

## LARYNGOLOGY

# How the operated larynx ages

## *Processi di invecchiamento della laringe sottoposta ad intervento chirurgico*

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## SUMMARY

After open partial laryngectomy (HOPL), many patients experience deterioration of laryngeal function over time. The aim of this study was to evaluate laryngeal functional outcome at least 10 years after surgery in a cohort of 80 elderly patients. The incidence of aspiration pneumonia (AP) and objective/subjective laryngeal functional assessments were carried out. Eight patients experienced AP including four with repeated episodes. A significant association was observed between AP and severity of dysphagia ( $p < 0.001$ ). Dysphagia was more pronounced than in a normal population of similar age, but less than would be expected. There was a significant association between the type of intervention and grade of dysphagia/dysphonia; a difference in voice handicap was found, depending on the extent of glottic resection. After HOPL, laryngeal function was impaired, but this did not significantly affect the quality of life. AP is more frequent in the initial post-operative period, and decreases in subsequent years.

**KEY WORDS:** Open partial laryngectomy • Elderly • Supraglottic partial laryngectomy • Supracricoid partial laryngectomy • Supratracheal partial laryngectomy • Aspiration

## RIASSUNTO

*Molti pazienti sottoposti ad intervento chirurgico di laringectomia parziale vanno incontro con il tempo a fenomeni di deterioramento della funzione laringea. L'obiettivo del presente lavoro è stato quello di valutare in un campione di 80 pazienti anziani la funzionalità laringea a distanza di almeno 10 anni dall'intervento chirurgico. Abbiamo valutato l'incidenza delle polmoniti da aspirazione (AP) e la funzionalità laringea da un punto di vista oggettivo e soggettivo. Otto pazienti hanno presentato polmoniti da aspirazione, di cui quattro episodi ripetuti. È stata riscontrata un'associazione statisticamente significativa tra polmonite da aspirazione e grado di severità della disfagia ( $p < 0,001$ ). Il fenomeno della disfagia è risultato essere maggiormente accentuato rispetto a quanto osservato nella popolazione normale di età analoga, ma meno di quanto ci si aspettasse. È stata riscontrata un'associazione statisticamente significativa fra tipo di intervento chirurgico e grado di disfagia/disfonia; è stata altresì evidenziata una differenza nel deficit funzionale vocale, a seconda dell'estensione della resezione glottica. Dopo interventi di laringectomia parziale, la funzionalità laringea appare alterata, ma questo non incide significativamente sulla qualità di vita del paziente. Gli episodi di polmonite da aspirazione sono più frequenti nell'immediato periodo post-operatorio, riducendosi poi di numero negli anni successivi.*

**PAROLE CHIAVE:** Laringectomia parziale • Anziano • Laringectomia orizzontale sopraglottica • Laringectomia sopracricoidea • Laringectomia sopratracheale • Aspirazione

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## Introduction

In the second half of the 20<sup>th</sup> century, horizontal open partial laryngectomies (HOPLs), including, supraglottic laryngectomies (SLs), supracricoid laryngectomies (SCPLs) and most recently, supratracheal laryngectomies (STPLs), have become established as a viable surgical option, primary or salvage, for the treatment of intermediate stage laryngeal cancer. Many authors<sup>1-3</sup> have reported the oncological and functional results of HOPLs, while others have reported data relating to complications and, in particular, on the more frequent and problematic complications, namely chronic aspiration of food and aspiration pneumonia (AP)<sup>4</sup>.

Globally, HOPLs have demonstrated the possibility to obtain a high rate of 5-year local/regional control of disease, often in over 70% of cases, and were used widely in the 1980s and 1990s, particularly for SCPLs<sup>5-7</sup>. It is therefore logical to assume that there is now the opportunity to observe a population of elderly patients, cured of laryngeal cancer, and who have experienced aging with an operated larynx.

An accurate literature analysis was carried out and, to our knowledge, there are few reports focusing on the interesting question of how the operated larynx ages. Therefore, a retrospective cohort study was carried out on a group

of 80 elderly patients (age > 70 years) who underwent HOPLs at least 10 years prior, focusing on swallowing and phonatory results. Laryngeal function analysis was performed using objective and subjective methods, comparing data on episodes of AP during the follow-up period. A comparison was then carried out with literature data on swallowing impairment in elderly subjects who had not undergone laryngeal surgery, as dysfunctions can be considered as an expression of the physiological aging of the larynx.

The goal was to evaluate functional outcomes at least 10 years after HOPL in a cohort of elderly patients to look for correlations between the amount of resection and grade of impairment of swallowing and phonatory parameters detected by self-evaluation and accurate functional tests. Another aim was to examine the relationship between the type of surgery and incidence of AP during follow-up.

## Materials and methods

From 1976 to the time of writing, 1486 HOPLs (supraglottic, supracricoid, supratracheal) have been performed at the Departments of Otorhinolaryngology of the Hospital of Vittorio Veneto and the Martini Hospital in Turin (Italy). This group represents a subset of 2986 patients suffering from invasive squamous cell carcinoma of the larynx (SCC) treated during the same period.

