FUNCTIONAL OUTCOMES IN SUPRACRICOID LARYNGECTOMY

Vittorio D’Aguanno1, Massimo Ralli1*, Marco Fiore2, Mauro Ceccanti3, Cinzia Severini2, Flavia Flaccadoro1, Lucia Longo1, Antonio Greco1, and Marco de Vincentiis4

1Department of Sense Organs, Sapienza University of Rome, Italy
2Institute of Cell Biology and Neurobiology, IBCN-CNR, Rome, Italy
3Centro Alcologico della Regione Lazio, Rome, Italy
4Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, Italy

Supracricoid laryngectomies (SCLs) are conservative surgical techniques for the treatment of selected laryngeal carcinomas and are considered an organ-sparing alternative to total laryngectomy and chemo-radiotherapy. The main characteristics of SCLs are the preservation of the main laryngeal functions as respiration, phonation and swallowing, without a permanent tracheostomy. Supracricoid laryngectomies have been questioned for many years as regarding functional and oncological outcomes and are currently accepted, although patient selection criteria and functional results are still debated. The mainstream of this surgery is the maintenance of one functioning cricoarytenoid unit to allow restoring of swallowing and phonation. Thus, post-operative rehabilitation protocol is required to archive functional outcomes and avoid functional failure of this surgery; an early rehabilitation protocol improves functional results, in particular regarding swallowing. Swallowing and voice functional outcomes differ among several centres and are often related to the post-operative management, although SCLs provide commonly good swallowing and respiratory outcomes. To date, SCLs are proven surgical procedures for the treatment of laryngeal cancer and should be a valuable option to total laryngectomy and chemo-radiotherapy for selected advanced laryngeal squamous cell carcinoma. In this clinical review, we discuss the clinical outcomes in patients treated with SCLs with particular attention to rehabilitation protocol and functional outcomes for swallowing and voice rehabilitation.

Biomed Rev 2018; 29: 65-71

Keywords: laryngeal squamous cell cancer, supracricoid laryngectomy, functional results, swallowing
Abbreviations used
CHT – chemotherapy
ELS – European Laryngological Society
FEES – fiberoptic endoscopic evaluation of swallowing
LSCC – laryngeal squamous cell carcinoma
MPT – maximum phonation time
NGT – nasogastric-tube
OPHL – open partial horizontal laryngectomies
OTT – oral transit time
PTT – pharyngeal transit time
RT – radiotherapy
RTOG – radiation therapy oncology group
SCLs – supracricoid laryngectomies
TL – total laryngectomy

INTRODUCTION
Laryngeal squamous cell carcinoma (LSCC) accounts for approximately 2% to 5% of all diagnosed cancers, with a peak incidence in men between the ages of 55 and 65 (1; also see Grasso et al in this volume of Biomedical Reviews). The therapeutic strategies developed in the twentieth century have significantly improved the overall survival of patients presenting this cancer; however, post-operatory laryngeal dysfunction and a poor prognosis still characterize this pathology in advanced stages (2-4). The proposed treatments include surgery alone or in combination with chemotherapy (CHT) and radiotherapy (RT) according to cancer location and stage at diagnosis. Initial stages (I and II) are treated with unimodal treatment which may include surgery and RT, while in advanced ones (III and IV) CHT and radical surgery are considered the best therapeutic approach (5-9).

Supracricoid laryngectomies (SCLs) are a valuable option as an alternative to total laryngectomy (TL) in patient with LSCC, since SCLs are considered an organ-sparing surgical treatment for selected LSCC in the T2–T4 staging. Surgical protocols of organ preservation with SCLs have been questioned for many years, regarding patient selection criteria and functional outcomes (10-13).

In this clinical review, we discuss the clinical outcomes in patients treated with SCLs with particular attention to rehabilitation protocol and functional outcomes for swallowing and voice rehabilitation.

Surgical procedure
SCLs are included by the ELS in the “open partial horizontal laryngectomies” system defined as “OPHL Type II”. This surgical technique requires resection of the entire thyroid cartilage, while the inferior limit is the upper edge of the cricoid ring. The differences between the various subtypes of OPHL Type II are related to the amount of supraglottis removed and their extension to one arytenoid.

