Eur Arch Otorhinolaryngol (2014) 271:1149–1155
DOI 10.1007/s00405-013-2725-4

LARYNGOLOGY

Central-part laryngectomy is a useful and less invasive surgical procedure for resolution of intractable aspiration

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Received: 1 May 2013 / Accepted: 19 September 2013 / Published online: 18 October 2013

Abstract A novel narrow-field laryngectomy procedure known as central-part laryngectomy (CPL) for less invasive laryngeal diversion in patients with intractable aspiration is introduced. We conducted retrospective case reviews of 15 patients who underwent CPL. In this procedure, an area of the glottis including the mid-part of the thyroid cartilage and cricoid cartilage is removed to separate the digestive tract from the air way. The lateral part of the thyroid cartilage, the entire hypopharyngeal mucosa and epiglottis are preserved. The superior laryngeal vessels and nerve are not invaded. All fifteen patients were relieved of aspiration without major complications. In good accordance with cutting of the cricopharyngeal muscles and removal of the cricoid cartilage, postoperative videofluoroscopy demonstrated smooth passages of barium. Ten of 12 patients who had hoped to resume oral food intake became able to do so after CPL and two others also achieved partial oral deglutition. CPL is a useful procedure for treatment of intractable aspiration and offers considerable advantages over other laryngotracheal diversion procedures from the view point of oral food intake.

Keywords Larynx surgery · Less invasive laryngectomy · Aspiration · Intractable pneumonia · Swallowing

Introduction

Severe dysphagia not only prevents oral food intake, but also causes intractable pneumonia that can sometimes be life-threatening. Although initial therapy includes both nutritional support and swallowing rehabilitation, surgical treatments can also be considered for cases that are not improved satisfactorily by conservative approaches. Surgical treatments for severe dysphagia can be placed in two categories: those aimed at improvement of swallowing with preservation of laryngeal vocal function, and those aimed at prevention of aspiration by separating the airway from the digestive tract [1]. The latter type of surgery is indicated for patients with poor laryngeal function, poor activities of daily living (ADL), and little likelihood of recovery from aspiration by other means.

Several procedures for prevention of aspiration have been reported, and their efficacies evaluated [2]. Among them, total laryngectomy is able to completely separate the airway from the digestive tract and is also a widely practiced surgical technique for relief of intractable aspiration. After total laryngectomy, a simple pharyngeal tract is formed by cutting the cricopharyngeal muscle, i.e., the upper esophageal sphincter. Because cricopharyngeal myotomy has been reported to facilitate smooth passage of the swallowing bolus [3, 4], the pharyngeal tract after

A part of this study has been presented in 9th congress of European Laryngological Society in June 2012 in Helsinki.

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laryngectomy is able to accommodate oral food intake. For prevention of aspiration, procedures of narrow-field laryngectomy, i.e., conservative laryngectomy, which are less invasive than ordinary total laryngectomy for the treatment of laryngeal cancer have been reported [5, 6]. In narrow-field laryngectomy, resection is limited to the epiglottis, thyroid cartilage, cricoid cartilage and arytenoid cartilages. The hyoid bone, piriform sinus and posterior wall of the hypopharynx and thyroid gland are not invaded. The procedure is, however, still more invasive than other forms of surgery for prevention of aspiration, for example laryngotracheal diversions [7, 8], supraglottic closure [9], glottic closure [10, 11] and cricoidectomy [12, 13]. In these procedures, the laryngeal components are not removed. These less invasive procedures have, therefore, been widely indicated for treatment of intractable pneumonia, especially in children or elderly patients in poor general condition [14–16]. In particular, glottic closure and cricoidectomy are preferable for reducing the degree of surgical invasiveness, because the target area is relatively superficial.

To exploit the merits of both total laryngectomy and less invasive surgery, we have devised a new narrow-field laryngectomy procedure for removal of the cricoid cartilage with the glottis, cutting the cricopharyngeal muscle, but preserving the epiglottis, the entire hypopharyngeal mucosa and major vessels running into the larynx. This novel strategy, which we have termed central-part laryngectomy (CPL), is herein described for treatment of intractable pneumonia.