This retrospective study focused on a cohort of 80 patients with the following characteristics: patients without evidence of disease with a minimum follow-up performed in the above-mentioned departments of at least 120 months, current age greater than 70 years and previous interventions of SL, SCPL or STPL. At the time of the last follow-up, the current age of the cohort of patients ranged between 70 and 83 years with a mean of 74.8 years.

Seventy-one patients were male (88.8%) and nine female (11.2%); at the time of surgery, 91% were current or former smokers, with a mean age of 63 years (range 56-73); all patients had a biopsy-proven laryngeal SCC staged from II to IVa according to the 2002 TNM staging classification system<sup>8</sup>.

During the 3 weeks preceding surgical treatment, all patients underwent the same diagnostic work-up that included flexible videolaryngoscopy, intraoperative rigid endoscopy with 0°/angled telescopes and biopsy during microlaryngoscopy under general anaesthesia, laryngeal and neck CT-scan or MRI, bronchoscopy and oesophagoscopy to rule out synchronous tumours, chest X-ray or CT-scan to exclude lung tumours or distant metastases, assessment of bronchopulmonary function and comorbidities for at-risk patients, as well as nutritional evaluation. The Karnofsky performance status index had to be at least 80 (i.e. patient able to carry out normal activities, even though with difficulty)<sup>9</sup>.

In addition to a Karnofsky score < 80, exclusion criteria were severe diabetes mellitus, severe bronchopulmonary chronic obstructive disease and severe cardiac disease. Even though historically an age of 70 years is an important cut-off age for relative surgical indication of some partial laryngectomies, in our experience advanced age is no longer, in itself, an exclusion criterion. After accurate selection of patients on the basis of the absence of important comorbidities and the strong desire of the patient to avoid permanent tracheostomy, age was also considered along with the patient's general condition.

On the basis of pathological findings, 13 patients (16.3%) were subjected to post-operative radiation therapy with a mean dose of 64 Gy delivered to the larynx (three patients, range 62-66 Gy) and 54 Gy to the neck (10 patients, range 50-66 Gy).

### Surgery

Of the 80 patients, 23 underwent SL, 45 underwent SCPL and 12 underwent STPL. In the subset of SLs, there were 6 extended supraglottic laryngectomies (ESL), 4 to the base of the tongue and 2 to the pyriform fossa. In the subset of SCPLs, the procedures used at the time of reconstruction were cricothyroidopiglottopexy (SCPL-CHEP) and cricothyroidopexy (SCPL-CHP). Removal of one arytenoid was indicated in the surgical records by adding the notation "+ A" to the abbreviation for the laryngectomy, specifying the side, left or right, of the removed arytenoids. In the subset of STPLs<sup>10</sup>, the procedures used at the time of reconstruction were tracheothyroidopiglottopexy (STPL-THEP) and tracheothyroidopexy (STPL-THP). Removal of one cricoarytenoid unit was again indicated by adding the notation "+ A" to the abbreviation for the laryngectomy, specifying the side, left or right, of the removed cricoarytenoid unit. Interventions carried out are reported in Table I.

Neck dissection (ND), classified according to the AAO-HNS<sup>11</sup>, was performed in all patients and was unilateral in

**Table I.** Surgical procedures in the study cohort.

Type of procedure	No. (%)
<b>SLs</b>	<b>17 (21.2)</b>
<b>Extended SLs</b>	<b>6 (7.5)</b>
to base of tongue	4
to pyriform sinus	2
<b>SCPLs</b>	<b>45 (56.3)</b>
CHEP	19
CHEP + A	17
CHP	4
CHP + A	5
<b>STPLs</b>	<b>12 (15)</b>
THEP	7
THEP + A	3
THP	2

36 and bilateral in 44 patients. Neck dissection was elective (level II-III-IV + ev. level VI in the case of subglottic extension) in 67 cN0 patients (83.8%) and curative (level II-V + ev. level VI in the case of subglottic extension) in 13 cN > 0 patients (16.3%). Overall, lymph node metastases were detected in 12 patients.

In all patients, resection margins were examined intraoperatively by frozen sections; when positive, the resection was expanded until the margins were negative. The margins of the surgical specimen were always checked again until pathology reports indicated that the margins were closed (< 3 mm) in four patients.

#### *Functional assessment*

All patients underwent the same rehabilitation protocol, with the obvious exception of those with serious early complications. The post-operative protocol consisted of the following: a) post-operative days 1-4: insertion of un-cuffed tracheal cannula and beginning of phonation; b) post-operative days 4-6: during daytime, intermittent occlusion of the tracheostoma with saline-soaked gauze and starting of feeding without the tracheal cannula in position; c) post-operative day 6 onwards: the nasogastric tube (NGT) was removed as soon as a good level of swallowing of both solids and liquids was achieved.

