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Clinical Review

FUNCTIONAL OUTCOMES IN SUPRACRICOID LARYNGECTOMY

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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.
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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 IIa and Type IIb. OPHL Type IIa, 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 IIa 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 IIa. The entire supraglottis and the pre-epiglottic space are removed. Larynx reconstruction is achieved by crico-hyoidopexy. Similarly, to Type IIa, 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, costo-diaphramatic 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 aspiration, presence of cough reflex and diet restrictions (15). Thus, a standard system for assessing swallowing function after partial laryngectomy should be defined.

The evaluation of voice can be achieved with different methods, although maximum phonation time (MPT) appears to be the most widely used aerodynamic parameter and is measured on the production of 3 sustained "a", where the longest phonation time was recorded. The GIRBAS scale is one of the most widely used scales for perceptual voice evaluation in dysphonic patients that specifically assesses different parameters of voice quality: grade (G), instability (I), roughness (R), breathiness (B), asthenia (A), and strain (S); the score ranges from 0 (normal voice) to 3 (severe dysphonia).

Self-assessment of patient's condition may be evaluated by several questionnaires to evaluate nutrition, phonation and social reintegration. Regarding postoperative swallowing, the evaluation of the degree of postoperative suction may be archived according to Leipzig (16) and Pearson scales (4) (1 = none, 2 = occasional cough but no clinical problem, 3 = worsening of coughing constantly with meals or swallowing, 4 = pulmonary complications). The same criteria, still using the Leipzig and Pearson scales, have been adopted to evaluate the discourse (1 = good subjective speech, 2 =adequate communication, 3 = occasional word or syllable produced, 4 = reading of the lips necessary to understand the sounds). Long-term results should be evaluated at least 6 months after surgery, interviewing each patient.

DISCUSSION

Laryngeal cancer treatment has been largely debated as regarding surgical and non-surgical treatment protocols in early-stage and in advantage-stage cancer. For initial cancer stages, there is a broad consensus that the oncological and functional results of transoral laser surgery or RT are equivalent in glottic T1 carcinomas (Phase I) and T2 (Phase II), reaching 80% to 95% of local control of disease (5, 17, 18). In locally advanced stages, the therapeutic choice includes TL, although the problem of vocal preservation and airway recovery persuaded surgeons to select procedures that spared the organ while guaranteeing oncological radicality. Such organ preservation protocols necessarily need to evaluate the effects on organ survival and function.

Radiotherapy and CHT have been proposed as an alternative to TL in locally advanced stages of LSCC in Northern Europe and United States. The evaluation of results after RT and CHT has been questioned by several studies as the Veteran Affairs and RTOG 91-11 (Radiation Therapy Oncology Group 91-11), regarding organ preservation and patient survival (5, 7). A severe speech and swallowing impairments are often associated with these aggressive protocols, suggesting that fibrosis and 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 laryngectony 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 IIa) (25). As confirmed by various studies, the reconstructive techniques of "OPHL Type IIa" 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 term 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 re-considered 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 justiciable 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-aritenoid 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-aritenoid 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.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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