OPHL Type II surgical techniques are divided into type Ia and Type Iib. OPHL Type Ia, previously defined as “supracricoid laryngectomy with crico-hyoido-epiglottopexy”, requires a horizontal incision of the thyro-hyoid membrane superiorly, then the pre-epiglottic space and epiglottic cartilage are transected so that the suprahyoid part of the epiglottis is spared. The inferior constrictor muscles are incised bilaterally, the piriform sinuses are dissected, the inferior horns of thyroid cartilage are cut, and the ventricular and vocal folds are divided down to the lower limit of resection in the subglottic region. Larynx reconstruction is achieved by crico-hyoido-epiglottopexy. OPHL Type Ia can be extended to one arytenoid. OPHL Type Iib, previously defined as “supracricoid laryngectomy with crico-hyoidopexy”, requires the resection of the thyro-hyoid membrane horizontally along the lower border of the hyoid bone. The posterior aspect of the hyoid is dissected, and the valleculae and the entire epiglottis are included in the surgical specimen. Laterally and inferiorly the procedure is carried out as in OPHL Type Ia. The entire supraglottis and the pre-epiglottic space are removed. Larynx reconstruction is achieved by crico-hyoidopexy. Similarly, to Type Ia, OPHL Type Iib can be extended to include one arytenoid in the surgical resection.

Rehabilitation protocol
In patients treated with SCLs, a rehabilitation protocol is essential to allow functional restoring of the “neo-larynx”. The rehabilitation protocol is structured in three different phases. In the first, starting from the second postoperative day, costodiaphragmatic breathing and pneumophonic coordination exercises are performed with strengthening exercises of preserved structures. The second phase takes place from the second to fourth postoperative day, and includes pneumophonic coordination exercises, head and neck mobilization, and protective reflex activity enhancement; moreover, exercises of swallow function in compensating posture are performed. In the third phase, occurring from the eighth postoperative day, patients start swallowing tests with semisolid foods.

Where practicable, tracheostomy tube should be removed between the second and the fourth post-operative day. The tracheostomy can be closed when the patient is able to tolerate
it without experiencing dyspnea. The nasogastric-tube (NGT) can be removed once the function of swallowing solids and semi-solids without pulmonary aspiration was regained.

**Functional endpoints**

The main functional endpoints after SCLs include the swallowing recovery, evaluated by the removal time of the NGT, and the respiratory recovery, assessed by the percentage of patients that achieve tracheostomy decannulation. Evaluation of functional results may require in some patients an endoscopic control via fiberoptic endoscopic evaluation of swallowing (FEES) and videofluoroscopic swallowing exam, estimating oral transit time (OTT) and pharyngeal transit time (PTT). The swallowing functional outcome is evaluated by clinical or instrumental assessments. The most common clinical assessment reported are the presence and severity of tracheal oedema with a poorly functioning larynx could be a possible reason for negative functional outcomes in organ-preservation therapy (19, 20). Moreover, mortality rates for LSCC in the 1990s and in the 1980s in United Stated showed decreased survival rate; this result has been attributed to an increase in patients treated with RT/CHT (21).

In several countries of Southern Europe, SCLs have been considered an important alternative to TL and RT/CHT for LSCC and have been performed for many years since the first sub-total laryngectomy proposed by Labayle (22) in 1972 (OPHL Type IIb). SCLs were not habitually performed in several Northern European countries as well as in the United States, where conservatory RT/CHT treatments have been preferred for many years. The explanation of this different behavior lies on the post-operative management of SCLs that requires a longer hospitalization time and the different functional results among centers (23). In the recent years, SCLs have gained an increasing agreement around the world including the United States.

In our clinical practice SCLs have been performed for numerous decades and the best results from an oncologic and functional point of view have been obtained with SCL according to Labayle and Bismuth (OPHL Type IIb) (24) and SCL according to Majer-Piquet (OPHL Type Ila) (25). As confirmed by various studies, the reconstructive techniques of “OPHL Type Ila” and “OPHL Type IIb” are valid in such a way as to...
equal the TL in terms of survival and oncological radicality (11, 26, 27). Moreover, the effectiveness of SCLs has been evaluated in residual or recurrent cancer after radiotherapy (28-32).

