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ORIGINAL ARTICLE

Vastus lateralis myofascial free flap for tongue reconstruction and hypoglossal-femoral anastomosis: neurophysiological study

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Abstract

Background Total or nearly glossectomy with laryngeal preservation may lead to development of dysfunction speech, chewing, and swallowing with orally disabled. Pellini et al. analyze the feasibility of vastus lateralis myofascial free flap (VLMFF) in tongue reconstruction and demonstrated that this treatment offers a better cosmetic result in tongue reconstruction, an adequate bulk when needed, a mass reduction of neo-tongue after 30 days post-surgery of 20–30%, an optimal functional results, and an obliteration of dead space and with thus preventing fistulas and infections with minimal morbidity. The aim of our study was to evaluate the innervation of tongue reconstruction performed with nerve anastomosis between the unilateral hypoglossal nerve and branch for vastus lateralis muscle of femoral nerve with neurophysiological study.

Results We performed a neurophysiological evaluation of four patients who underwent surgery and observed a reinnervation of tongue flap by the anastomosis hypoglossal-femoral nerve for the reconstruction of neo-tongue with vastus lateralis myofascial free flap. The reconstruction of neo-tongue with vastus lateralis myofascial free flap may be represent a valid surgery for patients with cancer tongue.

Keywords Tongue · Reconstruction · Neurophysiological study · Cancer

Introduction

Cancer of the tongue is the most common malignant tumor in the oral cavity. Smoking and alcohol consumption, especially in combination, are the major risk factors [1].

The tongue is composed of two muscle groups: (1) four intrinsic muscles that alter the shape of the tongue and are not attached to any bones and (2) four paired extrinsic muscles that change the position of the tongue in the mouth and are anchored to the mandible and hyoid bone. All of the muscles are supplied by efferent motor nerve fibers from the hypoglossal nerve.

The tongue is involved in numerous functions, including speech, swallowing, and airway protection. The aim of advanced tongue cancer treatment is to eradicate the neoplasm while maintaining the best possible function [2].

Total or near total glossectomy with laryngeal preservation unavoidably leads to development of dysfunction in speech, chewing, and swallowing [3]. The volume of the native residual tongue after resection strongly influences the entity of functional impairment. Moreover, chewing and swallowing disorders are reduced if one or both hypoglossal nerves are preserved during resection [4]. The reconstructive options for the extended lingual defect include local and pedicled locoregional flaps or distant free flaps. The free flaps are the more widely used reconstructive options in oral cavity defects because they are considered to be more favorable in terms of functional and esthetic results. Previous studies have shown that sensory reinnervation of free flaps in tongue reconstruction may have some functional advantages [5].

Pellini et al. [6] analyzed the feasibility of the free vastus lateralis myofascial free flap (VLMFF) with neuroanastomosis in tongue reconstruction and proved that this treatment offers satisfactory cosmetic and functional results with minimal donor site morbidity.

The aim of the present neurophysiological study was to evaluate the reinnervation of the VLMFF after surgical

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anastomosis between the hypoglossal nerve and the branch for the femoral nerve's vastus lateralis muscle.

Materials and methods

From July 2015 to September 2016, we conducted a pilot study on four patients who underwent tongue resection for squamous cell carcinoma. The local Institutional Review Board approved the study, and each patient provided a valid informed consent before enrollment.

Four patients with a median age of 62 years (range 50–70) were enrolled. Three had partial glossectomies, and one had a hemiglossectomy.

All patients had mono/bilateral neck dissection, temporary tracheostomy, and nasogastric feeding tube placement (Table 1). The portion of removed tongue was reconstructed using VLMFF (Fig. 1). The vascular pedicle of the vastus lateralis muscle is the descending branch of the lateral circumflex femoral artery (DBLCFA) and veins. The flap was transferred from the thigh to the oral cavity (Fig. 2) and the vessels (artery and veins) were anastomized to the vessels of the neck in order to obtain perfusion of the flap. The vastus lateralis motor nerve was harvested en bloc with the vascular pedicle and anastomized end-to-end to the hypoglossal nerve and, thus, was unavoidably transected during glossectomy. The neurorrhaphy was performed via placement of three simple interrupted sutures (9–0 monofilament nylon) through the epineurium of the neural stumps under loop magnification.

