Comparison between open partial laryngectomy with tube-free tracheostomy and total laryngectomy for hypopharyngeal cancer with cartilage invasion

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Abstract. The present study aimed to identify a feasible treatment strategy for hypopharyngeal cancer (HPC) with non-extensive invasion of the thyroid and/or cricoid cartilage. Between June 2008 and December 2014, patients with previously untreated HPC invading cartilage who had received either open partial laryngectomy (OPL) with tube-free tracheostomy or total laryngectomy (TL) with permanent tracheostomy and an artificial larynx (pneumatic tube) were retrospectively reviewed. The patients with extensive cartilage invasion and those with inoperable or T4b disease were excluded for OPL. Outcomes and quality of life were compared between the two treatment modalities. A total of 44 patients were included. The survival rates, complications, and Dysphagia Score were compared between the two treatment modalities. The outcome of the Voice Handicap Index (P=0.032), understandability of speech (P<0.001), normalcy of diet (P=0.041), senses (P=0.006), speech (P<0.001) and social contact (P=0.004) were significantly improved in the group receiving OPL compared with the group receiving TL. Therefore, OPL with tube-free tracheostomy may be a feasible option to treat patients with HPC with non-extensive invasion of the thyroid and/or cricoid cartilage.

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Introduction

Chemoradiation therapy (CRT) as a treatment for laryngeal cancer (LC) and hypopharyngeal cancer (HPC) has gained widespread acceptance as it has produced high rates of laryngeal preservation without compromising survival rates when compared with total laryngectomy (TL) (1-3). However, different conclusions (such as better results in terms of survival and/or local control achieved by surgery) were additionally drawn from other studies (4-6). Salvage laryngectomy was required in >50% of all patients with T4 [American Joint Committee on Cancer (AJCC) or Union for International Cancer Control] cancer (2,7). However, salvage laryngectomy may result in the loss of normal speech function and higher rates of postoperative complications (8). Strategies to preserve the larynx are not recommended for patients with T4a LC or T4a HPC, particularly those with cartilage invasion, and initial surgery is generally employed as the primary treatment method (9-11). A number of studies have revealed poorer local control and survival when treating LC or HPC with cartilage invasion by CRT compared with that when treated by initial surgery (9,12). High overall survival (OS) and laryngeal preservation rates have been reported for patients with T4 tumor with cartilage invasion treated with CRT (13), but the number of cases is small.

The most common location of HPC is the pyriform sinus (14). With regards to the anatomic structure, the incidence rates of thyroid or cricoid cartilage invasion in HPC should be higher compared with those in LC as HPC is often located or even concealed between the thyroid and cricoid cartilages (15). The treatment modalities for HPC and LC, therefore, should be different. In literature, various treatment modalities for partial laryngectomy were established for LC, but few were developed for HPC to avoid employing TL, including vertical hemilaryngopharyngectomy (VHLP) (16-18), supracricoid hemilaryngopharyngectomy (SCHLP) (19,20), extended supraglottic laryngectomy (ESGL) (21) and near-total laryngectomy (22). However, the oncologic and functional

outcomes of these surgical techniques have seldom been reported. Furthermore, HPC with simultaneous invasion of thyroid and cricoid cartilages is not infrequent from our clinical experiences (~39% of cartilage invasion in our series) (15). Additionally, the majority of open partial laryngectomy (OPL) procedures are usually used for non-extensive thyroid cartilage invasion (18-21), and there are a limited number of previous studies on the simultaneous invasion of thyroid and cricoid cartilages. TL and CRT are the procedures most often used for HPC with cartilage invasion, and these frequently cause unsatisfactory (either oncologic or functional) outcomes (9-11).

Long-term tube-free tracheostomy (TFT) results in a self-sustaining passage, which is established by a side-to-skin stoma between the trachea and the anterior neck skin (23). A side-to-skin tracheotomy may maintain adequate airway and allow the patient to phonate via remnants of laryngeal structures, simply by occluding the tracheal stoma (24-26). The present study aimed to identify a feasible treatment strategy for HPC invading the thyroid and/or cricoid cartilage by comparing the oncologic and functional outcomes and quality of life between OPL with TFT and TL with an artificial larynx (pneumatic tube).