Surgical preoperative selection is critical in the achievement of a successful therapeutic outcome in terms of functional and oncological results. Thus, surgical feasibility is not the most important factor in determining whether SCL is the best treatment for an individual patient. Furthermore, the choice between SCL and TL must be balanced, considering both technical and nontechnical aspects of treatment such as patient preferences and mental status. In fact, even when the extension of the cancer would allow a SCL, many LSCC patients are treated with TL for individual characteristics (26); moreover, SCLs can be intraoperatively converted into a OPHL type III (Supratracheal laryngectomy) or a TL by the surgeon in order to assure a complete excision of the tumor.

For the early stage of the disease, the extensive use of SCLs should be reconsidered as there are valid and proven less-invasive surgical and non-surgical alternatives with good functional results. In these cases, the use of SCL is only justifiable for cases at risk such as T1b glottic tumors with significant involvement of the anterior commissure and/or with difficulties in exposition in direct microlaryngoscopy and/or with suspect involvement of the prelaryngeal lymph nodes, T2 glottic tumors that involve the paraglottic space superiorly and/or inferiorly and that tend to behave biologically as authentic T3 cancers (33).

Given the reported clinical and functional outcomes, SCLs can be considered as extremely competitive not only in prognostic terms but also in terms of functional results such as a reduction in the number of TL, especially for intermediate stages and some advanced stages (T3 and selected T4a) (13).

The theoretical advantage of SCLs versus TL is the maintenance of the main laryngeal functions (respiration, phonation and swallowing) since at least one functioning cricoarytenoid unit is maintained facilitating neoglottic competence without a permanent tracheotomy (11, 26). Regarding functional results, a debate is open as concerning the recovery of swallowing, that depends on multiple factors. In fact, a compensatory mechanism with the reorganization of the stepwise sequence of neuromuscular events is necessary to restore swallowing and may require several months (34). Moreover, sphincteric approximation of the mobile arytenoid cartilage and base of tongue (in the case of OPHL Type IIb), or epiglottis (in the case if OPHL Type IIa) provides mucosal source of vibration, allowing for voice production (7).

Post-operative laryngeal oedema prevents arytenoid adduction, resulting in a reduction in laryngeal motility. Oedema reduction allows arytenoid motility recovery and greater effectiveness of neo-glottis closure mechanism. Speech therapy rehabilitation allows a progressive recovery of phonation and swallowing, improving neoglottic closure, due to the posterior motion of the tongue base (if a OPHL Type IIb has been performed) or the epiglottis (if a OPHL Type IIa has been performed) and the forward and inward rotation movement of one or both remaining arytenoids (34). Thus, a defective glottic closure still represents, in patients treated with SCLs, one of the most relevant causes of swallowing impairment.

Several factors may cause a delay in the restoring of swallowing. Woisard et al studied the pharyngeal phase of swallowing in patients treated with OPHL Type IIa, and showed defects consisting of a reduced movement of the back of the tongue, faulty backward tilting of the epiglottis, reduced anterior laryngeal movement and reduced laryngeal elevation (34). In patient treated with a OPHL Type IIb, a reduced movement of the back of the tongue may be also present with a reduced posterior motion of the tongue base, a reduced anterior laryngeal movement and a reduced laryngeal elevation (34).

For the above-mentioned conditions, a post-operative rehabilitation protocol is essential to archive satisfactory functional outcomes and should be started early to avoid stiffness of the arytenoid (35). Early mobilization avoids the onset of scarring fibrosis of the crico-arytenoid joint which is associated with the functional failure of the intervention, requiring a TL due to functional incompetence of the neoglottis. The purpose of the rehabilitation protocol is the enhancement of protective reflexes through voluntary cough exercises with forced expiration, setting the patient in the most appropriate and facilitating compensatory posture, and introducing the patient to supraglottic swallowing maneuver.

Compared to a few years ago, rehabilitation techniques recommend early decannulation to improve the sensitivity of the new glottis during air flow and laryngeal vibratory arrangement. In fact, the presence of the tracheostomy tube may protect against airway aspirations but also limits the motility of neolarynx and reduces its sensitivity. Moreover, a long permanence of tracheostomy tube is a risk factor for the formation of tracheo-cutaneous fistulas requiring local closure surgery in nearly 30% of cases. In these cases, the closure may be problematic for increased subglottic pressure during expiration and during cough related to chronic aspiration (36).

