate longitudinally following the path of least resistance. From the primary site along and between the intrinsic and extrinsic muscle fibres the pattern of spread varies according to the orientation of the infiltrated muscle(s) [1 3 5-10]. The arrangement of the extrinsic muscles, with a sharp bend from the base of the tongue to the floor of the mouth, allows fast progression of the tumour to the deeper tissue planes. The importance of longitudinal tumour resection is supported by these anatomical considerations, and is further corroborated by two clinical observations that have a significant prognostic role: 1) tumour invasion of nerves and vessels also progresses along a path parallel to the muscle fibres, and, 2) the sublingual areolar tissue and the sublingual gland, with modification of the surrounding tissue stroma, represent paths of potential spread [2 11].

Tumour size and depth of invasion of the extrinsic muscles are critical parameters in pathologic staging of the disease. In some cT2 tumours, it is difficult to determine whether or not the extrinsic lingual muscles are involved. Crossing this anatomical boundary at the microscopic level is one of the criteria for the classification of a tumour as a pT4 rather than a pT2 [12] with obvious implications for disease-free long-term survival, loco-regional recurrence and functional deficits as well as post-reconstructive rehabilitation and quality of life [1 4-5 13-16].

As muscles are cut, even if partially, they lose their function. The presence of a non-functional muscle tissue remnant becomes unnecessary and remains always a tissue bed of potential microscopic tumour infiltration. A non-functional muscle also becomes unnecessary for reconstructive purposes. In light of these anatomical considerations, we applied a surgical approach that allows the surgeon to carefully detach each of the involved muscle groups from their bony insertions, respecting the natural anatomical barriers of the oral cavity (periosteum and midline lingual septum).

In the last ten years, these considerations in the approach to primary, advanced and untreated tumours of the tongue led us to develop and improve an anatomical approach to demolition and reconstruction. We developed the principles of what we have called compartmental tongue surgery (CTS), analogous to those used in the treatment of musculo-skeletal sarcomas. There are 3 main components to CTS: 1) anatomical approach to the disease that requires removal of the primary lesion and all of its potential pathways of progression – muscular, lymphatic and vascular; 2) identification of a distinct territory at risk for metastatic representation of disease: the parenchymal structures between the primary tumour and the cervical lymphatic chain that include the muscular (mylohyoid), neuro-vascular (lingual nerve and vein) and glandular (sublingual and submandibular) tissues; 3) preparation for a rational reconstruction in consideration of a functional defect resulting from this anatomical demolition.

In this report, the notion of CTS is introduced to the field of Oral Surgery. The technique used in 155 patients treated from July 1999 to July 2009 at the European Institute of Oncology in Milano, Italy, is described.

## Surgical technique: Compartmental Tongue Surgery (CTS)

A standard pre-operative assessment is performed with risk stratification for surgery, laboratory examination (CBC, coagulation profile, basic metabolic panel), videolaryngoscopy and imaging for completion of clinical staging. Magnetic Resonance Imaging (MRI) is the preferred imaging modality as it allows identification of individual muscle involvement and has shown a strong and direct correlation with histological tumour thickness [17]. Total body computerized tomography (CT) scan and osseous scintigraphy, or alternatively a full body positron emission tomography (PET)-scan, are used to evaluate the presence or absence of distant disease.

Surgery is performed under general anaesthesia. A prophylactic tracheotomy (surgical or percutaneous), separate from the neck dissection field, is performed in all cases. Neck dissection was mono-lateral or bilateral, radical or functional, depending upon the location of the primary lesion and on the clinical status of the neck. Tongue surgery can be performed via mandibulotomy or in pull-through.

### *Skin Incisions*

Skin incisions are performed to allow: 1) the use of natural skin creases as much as possible, 2) the creation of a break in the arch of contracture that would be created by a vertical scar, 3) a true median approach to the mandible when a mandibulotomy is performed, 4) decreased potential risk of facial nerve injury and related asymmetries when the vertical incision in the mental region is performed in a paramedian fashion following Langer's lines. Horizontal incision points are placed at the labiomental fold, and in the submental/submandibular region. A vertical incision splits the lip from the wet-dry junction, through the vermillion border to the labio-mental incision point. A second vertical incision point is placed in the mental spine region to correspond to the chin-button area. A mid-neck horizontal incision, at the level of the hyoid bone, is then made following a natural skin crease, allowing separation of the tracheotomy from the surgical field and minimizing the extent of an unsightly scar. The horizontal incision points and the vertical incision lines are then connected by means of transverse incisions to create a Z-pattern (Fig. 1).