Materials and methods

Patients. Between June 2008 and December 2014, patients with previously untreated squamous cell carcinoma (SCC) (as confirmed by biopsy) in the hypopharynx invading the thyroid and/or cricoid cartilage, who underwent either OPL or TL at E-DA Hospital (Kaohsiung, Taiwan) and had a >6-month postoperative follow-up were retrospectively enrolled. The mean follow-up was 45 months (range, 12-89 months). The exclusion criteria were i) inoperability (due to internal carotid artery encasement); ii) extensive thyroid cartilage invasion; iii) refusal of adjuvant radiotherapy (RT)/CRT; and iv) T4b (AJCC) disease. Patients with extensive cartilage invasion and those with inoperable or T4b disease were treated using TL or CRT. In addition, patients with invasion of the post-cricoid area crossing the midline, bilateral vocal cords or arytenoids, tracheal ring and the base of the tongue (>2 cm) were excluded for OPL treatment (but were treated with TL). In total, 44 patients were included and all of them were male. Tumor invasion to thyroid and/or cricoid cartilage was determined by computed tomography (CT) scans. Tumor staging was based on the guidelines of the AJCC (2002) (27). The protocol of the present study was approved by the Institutional Review Board of E-DA Hospital (EMRP-102-077).

Surgical procedure. Surgical procedures were grouped into two types: i) OPL with TFT and ii) TL with permanent tracheostomy, followed by voice rehabilitation with an artificial larynx (pneumatic tube). All patients received either adjuvant RT or CRT. OPL in the present study included ESGL, SCHLP and VHLP. In the present study, ESGL was used for HPC with involvement of the supraglottis, extralaryngeal space and the thyroid cartilage. SCHLP was used for HPC with involvement of the preepiglottic, paraglottic and extralaryngeal spaces, thyroid cartilage and unilateral vocal fold paralysis. In addition, VHLP was used for hemilarynx fixation or when invasion of the apex of the pyriform sinus and the cricoid cartilage was present. Uninvolved tissues were preserved to the fullest extent during ESGL, SCHLP and VHLP in order to aid repair and retain function. These tailored surgical techniques were developed in order to preserve postoperative function and may result in different postoperative functional outcomes. The major surgical procedures in the OPL group consisted of: i) Either ESGL, SCHLP or VHLP (Fig. 1), ii) reconstruction of the epiglottis by suturing the residual epiglottis to the preepiglottic tissue, tracheal mucosa or interarytenoid mucosa (Fig. 2); and iii) TFT (Fig. 3). A postoperative view of the flap and the myomucosal shunt following tailored VHLP with resection extending to a segment of the right cricoid cartilage is presented in Fig. 3B. Lung-powered shunt speech was produced by covering the tracheostoma with a finger.

Postoperative RT was administered to patients with AJCC pathological stage N1-3 and T3-4 disease (27). Postoperative CRT was administered to patients with extracapsular spread, involvement of the surgical margins and N2-3 stage disease. Postoperative adjuvant RT (1.8-2.0 Gy/day, 5 days/week; 13-35 days/total) was administered to each patient. The mean total dose was 60.1 Gy (range, 23.4-66.5 Gy). Weekly cisplatin (20-40 mg/m^2) and cisplatin (100 mg/m^2) for 4 to 8 courses were administered as postoperative chemotherapy.

Questionnaires and voice evaluation. All participants provided written informed consent and answered various questionnaires, which were evaluated >6 months after surgery. Dysphagia score (DS) was evaluated based on symptoms during food deglutition (28). Performance Status Scale for Head and Neck Cancer (PSSHN) was used to evaluate the understandability of speech, the normalcy of diet and the ability to eat in public, and was rated on a scale from 0 to 100, with 100 representing normal function (29). The Voice Handicap Index (VHI) was designed for all voice disorders (30). A VHI score of 0-30 represented a minimal/mild voice impediment, 31-60 a moderate degree and 61-120 a significant degree of impediment. The European Organization for the Research and Treatment of Cancer Core Quality of Life Questionnaire (EORTC QLQ-C30) is a widely used questionnaire for various types of malignancies, including head and neck squamous cell carcinoma (HNSCC) (31). The EORTC Head and Neck Quality of Life Questionnaire (QLQ-H&N35) was a specific questionnaire used for patients with HNSCC (32). The scores of the QLQ-C30 and of the QLQ-H&N35 were transformed to a scale of 0-100, with higher scores on the symptom or single item scales indicating poorer functioning, and higher scores on the functioning and global Quality of Life (QOL) scales indicating improved functioning.

Statistical analysis. Baseline characteristics between the two study groups were compared with Pearson's χ^2 test and independent Student's t-test for categorical and continuous variables, respectively. The survival curves were constructed using the Kaplan-Meier method. OS analysis was based on mortality from any cause. For the calculation of disease-specific survival (DSS), the patients were censored if the cause of mortality was not directly associated with HPC. Mann-Whitney U test was used to compare nonparametric variables. All statistical analyses were performed using the Stata statistical software (version 12.1; StataCorp LP, College Station, TX, USA).