Among post-operative complications, laryngotracheal stenosis impacts negatively on postoperative period, requiring a
tracheostomy for a longer period and exposing the patient to infections and mucosal damage. The use of a Montgomery T-tube is a valid strategy in the management of these patients (37) often associated with transoral laser surgery/treatment. Specifically, this treatment strategy allows the ability to function either by tracheostomy or by stent cannula, with the possibility to close the outer branch in order to breath and have a natural phonation. The main disadvantages are tracheostomy maintenance and potential biofilm colonization.

Chronic aspiration after SCLs is a very controversial phenomenon and may be a cause of failure of this surgery. In a study from Simonelli et al., a sample of 164 SCLs patients were evaluated for chronic aspiration (38). The degree of postoperative aspiration was evaluated according to Leipzing’s (39) and Pearson’s (4) scales. A significant percentage (17.2%) of patients referred constant cough, worsening during meals. Studies through FEES showed that 68% of patients (79 out of 116) had various swallowing alterations and different degrees of aspiration without developing aspiration pneumonia. Therefore, some dysphagic patients may be able to tolerate certain aspiration degree without developing pneumonia suggesting that the action of the ciliary movement, the strength of the cough reflection and patient conditions may play a significative role.

A recent review by Schindler (15) regarding functional results of SCLs reported a great variability in the mean hospitalization time, feeding-tube removal time and tracheotomy tube decannulation time among differ studies (11, 40, 41). The mean length of hospital stay varied from a minimum of 5 days (42) to a maximum of 104 days (41). Mean feeding-tube removal time showed similar variability, ranging between 10 (34) and 88 days (43). Great heterogeneity was found in mean decannulation times, varying between 8 days (40) and 105 days (42). On the contrary, little variability was found in decannulation rates, which ranged between 85.7 and 100% (11, 41, 43, 44) confirming good respiratory outcomes following SCLs.

Concerning phonation recovery, correct and timely logopedic therapy is necessary. Reconstructive surgery dramatically changes the anatomy of the larynx and the phonation mechanism. Phonation function recovery is almost equivalent in both surgical techniques; slightly better voice quality is achieved in OPHL Type IIa. SCLs voice is characterized by moderate to severe alterations in roughness and grade, slight to moderate alterations in breathiness, slight or practically absent alterations in asthenia and slight or moderate alterations in strain (15). Assessing voice in SCLs patients with MPT appears to be the most widely used aerodynamic parameter. Moreover, most authors reported similar data of a highly reduced MPT, with values ranging between 8 (11) and 11 seconds (44).

CONCLUSIONS

Supracricoid laryngectomies allow the maintaining of the main laryngeal functions (respiration, phonation and swallowing) since at least one functioning cricoarytenoid unit is maintained, without a permanent tracheotomy. These surgical techniques have been demonstrated to be proven procedures for the treatment of selected laryngeal cancers and should be considered as a valuable option to TL and CHT/RT for selected patients. Post-operative rehabilitation is essential to achieve for functional outcomes and should be started early so as not to create stiffness of the arytenoid and avoiding the onset of fibrosis of the crico-arienoid joint which is associated with the functional failure. Voice and swallowing functional results following SCLs are often satisfactory, although these results may significantly vary among different centers.

To date, there is the need to have a consensus and clinical recommendations on early post-surgical management, on voice and swallowing assessment protocols and on recommended timing for rehabilitation.

ACKNOWLEDGEMENTS

We apologize to the authors of many relevant articles that were not quoted here for reasons of brevity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Curado MP EB, Shin HR. Age-standardized and cumulative incidence rates. Cancer incidence in five continents. Lyon, France. IARC Scientific Publication. 2007. pp 498–501.
2. Chen AY, Schrag N, Hao Y, Flanders WD, et al. Changes in treatment of advanced laryngeal cancer 1985-2001. Otolaryngol Head Neck Surg 2006; 135(6): 831-837. DOI: 10.1016/j.otohns.2006.07.012
3. Laccourreye O, Brasnu D, Biacabe B, Hans S, et al. Neoadjuvant chemotherapy and supracricoid partial laryngectomy with cricohyoidopexy for advanced endolaryngeal carcinoma classified as T3-T4: 5-year oncologic results. Head Neck 1998; 20(7): 595-599.
4. Pearson BW. Subtotal laryngectomy. *Laryngoscope* 1981; 91(11): 1904-1912.

