Abstract

Objective: to assess the voice-related quality of life (V-RQOL) in patients after total and partial laryngectomy.

Materials and methods: 96 patients treated for laryngeal cancer were enrolled in the study. The cohort of patients was divided into three groups depending on the surgical procedure carried out: total laryngextomy (TL), supracricoid partial laryngectomy (SCL) and/or horizontal glottectomy (HG). The maximum phonation time (MPT) and syllable diadochokinesis, were used for the aerodynamic assessment; Yanagihara score was used for acoustic analysis of the sustained /a/ and the GRBAS scale was used for perceptual assessment. Each of the patients completed the VHI. The Kruskall-Wallis and Mann-Whitney tests were used to analyse the mean difference among the three groups of patients.

Results: A comparison with the values found between groups noted that the TL group showed significantly higher scores of G, R and Yanagihara score, while the HG group showed a significantly higher score of B. No differences were found in the aerodynamic and acoustic measures among the 3 groups. The mean ± standard deviation of VHI total score were 35.3 ± 24.5 for TL group, 30.1 ± 21.6 for SCL group, 35.8 ± 9.6 for HG group. No significant difference was found across the three groups.

Conclusions: V-RQOL seems to be similar in patients who underwent significantly different surgical procedures even if the voice characteristics were different. These findings need to be considered in patient's counselling together with other data on general quality of life after total and partial laryngectomy.

Introduction

The surgical treatment of laryngeal carcinoma is still controversial and there is a wide range of available therapeutic options. Even if total laryngectomy (TL) has been the standard procedure for advanced-stage laryngeal carcinoma, over the last decades new surgical and non-surgical procedures have gained increasing acceptance [1]. In particular, the supracricoid laryngectomies (SCL) with cricohyoidopexy (CHP) or cricohyoidoepiglottopexy (CHEP) are now considered an oncologically sound alternative to TL for selected patients with T1b, T2, T3 and T4 supraglottic and glottic carcinomas [2, 3]. In SCL a permanent tracheostoma is usually not required because the main laryngeal functions (swallowing, respiration, phonation) are preserved, thanks to the functioning crico-arytenoid unit(s). The tracheal cannula is removed in 92-100% of the patients after an average of 3-109 days depending on the case series [4, 7-9]. Even if swallowing is usually recovered, a swallowing rehabilitation program is necessary and patients remain on enteral nutrition for weeks. Per os nutrition is achieved in 86-100 % of the patients after an average of 12-90 days, depending on the case series, and aspiration pneumonia may occur in up to 20% of the patients [4-9]. Voice is impaired both in the short-term and in the long-term; in fact long-term functional perceptual voice results showed moderate to severe dysphonia; besides, both mucosal wave and glottic airflow resulted severely impaired. [7].

Nowadays, is not possible to argue about the oncological outcomes of a surgical procedure, without considering the patient's self-impression on the success of the treatment, since health has to be considered as a multidimensional concept, as defined by the World Health Organization [10]. Despite the importance of this latter element, there is a paucity of published data on this subject in patients who underwent SCL and only a few studies have tried to compare the functional outcomes in patients treated with total and partial laryngectomy [11-18]. Weinstein et al [12] found that subjects treated with SCL had significantly higher domain scores than TL patients in general quality of life (QOL); in particular higher functioning was found in the following categories of SF-36:

physical function, physical limitation, general health, vitality, social functioning, emotional limitations and physical health summary.

When considering voice, most authors have reported a moderate reduction in voice-related QOL (V-RQOL) after SCL; however, the reports are somewhat contradictory. In the Weinstein et al. study the domains of physical functioning and total score of the V-RQOL were significantly better with SCL when compared with TL. On the contrary, Torrejano et al [14], using the Portuguese version of the questionnaire developed by Clements et al [19], found that TL patients scored significantly better than SCL patients. Finally, Dworkin et al [13] and So et al [11] found no differences in the scores of Voice Handicap Index (VHI) between TL and SCL patients.

Furthermore, the results of voice production in TL and SCL laryngectomy are contradictory. Dworkin et al [13] found that patients treated with TL generated significantly better scores in maximum phonation time (MPT), jitter and transglottal airflow rate in comparison with subjects treated with SCL. Torrejano et al [14] found that the mean F_0 during conversation, the roughness and the grade of voice quality were worst in SCL group compared to TL patients. Eksteen et al [15], on the contrary, reported that there was no difference in MPT between these two groups and So et al [11] found that speech after SCL was not better than speech after TL.