Grading of post-operative aspiration was performed according to Pearson's scale<sup>12</sup> (0 = none; I = occasional cough but no clinical problems; II = constant cough worsening with meal or swallowing; III = pulmonary complications).

The study took place in 2011, and during the annual follow-up visit, all patients underwent the following evaluations: ENT clinical examination coupled with fibre optic videolaryngoscopy; accurate assessment of episodes of AP occurring during the follow-up period; evaluation of dysphonia using subjective and objective methods; evaluation of dysphagia using subjective and objective methods.

All episodes of AP and acute pneumonia were considered, documented by chest X-rays and/or by a medical report, in the period from the day of discharge to the date of the last follow-up visit, whether the patient had required hospitalization or had been treated at home.

For evaluation of dysphonia, all patients were administered the Voice Handicap Index (VHI) questionnaire proposed by Benninger in 1998<sup>13</sup> for self-assessment of vocal disability. This is a questionnaire consisting of 30 items referring equally to three different aspects of vocal disorders: physical, functional and emotional. The patient can provide five possible answers, from never to always, assigning a score from 0 to 4. Summing the values assigned to the 30 responses, an overall score between 0 and 120 is obtained that corresponds to the highest level of phonatory disability perceived by the patient. Then a phoniatician and a speech therapist evaluated the voice

in all patients by assigning to each a score based on the GIBBAS scale<sup>14</sup>, after reading a standard text from SIFEL (Italian Society of Phoniatics and Logopedics).

For evaluation of dysphagia, all patients were administered the MD Anderson Dysphagia Inventory (MDADI) questionnaire<sup>15</sup>, which consists of 20 questions related to three different aspects of dysphagia: functional, physical and emotional. Again, the patient can provide five possible responses, ranging from never to always, assigning a score from 1 to 5, to obtain an overall score between 20 and 100, which corresponds to the highest level of disability perceived by the patient swallowing. Radiological study of swallowing was performed by videofluoroscopy. The radiographs obtained for each patient were then evaluated together by a radiologist (CB) and a phoniatician (PC), and each patient was assigned a score based on the DOSS (Dysphagia Outcome and Severity Scale)<sup>16</sup>. The DOSS assigns 7 degrees (the highest level of dysphagia corresponds to level 1), and is based on an objective assessment of dysphagia from the videofluoroscopy and the level of independence during the intake of food and type of food. This score allows us to understand which patients need more attention and care to avoid the risk of AP.

#### *Statistical analysis*

Statistical analyses were conducted using SAS System 9.2. The association between AP and type of intervention was analyzed using the chi-square test. Fischer's exact test was used since the number of cells with the expected frequency of less than 5 was greater than 50%. The association among the degree of dysphonia, dysphagia and type of intervention was analyzed using ANOVA tests, whereas the association between AP and degree of dysphagia was analyzed using the Student's *t*-test.

## **Results**

At the time of last follow-up, performed by clinical examination of the neck, fiberoptic videolaryngoscopy and chest X-ray, all 80 patients were free of disease.

At the end of the first post-operative month, normal swallowing (Pearson's Scale Grade 0) was achieved in 56 of 80 patients (70.0%), grades I and II were observed in 10 (12.5%) and 8 (10.0%) patients, respectively, while AP (Pearson's Grade III) was recorded in 6 of 80 patients (7.5%). The nasogastric tube remained in place for an average of 15 days after surgery (range 6-67 days), the mean duration of tracheostomy intermittent occlusion was 25 days (range 13-92 days), and the average time of tracheostomy closure was 57 days (range 29-131 days). In our protocol, progressive closure of the tracheostomy is preferred, and occurs spontaneously in the majority of patients following occlusion. For patients, this leads to a sensation of greater safety concerning small episodes of food inhalation, which are relatively frequent, especially

**Table II.** Number (%) of patients with AP and association between AP and type of procedure.

Surgical procedures	No. patients (%)	No. AP (%)
SL	1/23 (4.3)	2 (15.4)
SCPL	5/45 (11.1)	6 (46.1)
STPL	2/12 (16.7)	5 (38.5)
Statistical analysis	$p=0.0131$	

in the first week after discharge. When the tracheostomy has almost closed, a small plastic skin closure can then be performed. The tracheostomy tube was removed at average of 39 days after surgery (range 13-92 days), and always when the patient was able to feed themselves. Two months after surgery, Pearson's Grades I and II were noted in four (5%) and two (2.5%) patients, respectively. Due to intense dysphagia and AP episodes in 8 of 80 patients (10%), a temporary gastrostomy was needed; in 75% of the cases, this was removed during the first post-operative year. Only in one case was the gastrostomy maintained for a longer period (4 years) due to repeated episodes of AP and severe dysphagia for liquids. Two patients were subjected to endoscopic procedures of injective laryngoplasty using Vox-Implant which successfully resolved dysphagia, allowing gastrostomy removal.