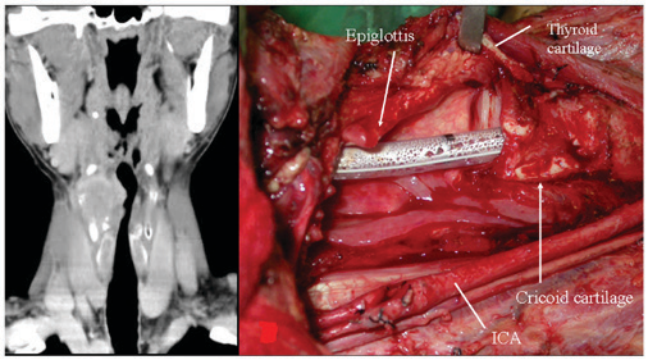

Figure 1. A 42-year old male with right pyriform sinus carcinoma. The left panel is a coronal computed tomography scan of the larynx showing erosions of thyroid and cricoid cartilages. The intraoperative view is presented in the right panel, which indicates residual epiglottis, thyroid cartilage and cricoid cartilage following tailored vertical hemilaryngopharyngectomy with resection including a segment of the cricoid ring. ICA, internal carotid artery.

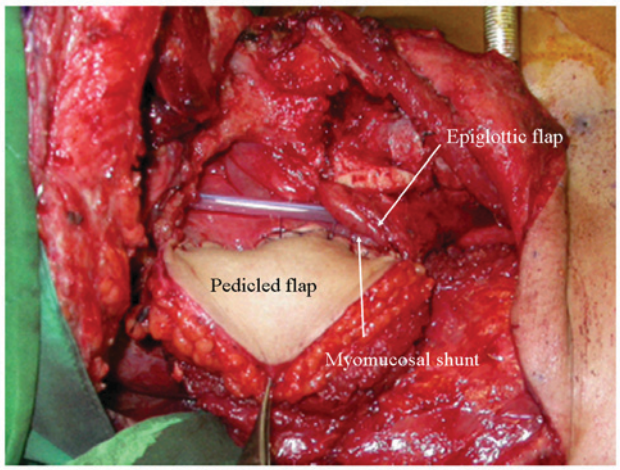

Figure 2. Image showing the construction of the epiglottis and the modification of the pectoralis major myocutaneous flap to create a myomucosal shunt and to repair the pharyngolaryngeal defect.

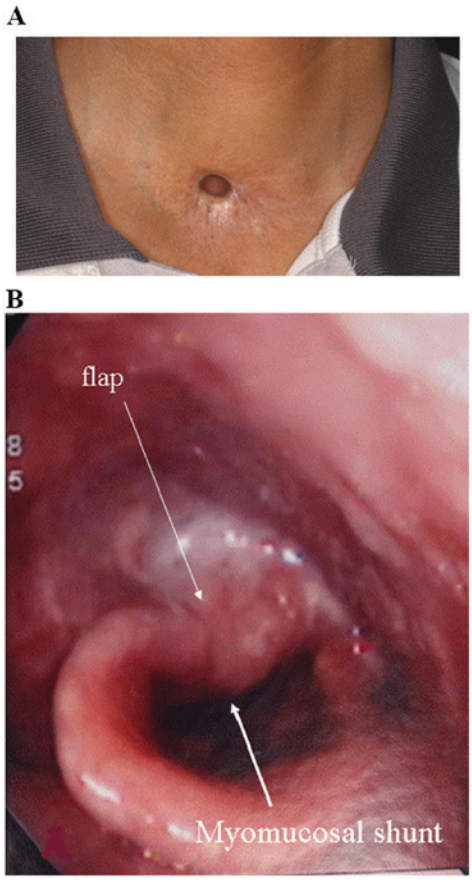

Figure 3. TFT was created by making an I-shaped incision over the anterior lower neck and a H-shaped incision over the anterior tracheal wall, followed by suturing the skin flap and the tracheal wall flap to the tracheal wall and the neck skin/subcutaneous tissue, respectively. (A) Postoperative appearance of the side to skin TFT. (B) Laryngeal view of the myomucosal shunt during phonation 25 months after surgery. TFT, tube-free tracheostomy.