Despite the above-mentioned studies, it is still unclear why the differences found in voice production do not match with the V-RQOL scores. A partial explanation lies in the fact that QOL involves many factors and it is possible that factors related to the pathology and its management, such as prolonged enteral nutrition and presence of tracheostoma cannula, rather than voice per sè impact on V-RQOL. For this reason, we compared V-RQOL, aerodynamic and perceptual voice measures in patients treated with TL, SCL and horizontal glottectomy (HG). This latter technique is an organ-preservation procedure for the treatment of selected T1 and T2 laryngeal carcinomas; it assures good functional results in terms of voice quality [20] through the removal of the entire glottis, thanks to a segmental resection of the glottis performed by means of two horizontal incisions, the lower through the cricothyroid membrane, and the upper across the wings of the

thyroid cartilage. The resulting defect is closed by approximating the cricoid to the thyroid remnants [21]. Even if this technique is not widely accepted, several publications by European authors have retrospectively reported good oncologic and functional results [20-28]. Furthermore, a permanent tracheostoma is not required in this technique because the main laryngeal functions are preserved and the tracheal cannula is usually removed within the first post-operative days; swallowing disorder do not usually arise and voice present a moderate to severe impairment [20].

The aim of this study is to compare V-RQOL measures and acoustic, aerodynamic and auditory perceptual analysis scores obtained in three different groups of patients, treated with different surgical techniques for laryngeal carcinoma.

Materials and Methods

Participants

Ninety-six patients, 88 males and 8 females, who had undergone TL, SCL or HG for laryngeal cancer from 2000 to 2008 were enrolled in the study. The mean age was 67.9 ± 10.2 years (range 45-84). All of the patients had no respiratory problems, no debilitating illness and no recurrence of disease and completed the oncological treatment at least one year before the study was undertaken. Depending on the surgical procedure adopted, the cohort of patients was divided into three groups (Table I): 24 patients were treated with TL (group 1), 40 patients were treated with SCL (group 2) and 32 patients were treated with HG (group 3). Mean age was 67.9 ± 10.3 in group 1, 69.8 ± 10.6 in group 2, 65.5 ± 9.7 in group 3. All the patients with TL were exclusive tracheoesophageal speakers with Blom-Singer Indwelling Advantage for more than one year.

Objective and subjective voice measurements

The patients who underwent HG or SCL were assessed through fiberoptic endoscopic evaluation of swallowing (FEES) with both liquids (5 ml) and semisolids (5 ml); it has been considered aspiration if part of the bolus was found below the neoglottis during FEES. The auditory perceptual vocal assessment was performed using the GRBAS scale [29]. The patients were asked to utter an /a/ in modal voice for as long as possible; the voice signal was recorded with the microphone approximately 15 cm from the voice source to avoid airflow effect and was directly stored in the host computer. The Computerized Speech Lab (CLS) (Version 5.05) with a 4300 external module of Kay Elemetrics Corporation (Lincoln Park, NJ) was used. The maximum phonation time (MPT) was determined by measuring the sustained /a/ in three productions on the basis of the oscillogram signal. The longest sustained phonation was used for further processing. Each subject was then asked to utter the syllable [pa] as rapidly as possible with a single breath; the syllable diadochokinesis was rated in syll/s. A spectrography of the sustained vowel [a] at FFT-1024 points ranging between 0 and 8 KHz was performed; the sample frequency was 20000 Hz. The

Yanagihara classification was used [30]. The Yanagihara's classification of hoarseness is based on the spectrographic representation of aperiodic signal. Hoarseness is scored as type I if aperiodic signal is found within the spectral ranges of the first two formants; a type II score is given when aperiodic signal is predominant in the ranges 2000-4000 Hz, while a type III score is given if only noise if found in the ranges 2000-4000 Hz. Finally, hoarseness is scored as type IV if aperiodic signal predominates in the ranges 500-4000 Hz of the spectrum. Finally, each patient completed autonomously the Italian VHI [31-32], to have self-assessment data on the perceived QOL.

Statistical analysis

The results were given as arithmetic mean ± standard deviation. Kruskal-Wallis test was used to analyze the mean difference between the three groups of patients, while Mann-Whitney test was used for post-hoc analysis. A significance level of 0.05 for all testing was used. Statistically analyses were performed using the SPSS 18.0 package (SPSS Science, Chicago, IL). The study was carried out according to the Declaration of Helsinki and approved by the Institutional Review Board of the L. Sacco Hospital of Milan.