The VLMFF was harvested in the necessary volume to reconstruct the removed portion of tongue.

The volume of VLMFF after insertion was evaluated by magnetic resonance imaging (MRI) during the immediate post-operative period (T0), 6 months later (T1), and 1 year after surgery (T2).

Speech, swallowing, and donor site morbidity were evaluated 3 months after surgery and rehabilitation.

Swallowing was evaluated using the Functional Oral Intake Scale (FOIS) [7] by interviewing patients during their follow-up periods. Electromyographic (EMG) and anastomosis nerve conduction studies of the muscle flap was performed in all patients at T0, 1, and 2 (3, 7, and 12 months after surgery, respectively).

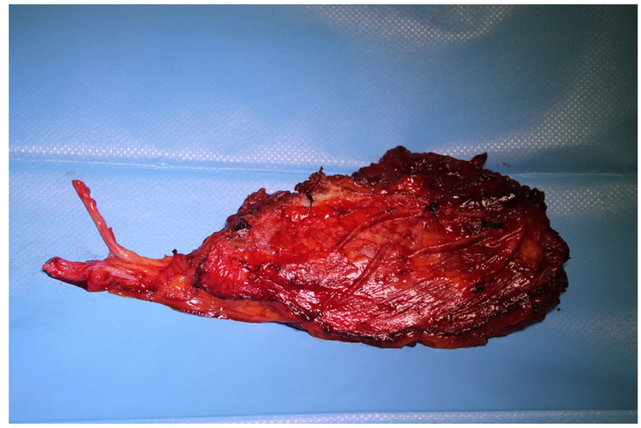

Fig. 1 Flap after harvesting before the insetting into the oral cavity. Note the vascular and distinct neurological pedicle

A T0 examination was done not before 3 months post-surgery because of local healing in progress. We utilized single used concentric needle electrodes of 1.2″ × 28 G (30 × 0.35 mm) inserted to 1 to 2 cm deep with 90 grades of perpendicular inclination in neo-tongue and in residual native tongues in patients who underwent partial glossectomy.

The nerve stimulator was a barred bipolar probe with 2-cm distance between anode and cathode applied on the submandibular corner corresponding arch of hypoglossal nerve both on the anastomosis and opposite sides.

The EMG signals were detected with software in an electromyographer set using two parameters:

1) EMG recordings: 10-Hz lower filter; 3-kHz high filter; sweep speed: 2 ms/division; sensitivity: 100 μV/division for spontaneous motor activity and from 500 μV to 2 mV to effort motor activity and
2) Nerve conduction and stimulation: 3-Hz lower filter; 10-kHz high filter; sweep speed: 3 ms/division; sensitivity: from 200 μV until 1 mV/division; stimulus: constant square wave impulses at 0 to 300 V for 0.5 ms of duration, stopping when the largest muscle action potential amplitude was evoked.

For each patient, the EMG signals in the flap and in residual tongue, if present, were analyzed subjectively and qualitatively by observing the fleeting visual and auditory signals

Table 1 Clinical data

Case	Sex/age	pTNM	Surgery	Complications	Decannulation/NGFT removal	Adjuvant therapy
P1	F/70	ypT2N0M0	Subtotal glossectomy + bilateral ND (I–IV)	None	5/13 days	No
P2	M/59	pT4N2cM0	Subtotal glossectomy + bilateral ND (I–V; I–IV)	None	8/16 days	Chemorad
P3	F/69	pT2N0M0	Hemiglossectomy + ipsilateral ND (I–III)	None	4/9 days	No
P4	M/50	pT3N2cM0	Subtotal glossectomy + bilateral ND (I–V; I–IV)	None	9/15	Chemorad

Fig. 2 The oral cavity after flap insetting

produced during three different activities: (1) at rest, as fibrillations, positive sharp waves (Jasper potentials), and fasciculations; (2) by single voluntary maximum contraction of the neo-tongue; and (3) tongue against strength of examiner's finger for 2 s after reaching a recognizable constant discharge waveform.