Results

Associations between clinicopathological characteristics and type of surgery and survival rates. In the study groups, a majority of the patients were pT4a (all cT4a) and stage IV. There was a significantly increased number of patients with lymphovascular invasion observed in the OPL group compared with the TL group (P=0.003). All the cases in the two groups exhibited clinical invasion of the thyroid cartilage, but there was a significantly higher number of cases with simultaneous invasion of thyroid and cricoid cartilages in the TL group compared with the OPL group (P=0.005; Table I). With a mean follow-up of 45 months (range, 12-89 months), the 5-year OS was 65.8 and 72.6% in the OPL and TL groups, respectively (P=0.533), while the 5-year DSS was 72.0 and 84.7% (P=0.330). The OS and DSS rates between groups were not significantly different (Fig. 4). The most common second primary cancer in this cohort was oral cancer (4/44, 9.1%), followed by esophageal cancer (3/44, 6.8%), renal cancer (2/44, 4.5%), liver cancer (1/44, 2.3%) and thyroid cancer (1/44, 2.3%).

Complications and life quality between groups treated with TL and OPL. The questionnaires (DS and QLQ H&N 35) were completed in 19 cases in the OPL group and in 11 cases in the TL group. In the OPL group, one patient had fed using percutaneous gastrostomy prior to OPL due to ischemic bowel following operation, so he could not be evaluated for DS and swallowing. In the TL group, one patient could not be evaluated for DS due to neopharyngeal stenosis, and thus had fed with percutaneous gastrostomy. An additional two other patients could not be evaluated for VHI, including one with stomal stenosis requiring Teflon as a stent and the other with a stomal skin allergy to the prosthesis. The complications (Table II) and the results from DS and QLQ H&N 35 questionnaires (Table III) were revealed to be comparable between the two groups. However, results of VHI (P=0.032), understandability of speech (P<0.001) and normalcy of diet (P=0.041) from PSSHN, and senses (P=0.006), speech (P<0.001), social contact (P=0.004) and smell (P=0.005) from QLQ H&N 35 were all significantly improved in the OPL group compared with the TL group (Table III).

Discussion

The results of the present study revealed that 23 (85%) of the 27 patients in the OPL group and 16 (94%) of the 17 patients in

Table I. Baseline characteristics of patients with hypopharyngeal cancer in OPL and TL treated groups.

	Surgery (n= 44)		
Characteristics	OPL (n=27)	TL (n=17)	P-value
Age, years (mean ± SD)	54.9±11.1	54.6±11.4	0.945
pT classification (T3/T4a), n	4/23	1/16	0.634
pTNM stage (III/IV), n	2/25	1/16	>0.99
Thyroid and cricoid cartilage[a], n (%)	6 (22.2)	11 (64.7)	0.005
OPL (ESGL/SCHLP/VHLP), n	6/3/18	-	
Cricoidectomy, n (%)	18 (67)	-	
Adjuvant RT/CRT, n	13/14	10/7	0.477

[a]Simultaneous invasion of thyroid and cricoid cartilage. SD, standard deviation; CRT, chemoradiotherapy; ESGL, extended supraglottic laryngectomy; OPL, open partial laryngectomy; pT, pathological T stage; RT, radiotherapy; SCHLP, supracricoid hemilaryngopharyngectomy; TNM, tumor-node-metastasis; TL, total laryngectomy; VHLP, vertical hemilaryngopharyngectomy.

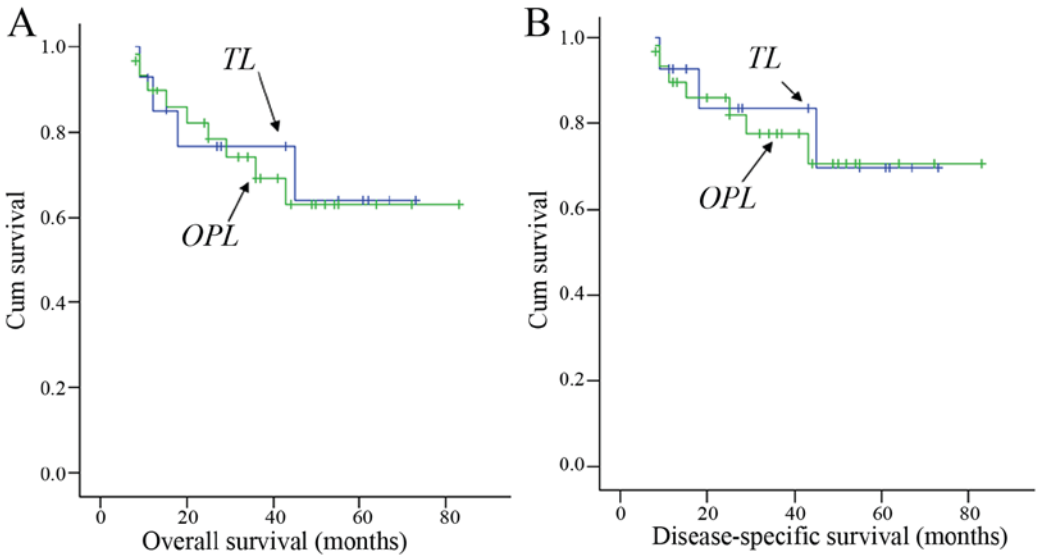

Figure 4. Comparison between survival rates of patients treated with TL and patients treated with OPL. (A) Overall survival and (B) disease-specific survival for the two treatment groups. TL, total laryngectomy; OPL, open partial laryngectomy.