From the day of discharge and during the whole period of follow-up, eight patients (10%) experienced at least one episode of AP, including four patients who experienced repeated episodes, for a total of 13 episodes of AP reported in the years after intervention (Table II). In three cases, hospitalization of the patient was necessary (1 SCPL-CHEP + A, 1 SCPL-CHP + A, 1 STPL-THEP + A), while among the cases treated at home, one patient had undergone extended SL (extended to base of tongue), five patients had been subjected to SCPL (2 SCPL-CHEP, 2 SCPL-CHEP + A, 1 SCPL-CHP + A), and two patients had been subjected to STPL (1 STPL-THEP + A, 1 STPL-THP). Analysis of AP episodes dem-

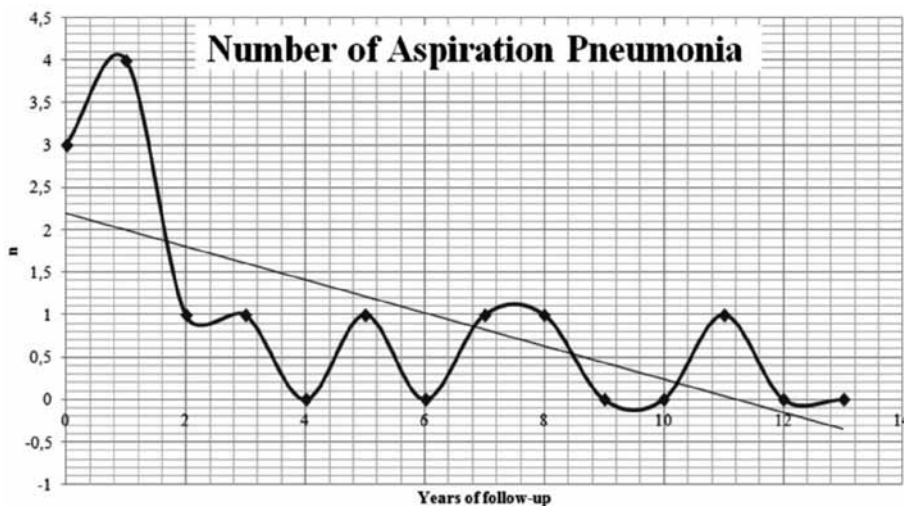
onstrated that these occur more frequently in the early years after surgery, but are less frequent at longer times after the operation, as illustrated in Fig. 1. There was a statistically significant association between AP and type of intervention (Fischer test,  $p = 0.0131$ ), and a higher rate of AP was observed in the more extended procedures (one arytenoid resection, one cricoarytenoid unit resection, enlargement at the base of the tongue, supratracheal resection).

The results of videofluoroscopy, assessed using the DOS Scale and divided by type of intervention, are shown in Table III. The vast majority of patients (58/80; 72.5%) achieved and maintained a very good level of rehabilitation over time, identified by grades 6-7 on the DOS Scale. The SLs reached grade 6-7 in 87.0% of cases (20/23), SCPLs in 77.8% (35/45) and STPLs in 25% (3/12); the more pronounced levels of dysphagia, corresponding to grade 3-4 of the DOS Scale, were found in SLs at a rate of 4.3% (1/23), in SCPLs at a rate of 8.9% (4/45) and in STPLs at a rate of 33.3% (4/12).

The study of swallowing function was completed by self-assessment of dysphagia using the MDADI questionnaire, and scores were stratified by type of intervention (Table IV). Overall, in 83.8% of patients, the degree of perceived swallowing disability was low with MDADI scores of 20-40, and it was possible to observe statistically significant differences between the various categories of intervention (100% of SLs, 82.2% of SCPLs, 58.3% of STPLs). The most significant perceived swallowing disability, with MDADI scores of 61 to 80, was observed in two interventions (4.4%) by SCPL. There was a statistically significant association between the type of intervention and degree of dysphagia, evaluated in an objective manner using videofluoroscopy and with the DOS Scale (ANOVA test,  $p < 0.001$ ), both perceived by the patient and self-assessed using MDADI (ANOVA test,  $p = 0.0125$ ). Additionally, in this case, the worst levels of

dysphagia were associated with the most extensive procedures resulting in anatomic-functional violation of the glottic sphincter, particularly when such violation led to the removal of one arytenoid or the removal of the entire cricoarytenoid unit as in supratracheal laryngectomies.