The recorded EMG patterns at maximal voluntary activation were classified in a score of six grades: (1) interference pattern: all motor units are recruited; (2) sub-interference pattern: recruitment from 70–90% of motor units; (3) lower pattern: recruitment from 50 to 70% motor units; (4) weak pattern: recruitment from 20 to 40% of motor units; (5) single potentials pattern: recruitment of 10% of single motor units; and (6) absence pattern: no motor activity. They successively underwent anastomosis neurophysiological studies by nerve stimulation and latency registrations (compound motor action potential (CMAP)), considering the normal latency of hypoglossal nerve conduction ranging from 1.3 to 3.2 ms.

Results

No complication were recorded in post-operative period. Tracheostomy and nasogastric feeding tube were removed on post-operative days 4–9 and 12–16, respectively.

Two patients had post-operative chemo-radiotherapy, and one out of four had surgery because of recurrence after radiotherapy.

Upon clinical examinations during follow-up, all patients reported a progressive subjective improvement of speech and swallowing and, within 3 months, recovered easily understood speech. In the analysis of swallowing function 3 months after surgery, all except one patient had a score > 4, indicating that they could at least consume a soft diet without any kind of dependence on a nasogastric feeding tube.

The mean flap volume at T0 was 36.23 cm^3 (range 31.11–41.35 cm^3). The overall mean flap volume at the second measurement (T1) was 30.67 cm^3 (range 24.71–36.63 cm^3). The overall mean flap volume at the T2 measurement was 28.72 cm^3 (range 23.41–34.03 cm^3). A mean flap volume loss of 20.72% was demonstrated between the T0 and T2 measurements. Thirty days after surgery, none of the patients reported any limitations in daily physical activity related to donor site defects that were only limited to the skin scars without significant loss of leg force.

Neurophysiological study

EMG/nerve conduction evaluation at T0 showed:

Patient 1 (P1) Fibrillations and positive sharp waves at rest; weak pattern of maximum effort motor voluntary activity in the neo-tongue at 0.8 to 1 mV; latency of CMAP of

Table 2 Neurophysiological evaluation

Patients and time	T0 F/Jp. (free flap)	T0 V.A. pattern (free flap)	T0 CMAP L. anastomosis)	T0 F/Jp (emi-tongue)	T0 V.A. pattern (hypoglossal nerve)	T0 CMAP L. (hypoglossal nerve)
P1 T0	+/+	Weak (0.8–1 mV)	3.5/80 ms/mm	–	–	0
P2 T0	+/0	Weak (0.3–0.5 mV)	5.3/90	–	–	0
P3 T0	+/+	Weak (0.5 mV)	0	–	–	0
P4 T0	0/0	Weak (0.3–0.5 mV)	0	+/0	Sub-interference (1.5 mV)	3.2/80 ms/mm
P1 T1	0/0	Sub-interference (1 mV)	3.5/80 ms/mm	–	–	0
P2 T1	0/0	Lowered (1 mV)	4.3/100 ms/mm	–	–	0
P3 T1	+/+	Sub-interference (0.5–1 mV)	7.1/120 ms/mm	–	–	0
P4 T1	0/0	Lowered (0.5 mV)	6/100 ms/mm	0/0	Sub-interference (1–1.5 mV)	3/90 ms/mm
P1 T2	0/0	Interference (2 mV)	2/80 ms/mm	–	–	0
P2 T2	Not performed	Not performed	Not performed	Not performed	Not performed	Not performed
P3 T2	Not performed	Not performed	Not performed	Not performed	Not performed	Not performed
P4 T2	0/0	Lowered (0.5 mV)	4.6/100 ms/mm	0/0	Interference (1.5 mV)	3.4/100 ms/mm

F, fibrillation; *Jp*, jasper potentials; *V.A. pattern*, voluntary activity pattern; *CMAP L.*, CMAP latency