the TL group with clinical invasion of thyroid and/or cricoid cartilage presented with pathologically confirmed cortical bone invasion. HPC has a more complex anatomic structure (lesions over the pyriform sinus and postcricoid mucosa frequently cannot be readily investigated by mere visual inspection) and less specific symptoms, which may cause delayed diagnoses and high rates of thyroid and/or cicoid cartilage invasion when compared with LC (15). These features also make treatment strategies for HPC different from those for LC. This accounts for why cricoidectomy is probably more frequently performed for HPC compared with LC. Advanced HPC with extensive invasion of the cartilage is difficult to treat with conventional OPL (16-19), and therefore, either TL or CRT is preferred. When TL and permanent tracheostomy are employed, laryngeal function and sensory function may be severely compromised (33). However, treatment with CRT may result in high rates of local recurrence (9,10,12), feeding tube dependence (34) and salvage laryngectomy (2,11).

In the present study, the partial resection of the cricoid cartilage was performed in 18 of 27 (67%) cases in the OPL group. In severe cases with total unilateral cordectomy, a tracheopharyngeal myomucosal shunt was created between the contralateral normal cord and a flap by tailoring the flap to precisely match the dimensions of the defect. To produce adequate lung-powered shunt speech, a narrow myomucosal shunt was required. However, oxygen supply was usually insufficient once a narrow myomucosal shunt had been created, so an additional oxygen supply provided by TFT or tracheostomy was necessary.

In the present study, TFT was performed by creating a superiorly based U-shaped and an inferiorly based inverted U-shaped flap on the anterior tracheal wall for the formation of a mucocutaneous junction between the trachea and the skin surface, which was a modification of the Bjork's tracheostomy flap (35). Several advantages of TFT compared with a standard tracheostomy include no irritation to the surrounding tissue by

Table II. Oncologic and functional outcomes and complications.

	Surgery		
Outcomes	OPL	TL	P-value
Hospitalization, days (mean ± SD)	27±6	31±10	0.114
Tumor recurrence, n (%)			
Local/regional	1/1 (3.7)	0/0	NA
Distant metastasis	6 (22.2)	1 (5.9)	0.220
5-year survival, %			
OS	65.8	72.6	0.533
DSS	72.0	84.7	0.330
Prognosis, n			
Alive without hypopharyngeal cancer	16	13	
Succumbed to hypopharyngeal cancer	6	1	
Succumbed to other causes	2	3	
Removal of NG			
Failure to remove NG, n (%)	3 (11.1)	5 (29.4)	0.227
Time to remove NG, days (mean ± SD)	58±51	35±33	0.181
Complications, n (%)			
Pneumonia[a]	1 (3.7)	0 (0.0)	>0.99
Flap failure	1 (3.7)	4 (23.5)	0.065
Stomal stenosis	4 (14.8)	3 (17.6)	>0.99
Postoperative hemorrhage	1 (3.7)	2 (11.8)	0.549

[a]Required admission for medical treatment within 1 year after surgery. DSS, disease-specific survival; NA, not available; NG, nasogastric tube; OS, overall survival; SD, standard deviation; TL, total laryngectomy; OPL, open partial laryngectomy.

the device, no risk of tube dislodgement, no monthly change of the tube, improved hygiene and speech without a tracheal tube (23,36). Therefore, the narrow myomucosal shunt was considered for better phonation, but the TFT was employed for providing a sufficient oxygen supply and for increasing QOL. In a number of patients with a sufficient oxygen supply, the tracheostoma may be closed completely. Extended and tailored radical surgery may impair many processes for swallowing, including tongue base retraction, neoglottic closure and hyolaryngeal anterior and vertical movement, which would easily result in aspiration (37). An epiglottis was constructed to prevent aspiration from the tracheopharyngeal myomucosal shunt.