### *Muscular Dissection*

Following completion of the neck dissection, the approach to the tumour is "from the bottom up": from the

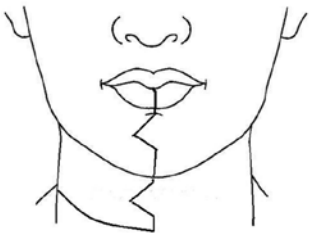

**Fig. 1.** Cutaneous incisions.

neck to the tumour. The dissected contents of the neck are kept in continuity with the primary lesion throughout the approach to the tongue. In cases of disease localized to an individual hemi-tongue compartment, the first objective is to detach, when involved, the muscles (mylo-, genio-, stylo-hyoid and genioglossus) from their insertions and origins (Figs. 2, 3).

The mylohyoid muscle is detached at the hyoid bone insertion site and then separated medially from the paired opposite. This approach allows identification of the exact location of the geniohyoid and genioglossus muscles bilaterally, as well as the midline septum. At this point, digital exploration allows clinical confirmation of disease confinement to a single hemi-tongue compartment. The hyoglossus muscle is detached from the hyoid bone insertion (Fig. 4). The ipsilateral lingual artery and hypoglossal nerve are ligated at the level of hyoid bone. This anatomical and radical dissection from the hyoid bone allows a direct approach and perfect control of a deeply infiltrating tumour of the base of the tongue, at the level of the vallecula. The mylohyoid muscle is detached from the mandibular insertion allowing optimal exposure of the sub-lingual area and the lingual nerve is cut as close as possible to the skull base. The styloglossus muscle is removed as close as possible to the styloid process and the genioglossus muscle is detached from the symphysis, separated from the paired opposite. The geniohyoid muscle is preserved except in case of parahyoid infiltration of the genioglossus muscle (for example, in base of the tongue tumours). The hemi-tongue compartment is now free of its anatomical boundaries.

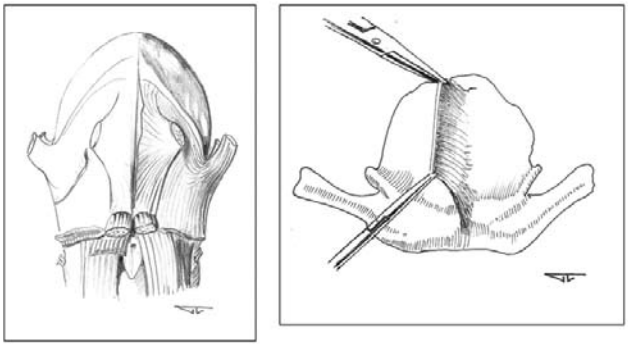

**Fig. 2.** Left panel: ventral view of tongue-extrinsic and infra-hyoid muscles. Right Panel: lingual septum and its hyoid bone insertions.

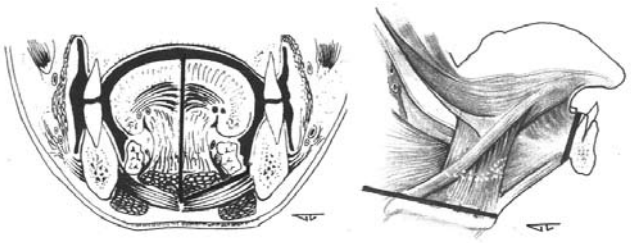

**Fig. 3.** Left panel: coronal view of hemi-tongue compartments; Right Panel: sagittal view of hemi-tongue compartment – Note: hypoglossal nerve in relation to hyoid bone (dotted line).

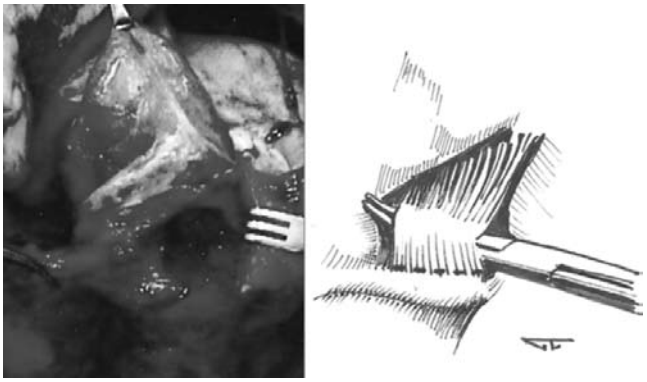

**Fig. 4.** Left: ventral view of tongue and isolation of genioglossus muscle; Right: approach to hyoid bone and detachment of the hyoglossus muscle.