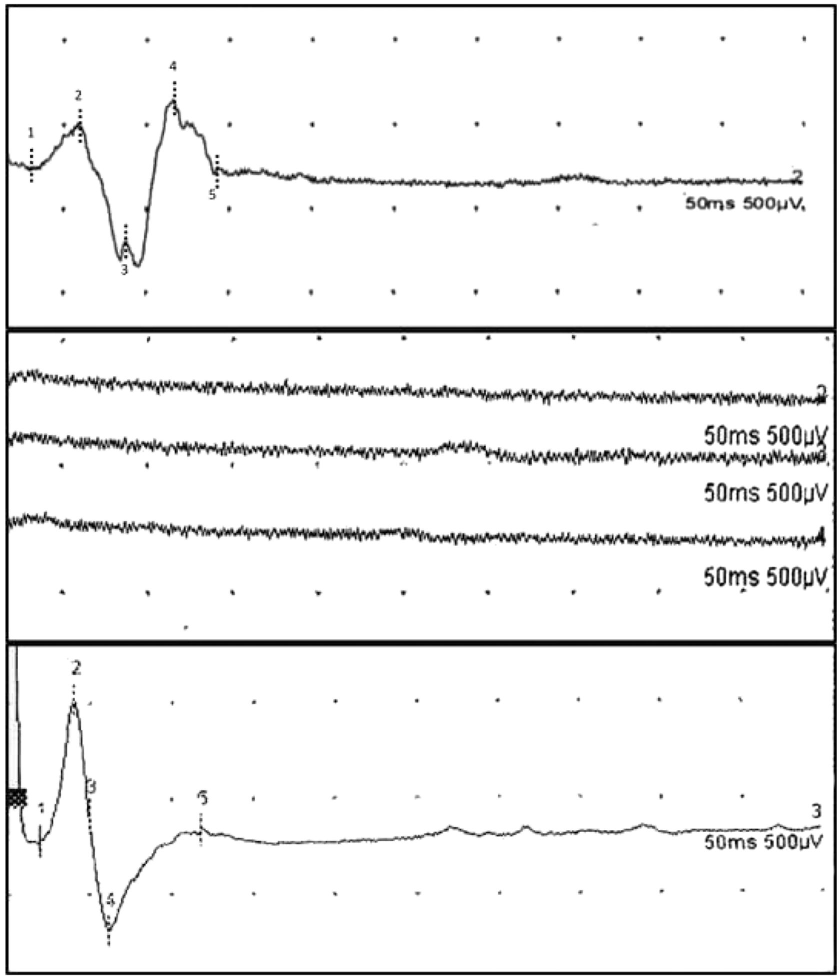

Fig. 3 CMAP of hypoglossal-femoral anastomosis at TO versus T1 time and contralateral cut hypoglossal nerve

hypoglossal-femoral anastomosis was 3.5 ms/80 mm; and absence of CMAP by stimulation of the cut hypoglossal nerve on the contralateral side.

Patient 2 (P2) Fibrillations at rest; weak pattern of maximum effort motor voluntary activity in the neo-tongue at 0.3–0.5-mV average amplitude; CMAP latency by stimulation of hypoglossal-femoral anastomosis was 5.3 ms/90 mm; and absence of CMAP by stimulation of the cut hypoglossal nerve on the contralateral site.

Patient 3 (P3) Fibrillations and positive sharp waves at rest; weak pattern of maximum effort motor voluntary activity in the neo-tongue 0.5-mV average amplitude; and absence of CMAP by stimulation of the anastomosis hypoglossal-femoral and by stimulation of the cut hypoglossal nerve on the contralateral site.

Patient 4 (P4) No fibrillations and positive sharp waves at rest; weak pattern of maximum effort motor voluntary activity in the neo-tongue 0.3–0.5-mV average amplitude; absence of CMAP by stimulation of the anastomosis hypoglossal-femoral; fibrillations at rest; and sub-interference pattern at 1.5-mV average amplitude of maximum effort motor voluntary activity on the partial tongue on the left with 3.2 ms/80 mm of CMAP latency.

At T1

P1 No fibrillations and positive sharp waves at rest and sub-interference pattern at 1-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue. Latency of CMAP by stimulation of hypoglossal-femoral anastomosis was 3.5 ms/80 mm.

P2 No fibrillations and positively sharp waves at rest; lower pattern at 1-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue. Latency of CMAP by stimulation of hypoglossal-femoral anastomosis is 4.3 ms/100 mm.