Methods

Patients

In this study, we retrospectively reviewed fifteen patients aged 23–80 years with intractable pneumonia, who were treated by CPL. Seven of them had cerebrovascular diseases, four had neurodegenerative disease, and the remaining four patients had suffered multiple injuries including the brain in a traffic accident, rheumatism affecting the cervical spine, disuse syndrome with a lung abscess or post-chemoradiation therapy for mesopharyngeal cancer. Preoperative information on the patients is given in Table 1. None of these fifteen patients had been able to take food or liquids orally for periods ranging from 3 to 48 months because of inability to swallow and suffered from recurrent pneumonia. Nine of the fifteen patients had been tracheotomized and cuffed tracheostomy tubes inserted preoperatively. All nine tracheotomized patients were unable to speak even they have tried to use speech canule with or without cuff, because severely aspirated saliva in the larynx and hypopharynx prohibited the expiration for the phonation. Other four of the fifteen patients were also unable to speak because of speech impediments and/or mental conditions. Twelve of the fifteen patients hoped to resume oral food intake, but the desires of three patients with regard to food intake were unclear because of mental or physical dysfunctions, including apraxia. Because of reduced laryngeal function or poor ADL, surgery to improve swallowing, for example laryngeal elevation [17] and cricopharyngeal myotomy [3], was not indicated.

Central-part laryngectomy (CPL)

CPL was carried out under general anesthesia with the patient supine in all cases. A six-centimeter vertical skin incision was made in the anterior midline of the neck just over the thyroid and cricoid cartilages (Fig. 1a). The bilateral sternohyoid muscles were moved aside to expose the anterior face of the thyroid and cricoid cartilages. The thyrohyoid muscle was cut at its attachment to the thyroid cartilage (Fig. 2a). A horizontal incision was made alongside the inferior edge of the cricoid cartilage, and the oral ventilation tube for anesthesia was replaced with a tube inserted via this incision. (Figs. 1b, 2b). If tracheotomy had been carried out before the operation, the incision was connected to the tracheostomy site by an anterior vertical incision to create an appropriate permanent tracheostoma. The lateral and posterior surfaces of the cricoid cartilage were elevated from the surrounding tissues.

In this process, the cricopharyngeal muscle was cut near the cricoid cartilage and the postcricoid region of the hypopharynx was preserved. Vertical incisions in the thyroid cartilage were made bilaterally medial to the oblique line to preserve the pyriform sinus of the hypopharynx and the thyropharyngeal muscle. (Figs. 1b, 2c). The anterior part of the thyroid cartilage was elevated in an upper-anterior direction together with the cricoid and arytenoid cartilages. (Figs. 1c, 2d, e). After cutting of the thyroid and cricoid cartilages in the anterior midline portion to observe the inner side of the larynx, a mucosal incision from the base of the epiglottis to the arytenoid region was made (Figs. 1d, 2f). This incision was advanced into the fat tissue and the thyroarytenoid muscle (Fig. 2g), and connected to the incision in the thyroid cartilage, finally allowing removal of the central part of the larynx, including the glottis (Figs. 2h, 3). The entire mucosa of the hypopharynx was preserved, leaving a three-to four-centimeter mucosal defect at the previous laryngeal entrance (Fig. 2i). This mucosal defect was closed by horizontal suturing with 4–0 PDS monofilament absorbable suture. (Figs. 1e, 2j). The sutured area was smaller and less tensioned than that