The results of voice analysis using the GIRBAS scale as well as the results of self-evaluation using the VHI questionnaire are shown in Table V and are stratified for each type of intervention. Objective assessment with the GIRBAS scale showed that overall, HOPLs enabled patients to achieve and

**Fig. 1.** Frequency of AP episodes during the follow-up period.

**Table III.** Videofluorographic study of swallowing assessed using the DOS scale and listed by type of procedure.

DOSS	No.	%	Type of procedure								
			SL	Extended SL	CHEP	CHEP + A	CHP	CHP + A	THEP	THEP + A	THP
7	34	42.5	15	-	12	4	1	2	-	-	-
6	24	30.0	1	4	3	11	1	1	1	2	-
5	13	16.3	-	2	3	1	1	1	5	-	-
4	7	8.8	1	-	1	1	1	1	1	-	1
3	2	2.5	-	-	-	-	-	-	-	1	1
Statistical analysis						p < 0.001					

**Table IV.** Results of dysphagia self-assessment using the MDADI questionnaire listed by type of procedure.

MDADI	No.	%	Type of procedure								
			SL	Extended SL	CHEP	CHEP + A	CHP	CHP + A	THEP	THEP + A	THP
20-40	67	83.8	17	6	15	15	3	4	6	1	-
41-60	11	13.8	-	-	3	1	1	1	1	2	2
61-80	2	2.5	-	-	1	1	-	-	-	-	-
81-100			-	-	-	-	-	-	-	-	-
Statistical analysis						p = 0.0125					

maintain very good voice restoration (GIRBAS score 0-1) in 20% of cases, only those patients who underwent SLs (16/23, 69.5%); 50% of patients (the group consisting of 4/23 SLs [17.4%], 30/45 SCPLs [66.7%] and 6/12 STPLs [50%]) showed a medium value of dysphonia (GIRBAS score 1.01-2); the worst results for dysphonia (GIRBAS score 2.01-3) were found in 30% of patients, the group consisting of 3/23 SLs (13.0%), 15/45 SCPLs (33.3%) and 6/12 STPLs (50%). Similar to what was observed for self-assessment of dysphagia, the study of phonatory function using the VHI questionnaire demonstrated that a large number of patients, representing 60% of the study cohort (69.5% of SLs, 62.2% of SCPLs and 33.3% of STPLs), perceived a low level of vocal handicap (VHI score 0-30), while 11 of 80 patients (13.8%) receiving SCPLs (8/45, 17.8%) or STPLs (3/12, 25%) complained of a high degree of speech handicap. Since there is a remarkable difference in voice handicap between HOPLs depending on the extent of glottic resection, a statistically significant association was found between the type of

intervention and grade of dysphonia, both perceived by patients (ANOVA test,  $p = 0.0125$ ) and evaluated in an objective manner (ANOVA test,  $p < 0.001$ ). In addition, in this case, poorer functional results were proportional to the amount of larynx resected downwards (best results for SLs followed by SCPLs and then STPLs).

To understand whether AP was associated with severity of dysphagia, the values of DOS scale and MDADI of the eight patients who developed AP during follow-up were considered (Table VI). A clear correlation was observed between pneumonia and severity of dysphagia both evaluated in an objective manner (Student's  $t$ -test,  $p < 0.001$ ) and perceived by the patient (Student's  $t$ -test,  $p < 0.001$ ). Patients who complained of repeated episodes of pneumonia were those who had more severe levels of dysphagia. The average DOS Scale value of patients who had at least one episode of pneumonia was 4.38 (range 3-6), whereas in those patients who had never developed an episode of pneumonia, this value was 6.19 (range 4-7). The average MDADI score in patients with at least one

**Table V.** Results of voice analysis by GIRBAS scale and by self-evaluation using the VHI questionnaire listed by type of procedure.

	No.	%	Type of procedure								
			SL	Extended SL	CHEP	CHEP + A	CHP	CHP + A	THEP	THEP + A	THP
<b>GIRBAS</b>											
0-1	16	20	15	1	-	-	-	-	-	-	-
1.01-2	40	50	1	3	12	11	4	3	4	1	1
2.01-3	24	30	1	2	7	6	-	2	3	2	1
Statistical analysis						p < 0.001					
<b>VHI</b>											
0-30	48	60	13	3	10	10	3	5	1	2	1
31-60	22	27.5	4	3	4	5	1	-	4	1	-
61-90	9	11.3	-	-	5	2	-	-	1	-	1
91-120	1	1.3	-	-	-	-	-	-	1	-	-
Statistical analysis						p = 0.0125					

episode of pneumonia was 56.38 (range 38-73), whereas in patients who had never complained of any episode of pneumonia, the score was 33.00 (range 20-67). These data allow us to conclude that these episodes of pneumonia are closely correlated with the degree of dysphagia.

## Discussion

Over the last three decades, HOPLs have emerged as an important weapon in the surgical treatment of laryngeal cancer at intermediate/advanced stages and, especially in Europe, there are now thousands of patients who have undergone HOPLs and are aging with an operated larynx<sup>1-3</sup>. Dysphagia, dysphonia and aspiration pneumonia have been recognized as major complications in patients subjected to these interventions, and can significantly affect their physical and emotional condition<sup>4,17</sup>.

Starting from the observation that the phenomena referred to as presbyphagia and presbyphonia represent functional alterations that can occur even in normal elderly subjects never subjected to laryngeal surgery, we asked a series of questions.