P3 Fibrillations and positive sharp waves at rest; sub-interference pattern at 0.5–1-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue.

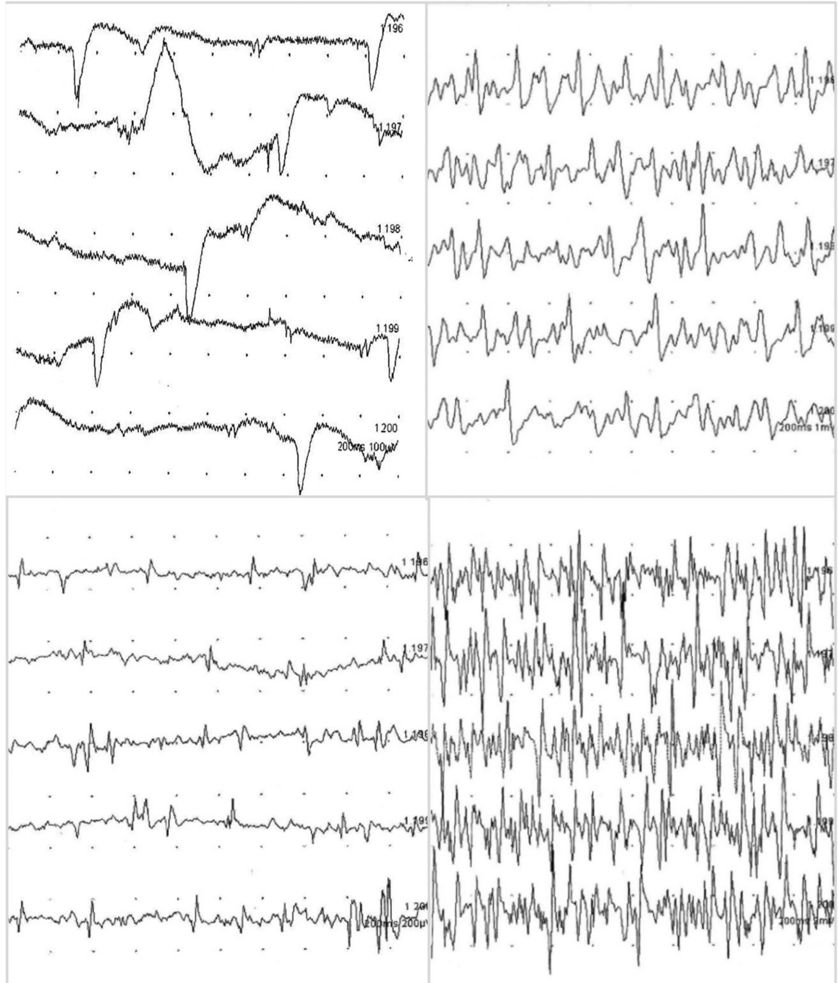

Fig. 4 Fibrillations and positive sharp waves of neo-tongue at rest at T0 versus T1 time and pattern of maximum effort under voluntary of neo-tongue at T0 versus T1 time

Latency of CMAP by stimulation of hypoglossal-femoral anastomosis was 7.1 ms/120 mm.

P4 No fibrillations and positive sharp waves at rest; lower pattern at 0.5-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue. Latency of CMAP by stimulation of hypoglossal-femoral anastomosis is 6 ms/100 mm; absence of fibrillations and positive sharp waves at rest and sub-interference pattern at 1–1.5-mV average amplitude of maximum effort motor voluntary activity on the partial tongue on the contralateral site with 3 ms/90 mm of CMAP latency.

At T2

P1 No fibrillations/positive sharp waves at rest and interference pattern at 2-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue. Latency of CMAP by stimulation of hypoglossal-femoral anastomosis was 2 ms/80 mm. Absence of CMAP for stimulation on the left side.

P2 Not performed because the patient refused.

P3 Not performed because the patient died.

P4 Absence of fibrillations and Jasper waves at rest and lower pattern at 0.5-mV average amplitude of maximum effort motor voluntary activity on the neo-tongue. Latency of CMAP by stimulation of hypoglossal-femoral anastomosis was 4.6 ms/100 mm; no fibrillations and positive sharp waves at rest and interference pattern at 1.5-mV average amplitude of maximum effort motor voluntary activity on the partial tongue on the left with 3.4 ms/100 mm of CMAP of hypoglossal conduction (Table 2).