Results

Voice laboratory measurements and assessment of the voice

The distribution for sex, age, years since surgery, radiotherapy and presence of aspiration for liquids or semisolids in the three groups of patients is reported in Table I. All of the 96 patients completed the voice laboratory measurements. The mean scores, the standard deviation and the range of perceptual and aerodynamic analysis for each of the three groups of patients are reported in Tables II and III respectively. Yanagihara scores were 4 ± 0; 3.7 ± 0.4 and 4 ± 0 in group 1, 2 and 3 respectively. Non-parametric Kruskal-Wallis analysis of variance revealed a significant main effect for group (r = 0.039 for G; r = 0.010 for R; r = 0.008 for B and r = 0.009 for Yanagihara score). The results of Mann-Whitney comparison of acoustic, aerodynamic and perceptual data among the three different groups of patients are reported in Table IV. The TL group showed significantly higher scores of G, R and Yanagihara score than those found in the HG and SCL group, while HG group showed significantly higher score of B than those found in the other groups.

VHI scores

The 94 patients included in the study all managed to complete the VHI without any need of assistance. The VHI mean scores, standard deviation and the range for each of the three patient groups are reported in Table V. In particular, the mean ± standard deviation of VHI total score in groups 1, 2 and 3 was respectively of 35.3 ± 24.5, 30.1 ± 21.6, 35.8 ± 9.6. For both the total score and the three subscales the HG group scored highest, followed by the TL and SCL group. No significant difference across the different groups, either for the total VHI score or for each of the three subscales was found with Kruskal-Wallis test.

Discussion

Carcinoma of the larynx is one of the most common head and neck cancers. The aim of the treatment is to cure the cancer and, at the same time, achieve the best functional results without any serious complications. Several surgical techniques are available for the treatment of laryngeal cancer and provide comparable cure rates, but the best method for achieving an oncological cure while minimizing adverse effects remains controversial. Patient's self-impression on treatment outcome is gaining an increasing role in the analysis of this controversy. In fact, health has to be considered as a multidimensional concept and it is not possible to argue about the oncological outcomes of a surgical procedure, without considering the patient's self-impression on the success of the treatment. The focus of the present study was on V-RQOL after different surgical procedures for laryngeal cancer. For this analysis the VHI was used. This latter tool is a self-administered questionnaire and consists of 30 items, equally distributed over three domains: functional, physical and emotional aspects of voice disorders.

the VHI is a psychometrically validated tool for measuring the psycho-social handicapping effects of voice disorders, has been has been used for V-RQOL appraisal. This latter tool is a self-administered questionnaire. It consists of 30 items, equally distributed over three domains: functional, physical and emotional aspects of voice disorders. The VHI has been translated and validated in several languages; it is widely applied throughout the world and has been used in different outcome studies. In particular, a recent study comparing the psychometric properties of voice-related QOL measures, concluded that the VHI was the most versatile and easiest to score instrument, providing the most relevant item information (Franic DM et al. Psychometric evaluation of disease specific quality of life instruments in voice disorders. *J Voice* 2005; 19: 300–315). In addition the VHI meets the criteria placed by the Agency for Healthcare Research and Quality for determining disability in speech-language disorders (Agency for Healthcare Research

and Quality. Criteria for determining disability in speech-language disorders. Evidence Report/Technology Assessment. January 2002, Number 52)

In the present study, mean VHI scores for patients who had undergone total laryngectomy, supracricoid partial laryngectomy and horizontal glottectomy were 35.3 ± 24.5, 30.1 ± 21.6 and 35.8 ± 9.6 respectively. While the difference between these scores and those reported in the literature on normal speakers is large, the perceived voice handicap was mild to moderate. Few studies have evaluated the VHI scores after total and partial laryngectomy and most authors found that VHI scores were not notably high after the surgical treatment [33-37]. In particular, Schuster et al [33] who applied the VHI in 20 male laryngectomees using tracheoesophageal voice found that the mean VHI score was 45.5 with large interindividual differences. Lundstrom et al [36] also investigated the VHI in laryngectomees and found that the mean VHI score in patients after laryngectomy was 48. Mekeieff et al [37] who evaluated the V-RQOL after SCL reported VHI mean value of 51.2. So et al [12], when comparing the speech outcomes of partial and total laryngectomy reported VHI scores of 61.7 and 49.8 respectively. In summary, previous studies applying VHI in patients after partial or total laryngectomy presented some kind of variability and found a moderate voice handicap. Our data showed a less severe voice handicap; a possible explanation for the lower VHI scores in our patients compared to scores reported in the literature lies in the fact that QOL brings many factors into play, including the patient's psychosocial traits, as well as cultural and ethnic backgrounds. Therefore, it is not surprising that different authors report different VHI scores on relatively small numbers of patients studied. Regarding the subscales of VHI, scores were higher for the physical and functional subscales compared to the emotional one. This datum suggests that the patients feel the characteristics and functional consequences of substitution voice, but they managed to react positively to it.