What can be expected for a patient subjected to HOPLs and aging with an operated larynx? Will the degree of dysphagia remain stable over time or will it undergo physiological deterioration? What is the degree of AP observed in a cohort of elderly patients undergoing HOPLs compared to a cohort of elderly subjects that were never subjected to laryngeal surgery? During follow-up, is it necessary to use corrective behaviour to ensure that the patient has a good quality of life?

The quality of voice is one of the most critical aspects of HOPL, especially when the resection is extended to the glottis or downward to the subglottis<sup>18</sup>. In a functional study on 64 patients who underwent SCPL, Makeieff<sup>19</sup> found that the intervention could have marked social and professional impact. Comparing voice analysis in patients subjected to total laryngectomy and voice prosthesis (TL-VP) vs. SCPL, Yoon Kyoung<sup>20</sup> demonstrated that the maximum phonation time was longer in the TL-VP group than in the SCPL group. Finally, Schindler<sup>21</sup> conducted a cross-sectional study on 20 patients who underwent SCPL and in whom perceptual assessment revealed a very harsh voice, acoustic analysis displayed an irregular signal, and aerodynamic measurements showed an inefficient system. A remarkable difference in voice handicap was found between HOPLs in the study cohort depending on the extent of glottic resection with a statistically significant association between the type of intervention and grade of dysphonia, both perceived by the patient and evaluated in an objective manner. A poorer functional result was found

**Table VI.** Correlation between number of AP episodes and grade of dysphagia.

Patient	Procedure	No. of AP episodes	DOSS grade	MDADI grade
1	THP	3	3	58
2	THEP + A	2	3	55
3	Extended SL	2	5	38
4	CHEP	2	5	67
5	CHEP	1	4	58
6	CHP	1	4	43
7	CHEP	1	6	59
8	CHEP	1	5	73
Statistical analysis			p < 0.001	p < 0.001

to be proportional to the extent of the larynx resected downwards (best results for SLs, then SCPLs and finally STPLs).

There are several studies on swallowing impairment following HOPLs, especially following SCPLs, demonstrating an overall incidence of temporary aspiration varying from 32-89%, regardless of patient age at surgery<sup>22</sup>; similarly, the rate of AP in the initial post-operative period ranges from 4.3-23%. In a large series of patients, Benito<sup>4</sup> have demonstrated that age (alone) should not be considered as a major contraindication for SCPLs despite the fact that statistical analysis has demonstrated a risk of Grade II-III aspiration (Pearson's scale) only in patients > 70 years old in the case of CHP with partial or total arytenoid resection. In another study, Schindler have compared 10 patients aged > 65 years at the time of surgery with 10 younger patients, concluding that age (alone) was not a major drawback in these interventions<sup>21</sup>. The cases in the present study cohort are different. Patients undergoing surgery ranged between 56 and 73 years, were analyzed after a minimum follow-up period of 120 months (range 120-232 months) and were subjected to different types of open partial interventions on the larynx (nine different types) that essentially differ in the amount of resection and in the functional violation of glottic and sub-glottic sites. This is therefore a study that directly and indirectly analyzes the function of the neolarynx at a considerable period of time after surgery, when, in particular, the function of swallowing may have largely stabilized and therefore be subjected to possible physiological deterioration of function, referred to as 'presbyphagia'.

In 2011, Van der Maarel-Wierink<sup>23</sup> conducted a systematic literature review of risk factors for aspiration pneumonia in the elderly, and the results showed evidence of a positive relationship between AP and dysphagia.

In another literature review, Eisenstadt<sup>24</sup> found that dysphagia and the resulting aspiration may be prevalent in the older population, but symptoms are not always clinically evident. In 1995, using videofluoroscopy, Frederick<sup>25</sup> showed an increase in swallowing alterations with aging. In particular, in subjects older than 60 years, persistence of the bolus in the valleculae and pyriform fossa was observed with an increased risk of laryngeal penetration

and aspiration, asymmetry and hypertrophy of the crico-pharyngeal muscle and, in some cases, the presence of a Zenker's diverticulum.

These latter features are the same as those found in a subset of our more dysphagic patients who, statistically, were those undergoing more extended resections. In this series, at the end of the first post-operative month, normal swallowing (Pearson's Scale Grade 0) was achieved in 70.0% of patients, while at 2 months after surgery some difficulties of swallowing were encountered with Pearson's Grades I and II in 5% and 2.5% of patients. Overall, for 8 of 80 patients (10%), a temporary gastrostomy was needed and in 75% of these cases, this was removed during the first post-operative year. Only in one case was the gastrostomy maintained for a long period (4 years) due to repeated episodes of AP and severe dysphagia for liquids until the patient had been subjected to two endoscopic procedures of injective laryngoplasty using Vox-Implant that successfully resolved the dysphagia, allowing gastrostomy removal.