Discussion

In the literature, previous experience describing the sensory recovery of the flaps used for tongue reconstruction have been described. Flaps as radial forearm and anterolateral thigh flaps showed superior recovery of the senses, including light touch, pain sensations, and temperature discrimination, compared to other flaps used for the reconstruction of tongue defects. However, evidence for beneficial effects on function is poor [8–11], and none of these studies has the motor activity been explored.

The tongue is a crucial organ for propulsion of the bolus from the oral cavity to the pharynx and plays a central role in speech articulation. Tongue reconstruction after oncological surgery is mainly based on fasciocutaneous flaps, and rarely are muscle flaps used.

In the present series, we used a muscle flap with motor reinnervation through nerve anastomosis with the hypoglossal nerve [12].

Tongue movement during speech and swallowing is characterized by fine coordination of each single muscle movement with the others that surround the tongue itself. The nerve fibers that furnish any single muscle of the tongue do not run separately in single nerves but run all together in the hypoglossal nerve.

In this scenario, it seems quite impossible that a single muscle (vastus lateralis) instead of the eight that compound the tongue could recreate some kind of coordinated movement useful to functional recovery that would be directly related to the remaining surrounding tissue. The motor reinnervation of the muscular flap used for tongue reconstruction has the main goal of maintaining the volume of the flap as much as possible because volume maintenance seems to be related to functional recovery [8–18]. A second aim of the reinnervation is to reduce the distance between the hyoid bone and mandible with voluntary contraction of the muscle in order to improve deglutition.

In this study, we mainly evaluated the neurophysiological characteristics of reinnervation of the revascularized-reinnervated neuro-fascio-muscular flap employed in tongue reconstruction.

It was observed that all patients presented some form of reinnervation of the flap trough of the hypoglossal-femoral anastomosis, and we noticed a small flap volume loss (mean 20.72%) between the T0 and T2 measurements. Therefore, in these patients, such an overcorrection should be appropriate to compensate for the flap shrinkage due to partial atrophy.

Electrophysiological characteristics of the growing tips of axon include very slow conduction velocities and very high thresholds to electrical stimulation and continuous conduction. Maturation of regeneration nerve fibers is associated with a progressive increase in conduction velocities, progressive declines in thresholds to electrical stimulation, and return to salutatory conduction. Characteristics of early motor unit activity potentials (MUAPS) include low amplitudes, long duration, hyper-complex features, unstable axonal and neuromuscular transmission, and prolongated latencies. Progressive maturation of MUAPS is associated with increases in the numbers of MUAPS that can be detected, increased amplitudes of shorter durations, more stable axonal and neuromuscular transmission, and shorter latencies [19].

In this study, we observed that all patients presented reinnervation of the neo-tongue with the classic neurophysiological patterns found in denerved and reinnerved muscle. At the T0 time, the majority of patients have a positive denervation potential with a weak pattern of maximum efforts as appeared in nerve injury. The characteristic pattern of reinnervation improved during follow-up (Figs 3 and 4). Also, the function of the anastomosis was confirmed by the presence of CMAP and the improvement of its latency during the follow-up period.

This surgical approach represents a valid reconstructive option considering the functional results (swallowing, speech) and the reinnervation of tongue as demonstrated by neurophysiological studies. This approach seems to play a central role in avoiding the atrophy of the muscle flap related to denervation.

This study presented the limitation of a small sample size. Studies on larger populations are necessary to confirm our data.

Authors' contributions Edvina Galié and Raoul Pellini study concepts and design, draft/revise the manuscript, analyze or interpret the data, accept responsibility for conduct of research and final approval, and acquire the data. Ferreli and Villani acquire the data, revise the manuscript, and accept responsibility for conduct of research and final approval. A Pace analyzes or interprets the data and accepts responsibility for conduct of research and final approval.

Compliance with ethical standards

The local Institutional Review Board approved the study, and each patient provided a valid informed consent before enrollment.

Conflict of interest The authors declare that they have no conflict of interest.

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