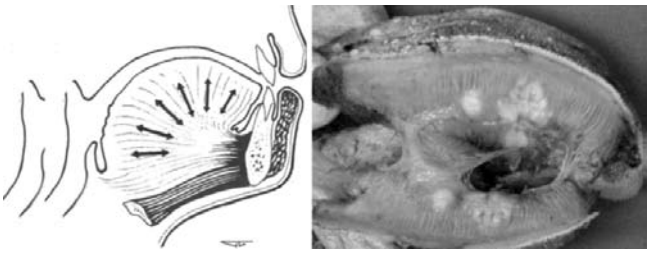

**Fig. 5.** Left panel: sagittal representation of tongue musculature and path of progression along longitudinal orientation of muscle fibres; Right panel: gross anatomical section showing disease progression along orientation of muscle fibres.

Surgery can now proceed with a combined trans-oral and submandibular approach having complete manual control of the entire compartment and the disease within it. The tongue is progressively divided posteriorly along the central septum and the latter is included in the surgical specimen. The hemi-tongue is removed with a portion of the floor of the mouth to include the entire sublingual gland and the areolar soft tissue that connects the submandibular gland around the mylohyoid muscle to the midline. Mucosal tissue at a distance from the tumour (base of the tongue and/or tip) can be preserved, maintaining residual sensitivity and contributing to functional reconstruction. The specimen is then removed *en-bloc* with the lymph nodes.

*Transmandibular Approach*

A transmandibular approach is not mandatory, however, it allows greater access to the primary disease, making anatomical dissection and functional in-setting of the reconstruction flap easier. Subperiosteal dissection is performed, the symphyseal area is exposed and anatomical landmarks are identified. Osteosynthesis plates are prebent and positioning holes drilled. A median mandibulotomy is performed, preserving the central incisor teeth if there is no apical inflammation or irregular course of the root. This approach reduces the risks of mental nerve injury associated with a paramedian osteotomy. The mandibulotomy is stepped with the inferior rung at the level of the mental spine allowing preservation of the insertion of both geniohyoid muscles in the absence of deep infiltration of the genioglossus muscle.

*Surgical Reconstruction*

Reconstruction is now finalized for restoration of function and not for volume reconstitution. The choice of the reconstruction flap depends upon the size and the function of the defect and of the contra-lateral tongue. The first reconstructive option is an antero-lateral thigh or a gracile muscle flap. In patients with a small initial tongue volume and primary lesion size, a forearm free flap can be used as an alternative, with the *palmaris longus* tendon re-creating the arch of tension between the hyoid bone and the mandibular symphysis. When microvascular reconstruction is contraindicated, or not feasible, the pedicled myo-cutaneous *pectoralis major* island flap is used. If performed, the mandibulotomy is rigidly fixed. Standard closure then takes place in a layered fashion.

## Discussion

In the surgical treatment of musculoskeletal or parenchymal sarcomas, the extent of excision, to ensure sufficiently radical surgery is centered upon the notion of "anatomical compartments". Clinically, tumour progression appears to follow the path of least resistance. In musculoskeletal or parenchymal locations, an "anatomical compartment" has been defined, where the fascia layers act as a barrier to primary tumour invasion, thus tumour spread is *forced* to follow the orientation of muscle fibres, parenchyma and soft tissues, including nerves and vessels. This is the reason why a single muscle, or a group of muscles, may be considered a "compartment". Radical and complete removal of this anatomical unit is the aim of compartmental surgery. The definition of surgical compartments and application of these criteria to the surgical treatment of sarcomas has statistically improved local disease control compared to wide resection [6-10]. In a series of 471 patients, Azzarelli [7] reported a statistically significant local disease control in 76% in patients treated with compartmental surgery, compared to 53% when treated with wide excision ($p < 0.001$) [7].