In E-DA Hospital, adjuvant chemotherapy is administered at a lower dosage [weekly cisplatin (20-40 mg/m^2) and cisplatin (100 mg/m^2) for 4 to 8 courses] compared with that suggested by National Comprehensive Cancer Network (NCCN) guidelines, as morbidities and/or mortalities have been frequently encountered when following NCCN guidelines. Attempts have been made to administer adjuvant RT to patients according to NCCN guidelines, but due to complications and a lack of compliance, a complete course of adjuvant RT was not achieved in many patients. A positive margin was revealed in only one patient (pT4aN1M0) in the OPL group. The patient experienced distant metastasis 5 months following surgery and succumbed to mortality 4 months following distant metastasis. Adjuvant CRT was administered to the patient prior to surgery due to the presence of the positive extracapsular spread and a positive margin. In patients with a positive surgical margin, adjuvant CRT rather than adjuvant RT, was administered in E-DA Hospital, which is recommended by suggested by NCCN guidelines.

Locoregional recurrence rate (3.7%) in the present study was lower compared with those of the treatment results for CRT (12.5-28.0%) for advanced LC and HPC with or without cartilage invasion (6,7,9,12,13,34). However, the rate of distant metastasis (22.2%) in the OPL group was higher compared with that (5.9%) in the TL group and higher compared with those treated with CRT for LC or HPC with cartilage invasion in previously published studies (12,13), so more frequent follow-up for lung metastasis is suggested for patients receiving OPL, and aggressive treatment for lung metastasis is also recommended. During the follow-up, 2 patients with early lung metastasis were identified in the OPL group and immediate lung wedge resection for metastatic lung nodules were performed. These 2 patients were then followed up for 16 and 47 months following lung wedge resection and remain alive at present. A total of 6 patients with distant metastasis were identified in the OPL group. However, only 1 patient experienced local recurrence 6 months after surgery and distant metastasis occurred 3 months after local recurrence. Locoregional control was improved by a surgical treatment strategy with adjuvant RT/CRT. In addition, regional recurrence was reduced by bilateral neck dissections in patients with suspected neck metastasis.

Table III. Comparison of quality of life between OPL and TL.

	Surgery		
Questionnaires	OPL (n=19)	TL (n=11)	P-value
Dysphagia score	1.8±0.6	1.4±0.5	0.133
VHI	20.1±15.3	35.9±22.8	0.032
PSSHN			
EIP	80.3±21.4	68.2±35.5	0.475
UOS	86.8±12.8	25.0±35.4	<0.001
NOD	76.8±27.9	57.3±26.1	0.041
QLQ H&N 35 assessment			
Swallowing	14.8±12.3	22.0±28.0	0.747
Senses	15.8±18.8	39.4±20.2	0.006
Speech	26.2±24.1	65.2±17.6	<0.001
Social contact	2.9±4.1	12.3±10.3	0.004
Smell	21.0±25.4	57.5±33.8	0.005

EIP, eat in public; NOD, normalcy of diet; PSSHN, performance status scale for head and neck cancer; QLQ H&N 35, head and neck quality of life questionnaire; UOS, understandability of speech; VHI, voice handicap index; TL, total laryngectomy; OPL, open partial laryngectomy.

At E-DA Hospital, the regular annual follow-up images included chest x-rays, head and neck CT/magnetic resonance imaging (MRI) with contrast, abdominal ultrasound, bone scans and panendoscopy with NBI. If any abnormal finding was identified by chest x-ray, abdominal ultrasound or bone scans, then an abdominal CT, chest CT or bronchoscopy would be arranged. If recurrence or distant metastasis cannot be distinguished by these methods, positron emission tomography-CT would be arranged for further confirmation. Regular follow-ups at the outpatient department would be performed every 1-3 months in the first year, every 2-4 months in the second year, every 4-6 months in the third to fifth year and every 6-12 months after the fifth year. If recurrence or distant metastasis was suspected, abdominal ultrasound, chest x-ray, fiberscope, panendoscopy, abdominal CT, chest CT or head and neck CT/MRI would be arranged to rule out the disease.

The 5-year OS was 65.8 and 72.6% in the OPL and TL groups, respectively (P=0.533), while the 5-year DSS was 72.0 and 84.7% (P=0.330). The 5-year survival of the patients in the present study was higher compared with those reported in the literature (6,7,9,13,34). The survival outcomes do not indicate that patients treated with OPL have an improved prognosis compared with TL, or that patients treated with TL have a better prognosis compared with CRT, as patients with T4b stage disease and extensive cartilage invasion often receive either TL or CRT as primary treatment. The high survival rates in the OPL group were presumably due to the following reasons: i) Relatively non-extensive invasion of the base of the tongue and cartilage; ii) exclusion of patients with T4b and inoperable diseases; iii) surgical treatment strategy with adjuvant RT/CRT for raising local control; iv) treatment with bilateral neck dissections for reducing regional recurrence; v) inclusion of patients with early second primary tumor (1 case of early esophageal cancer and 1 case of esophageal high grade dysplasia with endoscopic submucosal dissection); vi) inclusion of patients with early lung metastasis (2 patients received lung wedge resection) and vii) shorter follow-up periods. Despite a low larynx preservation rate in the present cohort of patients due to the presence of tracheostoma, the treatment strategies with OPL and TFT may still achieve high rates of local control, survival and lung-powered shunt speech.