The differences in the three studied groups of patients for the VHI total score, as well as for the

scores of the three subscales, were not statistically significant, demonstrating the similarity of V-RQOL in these three groups. Therefore, it seems that factors related to the pathology management, such as prolonged enteral nutrition, presence of tracheostoma cannula and aspiration do not impact on long-term V-RQOL. A different situation could be found analyzing V-RQOL in the first months after surgery; in fact, it is well known that head and neck cancer patients often return to roughly pre-treatment values of several QOL measures by 1 year after diagnosis, though there is considerable inter-patient variability [38]. While physical domains of functioning often follow a characteristic trajectory of marked decline, and subsequent recovery, psychosocial outcomes tend to follow a different course. Progressive improvement in emotional functioning once the patients have adapted to initial disequilibrium associated with diagnosis and early treatment is reported in many investigations.

Perceptual, acoustic and aerodynamic analysis of the voice in the three group of patients was also conducted; since substitution voices present a high degree of irregularity, acoustic perturbation analysis could not be used and spectrography was applied; besides, syllable diadochinesis was added in the aerodynamic measures. Perceptual and acoustic analysis of the voice signal showed that Yanagihara score and the perceptual G, R and B parameter scores significantly R and Yanagihara score than those found in the other groups, while HG group showed significantly higher score of B. Even if these findings are different from those of Torrejano et al [14], who reported that the roughness (R) and the grade of voice quality (G) were worse in the SCL group compared to TL patients, our results of GRBAS scale in SCL and HG patients are very similar to those found in other studies [20, 39].

It seems therefore that, even if the perceptual auditory analysis shows some significant differences, those differences do not match the perceived V-RQOL scores of the patients. It might be speculated that this latter element does not depend on vocal production alone. Other factors could also be considered important in the assessment of V-RQOL in a patient who has experienced TL, HG or SCL. A possible explanation could be that the patient considers the voice impairment after

laryngeal surgery an inevitable consequence of the cancer treatment and consequently the patient may view it as less important and with a lower disabling impact on everyday life. This element could also explain the lower VHI scores in patients with substitution voice in comparison with those found in patients with non-neoplastic lesions [34]. Another possible explanation could be found in the patient's expectations of their quality of voice. For patients with laryngeal cancer, the ability to communicate may be more important than their quality of voice. Finally, patient perceived voice outcome is influenced not only by the patient's satisfaction with being cured, but also by several other factors, such as personality, marital status, job requirements, age, and tobacco. It has recently been demonstrated that VHI scores are significantly higher for patients who had withdrawn from their professional activity or who had had to adapt them [37].

A previous study on QOL after different surgical treatments for laryngeal carcinoma used the European Organization for Research and Treatment of Cancer (EORTC) QOL Core Questionnaire (QLQ – C30) and EORTC QLQ Head and Neck Module (H & N 35) questionnaire [40]; the general QOL and ENT-specific QOL were better in patients with maintained larynx in comparison to laryngectomised patients. However, the symptom scale "speech problems" did not show any difference. The authors speculated that the questionnaires were not sensitive enough to identify vocal efficiency and suggested the need for more precise questionnaire. While the VHI is a more precise tool for V-RQOL compared to the EORTC QLQ H & N 35, it is possible that its items are not specific enough to catch voice handicap difference between laryngeal and substitution voice users as well as among substitution voice users.

In conclusion, V-RQOL seems to be similar in patients who underwent significantly different surgical procedures, irrespective of the voice characteristics and the way it is produced. Since the voice is mainly used for everyday verbal communication, and the speaking activity was preserved in the studied population, it is possible that V-RQOL was perceived by patients as not being greatly compromised, even if the voice per sè was rather poor. While these data are important in patient counselling before surgery, other information on the treatment oncologic efficacy and on QOL

should also be considered. In particular, the literature on general QOL should be added in the discussion on QOL outcome after laryngeal surgery.

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Conflict of interest

The manuscript is original, has not been published previously and is not being considered concurrent by another publication. Each of the authors has contributed to, read, and approved this manuscript. None of the authors has any conflict of interest, financial or otherwise.

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Table 1: Age and sex distributions of the control and the pathological groups.