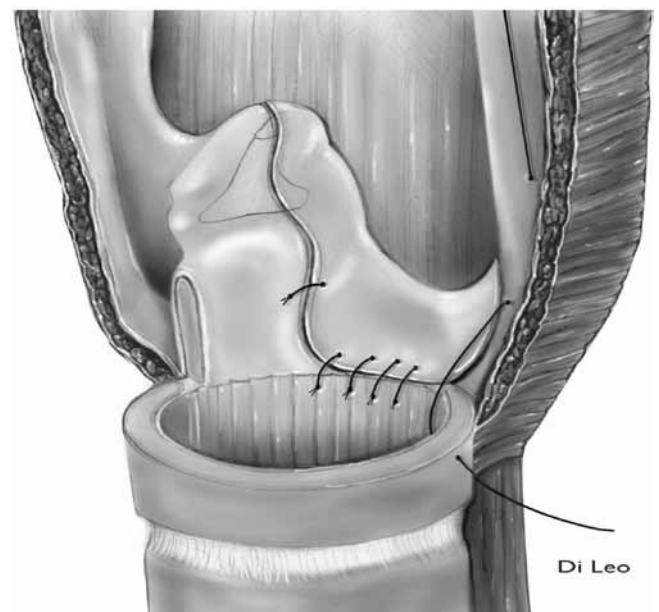
After a long-term follow-up period, swallowing analysis showed that, in patients aging with a larynx subjected to HOPLs, the severity of dysphagia in those aged > 70 years was definitely more pronounced than in a normal population of similar age, but certainly less than would be expected as 72.5% of patients, despite a previous intervention of HOPL, achieved and maintained a very good level of rehabilitation, identified by grades 6-7 of the DOS Scale. Since all of these patients were elderly (mean age 74.8 years) at the time of the videofluorographic study of swallowing, it is clear that, in patients who had achieved a good level of swallowing rehabilitation after surgery, dysphagia remains stable over time and, compared to a population of the same age not suffering from particular diseases, is not significantly worse.

These considerations do not apply to patients who have already suffered important swallowing disorders in the immediate post-operative period. The more severe levels of dysphagia, grade 3-4 of the DOS scale, were found in SLs at a rate of 4.3%, in SCPLs at a rate of 8.8% and in STPLs at a rate of 33.3%. AP episodes occur more frequently in the early years after surgery in the more extended procedures (one arytenoid resection, one cricoarytenoid unit resection, enlargement to the base of the tongue, supratracheal resection), but are less frequent at longer times after the operation.

The latter data referring especially to supratracheal laryngectomies require careful and cautious evaluation. In a series of 70 consecutive supratracheal laryngectomies, Rizzotto<sup>2</sup> observed acute complications in 7.1% of patients. The most frequent was AP, found in 60% of all acute complications. Late sequelae occurred in 28.6% of patients. Of these, the majority were due to laryngeal obstruction (70% of late sequelae), most of which were related to chronic oedema or mucosal flaps of the neolarynx, while in 27.1% of cases, patients suffered from intermittent or persistent

aspiration. The authors emphasized that the majority of late sequelae were treated by one or two transoral procedures using a CO<sub>2</sub> laser. In patients who developed late sequelae, the larynx was spared in 17 of 20 cases (85%), and total laryngectomy was proposed in only one patient for persistent aspiration even though he refused preferring to keep the gastrostomy and maintain voice. After these "extreme" function sparing procedures, it is necessary to be prepared for subsequent endoscopic surgery, laser surgery or injective laryngoplasty to correct anatomical and functional results and to achieve the best possible outcome. Fortunately, in only a few cases, persistent dysphagia and aspiration pneumonia still represent major complications in patients undergoing STPLs and significantly affect their physical and emotional condition.

The reality, therefore, is that, after a supratracheal laryngectomy with cricoarytenoid unit resection, it is difficult to achieve an optimal degree of recovery of swallowing (grade 7-6 of the DOSS in only 25% of cases), and, in most cases (> 75% of cases), the patient still manages to reach and maintain a sufficient level of rehabilitation from dysphagia over time (DOSS grade > 4), which corresponds to an acceptable autonomy of solid and liquid food oral intake. This aspect can be understood by analyzing the characteristics of supratracheal laryngectomy extending to a cricoarytenoid unit<sup>10</sup>. In this case, from the side of the resected hemy-cricoid plate, there is a clear lack of wall between the hypopharynx and larynx, represented by the posterolateral portion of the cricoid cartilage, which is only replaced by suturing the hypopharyngeal mucosa to the tracheal stump to recreate good patency of the pyriform sinus (Fig. 2). This defect may represent a route of



**Fig. 2.** Supratracheal laryngectomy, highlighting the reconstructive step with suturing of the hypopharyngeal mucosa to the tracheal stump in order to recreate a good patency of the pyriform sinus.

food entry into the larynx that can be treated by maintaining a proper laryngopharyngeal sensation, recreating a functional neoglottic valve with the contralateral cricoarytenoid unit, constructing a pexy between the trachea and hyoid bone, and enhancing physiological coordination during swallowing.