5. Department of Veterans Affairs Laryngeal Cancer Study G, Wolf GT, Fisher SG, Hong WK, *et al.* Induction chemotherapy plus radiation compared with surgery plus radiation in patients with advanced laryngeal cancer. *N Engl J Med* 1991; 324(24): 1685-1690. DOI:10.1056/NEJM1991061332424202

6. Abdurehim Y, Hua Z, Yasin Y, Xukurhan A, *et al.* Transoral laser surgery versus radiotherapy: systematic review and meta-analysis for treatment options of T1a glottic cancer. *Head Neck* 2012; 34(1): 23-33. DOI:10.1002/hed.21686

7. Forastiere AA, Goepfert H, Maor M, Pajak TF, *et al.* Concurrent chemotherapy and radiotherapy for organ preservation in advanced laryngeal cancer. *N Engl J Med* 1991; 324(24): 1685-1690. DOI:10.1056/NEJM1991061332424202

8. Bussu F, Paludetti G, Almadori G, De Virgilio A, *et al.* Comparison of total laryngectomy with surgical (cricohyoidopexy) and nonsurgical organ-preservation modalities in advanced laryngeal squamous cell carcinomas: A multicenter retrospective analysis. *Head Neck* 2013; 35(4): 554-561. DOI:10.1002/hed.22994

9. De Virgilio A, Ralli M, Longo L, Mancini P, *et al.* Electrochemotherapy in head and neck cancer: A review of an emerging cancer treatment. *Oncol Lett* 2018; 16(3): 3415-3423. DOI:10.3892/ol.2018.9140

10. Benito J, Holsinger FC, Perez-Martin A, Garcia D, Weinstein GS, Laccourreye O. Aspiration after supracricoid partial laryngectomy: Incidence, risk factors, management, and outcomes. *Head Neck.* 2011; 33(5): 679-685. DOI:10.1002/hed.21521

11. de Vincentiis M, Minni A, Gallo A, Di Nardo A. Supracricoid partial laryngectomies: oncologic and functional results. *Head Neck* 1998; 20(6): 504-509.

12. Laudadio P, Presutti L, Dall’olio D, Cunsolo E, *et al.* Supracricoid laryngectomies: long-term oncological and functional results. *Acta Otolaryngol.* 2006; 126(6): 640-649. DOI:10.1080/00016480500469024

13. Rizzotto G, Crosetti E, Lucioni M, Succo G. Subtotal laryngectomy: outcomes of 469 patients and proposal of a comprehensive and simplified classification of surgical procedures. *Eur Arch Otorhinolaryngol* 2012; 269(6): 1635-1646. 10.1007/s00405-012-1928-4

14. Succo G, Peretti G, Piazza C, Remacle M, *et al.* Open partial horizontal laryngectomies: a proposal for classification by the working committee on nomenclature of the European Laryngological Society. *Eur Arch Otorhinolaryngol* 2014; 271(9): 2489-2496. DOI:10.1007/s00405-014-3024-4

15. Schindler A, Pizzorni N, Mozzanca F, Fantini M, *et al.* Functional outcomes after supracricoid laryngectomy: what do we not know and what do we need to know? *Eur Arch Otorhinolaryngol.* 2016; 273(11): 3459-3475. DOI:10.1007/s00405-015-3822-3

16. Leipzig B. Neoglottic reconstruction following total laryngectomy. A reappraisal. *Ann Otol Rhinol Laryngol* 1980; 89(6 Pt 1): 534-537. DOI:10.1177/0003489480890090609

17. Mendenhall WM, Parsons JT, Million RR, Fletcher GH. T1-T2 squamous cell carcinoma of the glottic larynx treated with radiation therapy: relationship of dose-fractionation factors to local control and complications. *Int J Radiat Oncol Biol Phys* 1988; 15(6): 1267-1273.

18. Mendenhall WM, Parsons JT, Stringer SP, Cassisi NJ. Management of Tis, T1, and T2 squamous cell carcinoma of the glottic larynx. *Am J Otolaryngol* 1994; 15(4): 250-257.