	Sex	Age	Radiotherapy	Years since surgery	Aspiration
Group 1 TL	M = 22 F = 2	67.9 ± 10.3 (48-82)	8/24 (33%)	2.9 ± 1.8 (0.4-1.8)	0/24 (0%)
Group 2 SCL	M = 40 F = 0	69.8 ± 10.6 (51-84)	8/40 (20%)	8.8 ± 3.7 (3-15)	18/40 (45%)
Group 3 HG	M= 26 F= 6	65.5 ± 9.7 (45-79)	2/32 (6%)	3.3 ± 1.3 (1-5)	0/32 (0%)

M = males; F = females; TL = total laryngectomy; SCL = supracricoid laryngectomy; HG = horizontal glottectomy

Table 2. The mean, standard deviation and range of perceptual analysis of the vocal signal in the three different groups of patients are reported. The results are reported as mean ± standard deviation; range values are reported in brackets.

	G	**R**	**B**	**A**	**S**
Group 1 TL	3 ± 0 (3-3)	2.9 ± 0.2 (2-3)	0.5 ± 0.9 (0-2)	0.5 ± 1 (0-3)	0.6 ± 1.1 (0-3)
Group 2 SCL	2.5 ± 0.6 (1-3)	2.1 ± 0.9 (0-3)	1.1 ± 1.2 (0-3)	0.5 ± 0.8 (0-2)	0.9 ± 0.9 (0-3)
Group 3 HG	2.7 ± 0.4 (2-3)	1.9 ± 0.9 (0-3)	1.8 ± 1.1 (0-3)	0.8 ± 1.1 (0-3)	0.7 ± 0.8 (0-2)
Total	2.8 ± 0.4 (2-3)	2.3 ± 0.8 (0-3)	1.4 ± 1.2 (0-3)	0.6 ± 0.9 (0-3)	0.7 ± 0.8 (0-3)

G = overall grade of dysphonia, R = roughness, B = breathiness, A = asthenia, S = strain; TL = total laryngectomy; SCL = supracricoid laryngectomy; HG = horizontal glottectomy

Table 3: The mean, standard deviation and range of aerodynamic voice evaluation of the vocal signal in the three different groups of patients are reported. The results are reported as mean ± standard deviation; range values are reported in brackets.

	MPT	**syll/sec**
Group 1 TL	7.0 ± 6.3 (0.9-17)	2.8 ± 0.7 (1.6-4.5)
Group 2 SCL	7.5 ± 4.2 (2-18)	3.2 ± 1.2 (1.3-5.5)
Group 3 HG	8.2 ± 4.7 (3.4-22.6)	3.5 ± 1.2 (2.4-5.9)
Total	7.6 ± 4.9 (0.9-22.6)	3.2 ± 1.1 (1.3-5.9)

MPT = maximum phonation time; TL = total laryngectomy; SCL = supracricoid laryngectomy; HG = horizontal glottectomy

Table 4. Results of aerodynamic, acoustic and perceptual comparison between the three groups of patients; the Mann-Whitney test was used.

Group	MPT	Yan	G	R	B	A	S	syll/sec
TL vs HG	0.227	1	0.066	0.004*	0.003*	0.244	0.659	0.125
TL vs SCL	0.301	0.039*	0.013*	0.009*	0.290	0.669	0.430	0.065
HG vs SCL	0.726	0.018*	0.281	0.041*	0.030*	0.324	0.655	0.118

* = statistically significant ($p < .05$).

MPT = maximum phonation time, Yan = Yanagihara score, G = overall grade of dysphonia, R = roughness, B = breathiness, A = asthenia, S = strained; TL = total laryngectomy; SCL = supracricoid laryngectomy; HG = horizontal glottectomy.

Table 5. The mean, standard deviation and range of total VHI scores as well as the emotional, physical and functional subscales scores in the three different group of patients and in the control group are reported. The results are reported as mean ± standard deviation; range values are reported in brackets.

	Physical VHI	**Functional VHI**	**Emotional VHI**	**Total VHI**
Group 1 TL	14.5 ± 7.0 (5-27)	12.4 ± 9.5 (2-33)	8.5 ± 9.6 (0-30)	35.3 ± 24.5 (9-90)
Group 2 SCL	10.4 ± 6.9 (3-21)	12.4 ± 8.6 (0-33)	7.1 ± 8.6 (0-32)	30.1 ± 21.6 (3-79)
Group 3 HG	14.6 ± 3.5 (6-19)	13.9 ± 4.6 (8-24)	6.5 ± 4.2 (0-14)	35.8 ± 9.6 (14-52)
Total	12.8 ± 6.2 (3-27)	12.9 ± 7.6 (0-33)	7.2 ± 7.6 (0-32)	33.2 ± 19.1 (3-90)

TL = total laryngectomy; SCL = supracricoid laryngectomy; HG = horizontal glottectomy