Since the dysphagia observed in patients who underwent HOPL is undoubtedly the product of anatomical and physiological alterations of the larynx, but also due to presbyphagia, what possible explanation can be given for the interesting phenomenon represented by having a degree of dysphagia less than expected (taking into account the amount of larynx resected) and in particular, that the dysphagia does not appear to deteriorate during aging? Furthermore, why did data collected from patients using self-assessment questionnaires of dysphagia report rates that were more than satisfactory in 97.5% of cases?

The explanation could be that, in addition to providing the cornerstone of functional recovery, all horizontal partial laryngectomies offer the following surgical highlights: (a) preservation of the superior laryngeal nerves, (b) good patency of the pyriform sinuses, (c) the presence of at least one functioning cricoarytenoid unit and finally, (d) the suspension of the residual larynx to the

hyoid bone. This latter condition involves the placement of the cricoid at a level higher than what is physiologically found in the healthy adult, in a position more similar to what is found in the newborn, where a facilitated swallowing act is favoured by the higher position of the larynx and large patency of the pyriform sinuses. This is what is obtained by raising the cricoid closer to the base of the tongue, in a more advantageous position for swallowing, and is equivalent to what is observed in the adult during the pharyngeal phase of swallowing. As evidence of this statement, videofluorography frames are shown during the respiratory phase in a newborn (Fig. 3A), in a normal elderly subject (Fig. 3B) and in an elderly patient who had undergone SCPL-CHEP (Fig. 3C). As can be seen, the lower edge of the cricoid both in the newborn and in the patient subjected to SCPL-CHEP is located at the level of the vertebral body of C5, and this is a consistent condition in all patients subjected to HOPL; on the other hand, in the elderly patient, the lower edge of the cricoid is located at the level of the vertebral body of C6-C7, in a less advantageous functional position. It can therefore be said that this condition, reproducing the anatomical conditions found in the newborn, tends to counteract the physiological decay of the laryngeal swallowing function, despite the fact that significant portions of the larynx have been sacrificed.

In this way, it is possible to explain the low incidence of AP episodes observed during long-term follow-up and the fact that the clinical evaluation of pulmonary function of patients at last follow-up was still satisfactory (no cases of dyspnoea at repose, only four patients with a Karnofsky score less than 80, two patients with a Karnofsky score less than 70). After discharge, 13 episodes of AP were observed, which occurred in only eight of 80 patients. Overall, three episodes of AP occurred in the last 3 years and 10 in the previous 12 years, nine of which occurred in the first 3 years after surgery. In our opinion, this is related to the adoption by physicians and patients of measures to reduce the risk of aspiration (placement of temporary gastrostomy for patients suffering from severe dysphagia, prolonged and repeated chest therapy and swallowing rehabilitation, elimination of at-



**Fig. 3.** Videofluorography during the respiratory phase in a newborn (A), in a normal elderly subject (B), and in an elderly patient who had undergone SCPL-CHEP + A (C). The line is placed at the level of the lower edge of the cricoid plate.



risk foods in two patients with more than one episode of pneumonia during follow-up) and the possibility to carry out corrective endoscopic procedures (e.g. injective laryngoplasty in two patients with more than one episode of pneumonia during follow-up).

It is thus established on the basis of indirect findings on the AP episodes that the incidence of these phenomena increases slightly with age, but this is not statistically significant, while a statistically significant correlation was confirmed between the extent of resection and the risk of AP, as already observed by Benito<sup>4</sup>.

In conclusion, the results of laryngeal functionality in a sample of elderly patients (age > 70 years subjected to HOPLs and examined at least 10 years after surgery) are undoubtedly stable and repeatable both for SLs and SC-PLs, as already reported by many authors. For STPLs, this is the first study in terms of functional outcome and, although the function of the remaining larynx is poorer, both objective and subjective outcomes have demonstrated the quite satisfactory validity of STPLs in sparing laryngeal function, albeit at the obvious expense of a 'simplified' laryngeal framework. This shows the immense ability of this organ to recover the essentials of its function after partial surgical mutilation, provided that tissue has been sacrificed and the organ reconstructed according to 'functional criteria'.

The results of this study reveal that, despite the disruption of the normal anatomy of the larynx, in patients who underwent HOPLs (and aged with an operated larynx), laryngeal functions, in particular swallowing, are impaired but this did not significantly affect the quality of life, especially when compared to the laryngeal functions of elderly subjects who did not receive any procedures on the larynx.

Aspiration pneumonia, the most dangerous complication of HOPL, seems to be more frequent in the initial post-operative period and less so in subsequent years, thanks to the maintenance of temporary gastrostomy, prolonged chest therapy and rehabilitation of swallowing. Finally, injective laryngoplasty techniques can now offer effective solutions in the more dysphagic patients<sup>26</sup>.

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