In head and neck anatomy, there are natural barriers that can act as potential obstacles to tumour progression. In the oral cavity, the tongue is a symmetrically paired organ, the extreme boundaries of which are the periosteum (lateral, inferior, anterior) and the midline lingual septum. The tongue may, therefore, be compared to a fascial compartment similar to those found elsewhere in the body [1], with the midline septum and the periosteum acting as boundaries that restrict and force tumour spread within the compartment and along the muscle fibres it contains. Each hemi tongue can be considered a compartment, and a single muscle (extrinsic) or a group of muscles (intrinsic) within it may be considered as sub-compartments (Figs. 2, 3). Clinical evidence confirms the longitudinal path of progression of disease in the tongue musculature [1 5] as in the musculo-skeletal system (Fig. 5). We applied the radical criteria of compartmental surgery to cancer lesions anatomically confined in well-delineated surgical compartments of the tongue. The aim of this approach is to control tumour spread to the deep muscles, especially the extrinsic muscle groups, where the strong contractile activity promotes rapid tumour progression and metastatic spread. Control of tumour progression along nerves and vessels, and spread to the sublingual connective tissues and the sublingual gland are of significant prognostic relevance [2 4 11 13 18]. The lingual septum acts as a reference landmark allowing delineation of a well-defined boundary (medial margin) for the hemi-tongue compartment and better macroscopic visualization of the disease confined within it. In our patient population, all of the cases with contra-lateral extension of the disease showed invasion that was limited to the contra-lateral transversal intrinsic muscles providing evidence that the functional role of the septum, in tumour progression, may go beyond that of a geographical boundary.

All these considerations support the importance of radical longitudinal resection and introduce a rational definition of what constitutes an adequate margin beyond the arbitrary 1.5-2 cm commonly used in traditional tongue surgery. Oncologic radicality can be obtained from longitudinal resection and removal of the individual hemi-tongue compartment and its components as it represents the likely path of spread of the disease and potential subsequent recurrence more accurately. This paradigm shift (from circumferential to longitudinal resection) paradoxically appears to be initially more destructive, but results in a rational and functionally conservative demolition (avoiding unnecessary violation of the contra-lateral hemi-tongue compartment) with improved reconstructive and oncologic outcomes.

The criteria for this surgical approach are anatomically based, conservative and allow rational pre-operative treatment planning. Imaging with MRI provides multiple advantages compared to other imaging modalities: identification of individual muscle involvement providing valuable information for the design of the demolition

and reconstruction, as well as a close and direct correlation with histological tumour thickness [17]. Good access to the primary lesion allows adequate three-dimensional compartmental resection of the tongue tumour. Division of the muscles, at their insertion on the genial tubercle, is the rationale of an anatomical resection of the tumour; median or paramedian mandibulotomy with a lower lip splitting incision is an excellent surgical approach that allows the best access to all areas of the oral cavity and oropharynx. We have not encountered any detrimental effects on appearance and function, from the lip-splitting incision and the mandibulotomy approach, in agreement with several reports in the literature [19-21]. The osteotomy should always be prepared to create a mandibular cleavage analogous to a favourable fracture. This design, as well as the loss of muscular attachments to the hemi-mandible, on the ipsi-lateral side of the disease, and adequate rigid fixation, offers the best conditions for post-operative bone healing. A median mandibulotomy approach reduces the risk of mental nerve injury that can be associated with a paramedian approach (between the canine and the premolars), and places the area of osteosynthesis at the extreme boundary of the post-operative irradiation field.

One of the main disadvantages of this technique would appear to be the residual functional and anatomical defect. We have not found any detrimental effects of this technique as far as concerns aesthetic and functional aspects. The observation that muscle looses function, even if only partially cut, implies that complete removal of the extrinsic muscles from their bony insertions does not increase the functional defect any more than partial removal of the muscle involved. This new surgical approach is maximally conservative since it maintains intact a functional contra-lateral hemi-tongue compartment. Rather than hindering, the loss of an entire functional anatomical unit leads the surgeon to approach the reconstruction as an effort to recreate a functional volume, improving the residual tongue function and not simply filling a void. The greatest advantage, however, remains oncologic: removal of the disease, as a compartmental unit (primary, stroma, and muscular tissues that would remain after conventional surgery), allows removal of a potential microscopic bed for local recurrence and spread of the disease to the deeper and less accessible planes.

## Conclusions

The advantages of this technique are three-fold: 1) Complete removal of an involved muscle compartment, even if only partially affected by the tumour, allows elimination of a potential loco-regional site of micro-metastatic spread, despite its lack of function (complete or partial); 2) This approach represents a paradigm shift from circumferential to longitudinal resection that enables the surgeon to perform a radical oncological resection while at the same time eliminating non-selective demolition achieved using the principle of wide margin resection, particularly in the early stage of the disease; 3) With adequate pre-operative imaging, it is possible to know in advance the extent of the anatomical and functional defect and plan the appropriate reconstruction in order to maximize function and quality of life outcomes.

The potential impact of this technique on the oncologic outcomes of the surgical treatment of tongue tumours is remarkable. Oncologic results will be presented in a forthcoming report.

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