Of the 44 patients in the present study, only 1 patient presented with a positive margin in the OPL group. Distant metastasis was identified 5 months following surgery and the patient succumbed to HPC 9 months after surgery. It appears that the presence of a positive surgical margin may result in poorer survival rates. However, a cohort study with a large number of cases will be required in order to confirm the results.

In the OPL group, 1 patient with esophageal cancer (T1N0M0) received endoscopic submucosal dissection. In the TL group, 1 patient with esophageal cancer (T2N1M0) received CCRT, and the other patient with esophageal cancer (T1bN0M0) received an esophagectomy. The patient in the OPL group experienced distant metastasis 15 months following surgery and succumbed to HPC 16 months following surgery. In the TL group, 1 patient succumbed to HPC 45 months following surgery, and the other patient succumbed to mortality due to esophageal cancer-associated complications (gastric invasion with massive bleeding and pneumonia). As only 3 patients with HPC with second esophageal cancer were identified in the present cohort and only 1 of the 3 cases succumbed to esophageal cancer-associated complications, it was difficult to derive the survival impact from the 3 cases.

Removal of the NG tube failed in 3 (3/17; 11.1%) patients in the OPL group and 5 (5/17; 29.4%) patients in the TL group. In the OPL group, failure to remove the NG tube was presumably the result of esophageal cancer (T1N0M0) post-endoscopic submucosal dissection in 1 patient, old age (72 years) with partial resection of the base of the tongue and cricoid cartilage in 1 patient, and oncological failure (weakness following surgery and adjuvant CRT, distant metastasis 5 months after surgery and succumbed to mortality 4 months after distant metastasis) in 1 patient. In the TL group, failure to remove the NG tube was presumably caused by a failure in the reconstruction of pharyngeal defects (including 2 cases of upper esophageal defects) in 4 patients (2 cases with anterolateral thigh flap tubing, 1 case with radical ablative surgery and radial forearm free flap, 1 case with jejunal flap; followed by salvage deltopectoral flap or pectoralis major myocutaneous flap) and esophageal high grade dysplasia (over middle third of the esophagus) post-endoscopic submucosal dissection in 1 patient. Esophageal diseases, including HPC with upper esophageal involvement or esophageal tumor, were identified in 1 of the 3 patients in the OPL group and in 3 of 5 patients in the TL group, in whom the removal of the NG tube failed, indicating an association of esophageal diseases with a failure to remove the NG tubes. The DS was 1.8 and 1.4 in the OPL and TL groups, respectively (P=0.133). This indicated that coughing rarely occurred during liquid food deglutition in the two groups.

Generally, following the healing of the primary (pharyngolaryngeal) and cervical wounds and the completion of adjuvant

therapy, swallowing evaluation and rehabilitation would be arranged to assess the postoperative swallowing function and to assist with improving oral intake (using methods including position change and food selection). Azevedo *et al* (38) reported that the mean total scores of VHI following the treatment of advanced SCC of the larynx and hypopharynx were 24.0, 28.2 and 34.2 in patients who underwent PL, TL and total pharyngolaryngectomy, respectively. In addition, in another previous study where VHI was assessed in patients treated with CRT for advanced HPC, a majority of patients were observed to reveal mild or mild to moderate problems with speech rehabilitation (39).

In the present study, the mean VHI score for patients treated with OPL was 20.1, which was improved when compared with that obtained from the patients treated with TL (and not worse when compared with those treated with CRT) (39). According to the PSSHN results, patients who underwent OPL obtained higher mean scores compared with those who underwent TL for the categories, the understandability of speech (86.8 vs. 25.0; P<0.001) and normalcy of diet (76.8 vs. 57.3; P=0.041). This is consistent with previously published results (29). In the present study, patients treated with TL had increased sensory problems (P=0.006) and greater impairment with speech (P<0.001) compared with those treated with OPL, which was also consistent with previously published data (40). On the contrary, from a systemic review assessing the functional outcomes following pharyngolaryngectomy, successful speech outcomes are more likely to be achieved with surgical (namely, tracheoesophageal voice prosthesis) procedures compared with non-surgical techniques (41). The tracheoesophageal voice prosthesis is a good option, however there are a number of disadvantages, including the requirement for frequent replacements for a new tracheoesophageal voice prosthesis by surgical intervention under general anesthesia and complications, including wound infection, valve incompetence, formation of granulation tissue, aspiration of the prosthesis into airway and aspiration pneumonia (42,43).