19. Fung K, Lyden TH, Lee J, Urba SG, Worden F, *et al.* Voice and swallowing outcomes of an organ-preservation trial for advanced laryngeal cancer. *Int J Radiat Oncol Biol Phys* 2005; 63(5): 1395-1399. DOI:10.1016/j.ijrobp.2005.05.004

20. Olsen KD. Reexamining the treatment of advanced laryngeal cancer. *Head Neck* 2010; 32(1): 1-7. DOI:10.1002/hed.21294

21. Hoffman HT, Porter K, Karnell LH, Cooper JS, *et al.* Laryngeal cancer in the United States: changes in demographics, patterns of care, and survival. *Laryngoscope* 2006; 116(9 Suppl 111): 1-13. DOI:10.1097/01.mlg.0000236095.97947.26

22. Labayle J. [Reconstructive total laryngectomy]. *Rev Laryngol Otol Rhino (Bord)* 1972; 93(1): 69-77.

23. Brasnu DF. Supracricoid partial laryngectomy with cricohyoidopexy in the management of laryngeal carcinoma. *World J Surg* 2003; 27(7): 817-823.

24. Labayle J. [Reconstructive total laryngectomy]. *Otori- nolarinologie.* 1972; 17(2): 115-124.

25. Piquet JJ DA, Decroix G. . Crico-hyoido-epiglott-o-pxey. Surgical technic and functional results. *Ann Otolaryngol Chir Cervicofac.* 1974; 91: 681-686.
26. De Virgilio A, Fusconi M, Gallo A, Greco A, Kim SH, Conte M, et al. The oncologic radicality of supracricoid partial laryngectomy with cricohyoidopexy in the treatment of advanced N0-N1 laryngeal squamous cell carcinoma. *Laryngoscope* 2012; 122(4): 826-833. DOI:10.1002/lary.23178

27. Laccourreye H, Laccourreye O, Weinstein G, Menard M, Brasnu D. Supracricoid laryngectomy with cricohyoidoepiglottopexy: a partial laryngeal procedure for glottic carcinoma. *Ann Otol Rhinol Laryngol* 1990; 99(6 Pt 1): 421-426. DOI:10.1177/00034894909900601

28. Spriano G, Pellini R, Romano G, Muscatello L, Roselli R. Supracricoid partial laryngectomy as salvage surgery after radiation failure. *Head Neck*. 2002; 24(8): 759-765. 10.1002/hed.10117

29. Makeieff M, Venegoni D, Mercante G, Crampette L, Guerrier B. Supracricoid partial laryngectomies after failure of radiation therapy. *Laryngoscope* 2005; 115(2): 353-357. DOI:10.1097/01.mlg.0000154751.86431.41

30. Nakayama M, Miyamoto S, Okabe S, Okamoto M. Salvage supracricoid laryngectomy after failed radiotherapy and partial laryngectomy. *J Laryngol Otol* 2015; 129(1): 101-105. DOI:10.1017/S0022215114003235

31. De Virgilio A, Pellini R, Mercante G, Cristalli G, Manciocco V, et al. Supracricoid partial laryngectomy for radiorecurrent laryngeal cancer: a systematic review of the literature and meta-analysis. *Eur Arch Otorhinolaryngol* 2018; 275(7): 1671-1680. DOI:10.1007/s00405-018-4986-4

32. de Vincentis M, de Virgilio A, Bussu F, Gallus R, et al. Oncologic results of the surgical salvage of recurrent laryngeal squamous cell carcinoma in a multicentric retrospective series: emerging role of supracricoid partial laryngectomy. *Head Neck* 2015; 37(1): 84-91. DOI:10.1002/hed.23563

33. Peretti G, Piazza C, Mensi MC, Magnoni L, Bolognini A. Endoscopic treatment of cT2 glottic carcinoma: prognostic impact of different pT subcategories. *Ann Otol Rhinol Laryngol* 2005; 114(8): 579-586. DOI:10.1177/000348940511400801

34. Woisard V, Puech M, Yardeni E, Serrano E, Pessey JJ. Deglutition after supracricoid laryngectomy: compensatory mechanisms and sequelae. *Dysphagia* 1996; 11(4): 265-269.