Speech rehabilitation with tracheoesophageal voice prosthesis was not widely accepted in Taiwan in previous decades. Despite unsatisfactory intelligibility and speech quality, speech rehabilitation with an artificial larynx (pneumatic tube) was still more commonly used compared with tracheoesophageal voice prosthesis (44). In the present study, better social contact was also identified in the OPL group (P=0.004), which is consistent with previously published findings by Lee *et al* (40). Compared with the results on the subscales of swallowing, senses (smell, taste) and speech (with mean scores of 34, 34 and 31, respectively) as reported by Keereweer *et al*w39) in a study on the treatment of patients with CRT for advanced HPC, a markedly improved QOL with regards to swallowing and senses and a similar improvement in speech were identified in patients in the OPL group of the present study. Furthermore, an improved QOL with regards to swallowing was observed for patients receiving OPL and TL. The swallowing dysfunction may be attributed to the post-radiation pharyngolaryngeal edema, decreased tongue movement, decreased laryngeal elevation and epiglottic inversion. A number of surgical treatment modalities have been successfully applied to LC, but a limited number of procedures have been reported for advanced HPC with cartilage invasion. With regards to the modification of surgical interventions for preservation of more normal mucosa, tissue and cartilage (tailor made for each patient) for further repair, a combination of OPL and TFT may be an alternative procedure that can be successfully applied to treat selected cases of HPC with non-extensive cartilage invasion, which offers favorable functional outcomes and QOL without compromising survival. From clinical experiences, it was revealed that to survive and return to a normal life, numerous patients require pulmonary-driven speech and numerous patients require a working sense of smell and taste. The ability to detect gas leaks and toxic chemicals, and to differentiate fresh from spoiled food is also required by the majority of patients. To fulfill these requirements, OPL with TFT is a feasible treatment modality for the treatment of patients with HPC with non-extensive invasion of the thyroid and/or cricoid cartilage.

In the present study, patients in the TL group have a more severe invasion of thyroid and cricoid cartilages compared with those in the OPL group, thus it is not reasonable to compare the survival outcomes between the two treatment modalities. However, the result may reflect that the acceptable oncologic outcome is achievable by treatment with OPL and TFT. Furthermore, despite of the difference in patient selection, the comparative results may partially reflect that markedly improved functional outcomes of speech and senses of smell and taste may be achieved by treatment with OPL and TFT.

The QLQ H&N 35 questionnaires were completed by 30 of the 32 (93.8%) living patients in the present study. Due to the retrospective nature of the present study, 12 of the 44 (27.3%) patients had succumbed to mortality prior to completion of the study. Overall, response rates to the QLQ H&N 35 questionnaires were 19 out of 27 (70.4%) cases in the OPL group and 11 out of 17 (64.7%) cases in the TL group. Although the compliance rates were high, the response rates of the questionnaires were not.

There were a number of limitations to the present study, including differences in patient selection between TL and OPL groups, where patients in the TL group presented with a more severe invasion of thyroid and cricoid cartilages. Additionally, the response rates of the QLQ H&N 35 questionnaires were low, which makes it prone to selection bias and overoptimistic results. The study also involved a small number of cases and it was a non-randomized study. Furthermore, there was a lack of pre-treatment QOL scores. The follow-up periods were also relatively short, where the shortest follow-up was 12 months. Therefore a longer follow up period would provide a more accurate assessment of survival time, complications and QOL.

In conclusion, the main advantage of OPL with TFT includes good postoperative oncologic and functional outcomes, and QOL on the subscales of swallowing, speech, senses (smell) and social contact. Therefore, OPL with TFT is a feasible option to treat selected HPC cases with non-extensive invasion of the thyroid and/or cricoid cartilage.

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Availability of data and materials

The datasets used and analyzed during the present study are available from the corresponding author on reasonable request.

Authors' contributions

CFL and TZH conceived the study, analyzed the data, drafted the manuscript and revised the intellectual content. CCW performed data acquisition and interpretation, and drafted the manuscript. HHW performed data analysis and interpretation, and revised the manuscript for intellectual content. CFL designed and interpreted the data, and drafted the manuscript. BSL performed data interpretation and revised the manuscript. CYL performed data acquisition and interpretation, and drafted the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

All patients provided written informed consent. The protocol of the present study was approved by the Institutional Review Board of E-DA Hospital (EMRP-102-077).

Patient consent for publication

In the present study, no identifiable information was contained. The patient granted permission to publish unidentifiable images.

Competing interests

The authors declare that they have no competing interests.

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