Table 1 Fifteen cases of severe dysphagia treated by central-part laryngectomy

No.	Age	Gender	Disorders causing dysphagia	Duration without oral deglutition (months)	Preoperative patient's conditions				Surgical complication	Postoperative nutrition
					Nutrition	Tracheotomy	Speech ability	Will for eating		
1	48	Female	Spinocerebellar ataxia	21	Gastrostomy tube	No	No	Yes	None	Oral food intakes (special food)
2	79	Male	Cerebral hemorrhage	11	Central vein catheter	No	No	Yes	None	Oral food intakes (ordinary food)
3	59	Male	Cerebral infarction Schizophrenia	3	Central vein catheter	No	Yes	Yes	None	Oral food intakes (ordinary food)
4	72	Male	Dementia with Lewy Bodies	12	Gastrostomy tube	No	No	No	None	Oral food intakes (special food) and Gastrotomy tube
5	66	Male	Cerebral hemorrhage	8	Gastrostomy tube	Done	No	Yes	Stomal minor hemorrhage	Oral food intakes (special food) and Gastrotomy tube
6	63	Male	Parkinson disease	5	Gastrostomy tube	No	No	Yes	None	Oral food intakes (special food)
7	63	Male	Systemic high energy trauma Acute epidural hematoma	8	Jejunal tube	Done	No	Yes	None	Oral food intakes (ordinary food)
8	78	Female	Rheumatism affecting cervical spine	5	Gastrostomy tube	Done	No	Yes	None	Oral food intakes (ordinary food)
9	23	Female	Hypoglycemic encephalopathy	48	Gastrostomy tube	Done	No	No	Temporary granulation around stoma	Gastrotomy tube
10	77	Male	Cerebral hemorrhage	5	Gastrostomy tube	Done	No	No	None	Gastrotomy tube
11	58	Male	Amyotrophic lateral sclerosis	5	Gastrostomy tube	Done	No	Yes	None	Oral food intakes (special food) and Gastrotomy tube
12	80	Male	Disuse syndrome with lung abscess	3	Nasogastric tube	Done	No	Yes	None	Oral food intakes (ordinary food)
13	67	Male	Pharyngeal cancer chemoradiation	12	Gastrostomy tube	Done	No	Yes	None	Oral food intakes (ordinary food)
14	82	Male	Cerebral infarction	5	Gastrostomy tube	No	Yes	Yes	None	Oral food intakes (ordinary food)
15	51	Male	Cerebral infarction	7	Gastrostomy tube	Done	No	Yes	None	Oral food intakes (special food)

after total laryngectomy. A drainage tube was placed in the wound, a permanent tracheostoma was made at the first tracheal cartilage ring, and the skin incision was closed (Fig. 1f).

In CPL, the tissues removed from around the glottis are limited in comparison with standard total laryngectomy (Fig. 4). The thyroid gland, strap muscles without the thyrohyoid muscle, superior laryngeal vessels and nerve, and the entire hypopharyngeal mucosa are not involved in the procedure.

Results

In all fifteen cases, the amount of hemorrhage during surgery was <50 ml and there was no postoperative bleeding.

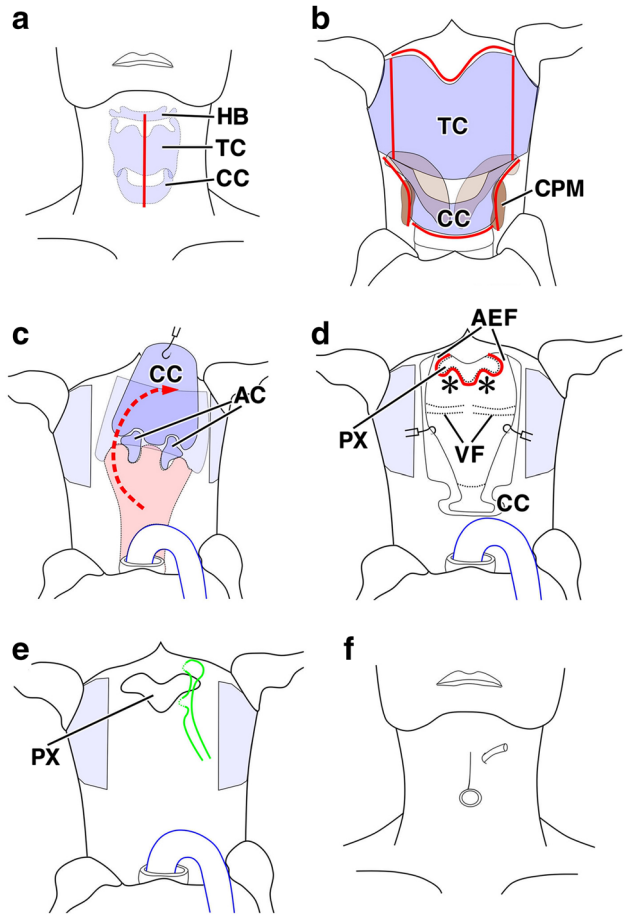

Fig. 1 Schematic drawings of central-part laryngectomy. **a** A six-centimeter vertical skin incision is placed in the midline of the anterior neck. *HB* hyoid bone, *TC* thyroid cartilage, *CC* cricoid cartilage. **b** Medial part of thyroid cartilage (*TC*) and whole cricoid cartilage are involved in resection with cutting of the cricopharyngeal muscle (*CPM*). **c** Cricoid cartilage (*CC*), arytenoid cartilages (*AC*) and medial thyroid cartilage with the glottis are elevated in an upper direction with preservation of the entire postcricoid mucosal tissue of the hypopharynx. **d** To make an incision line between the base of the epiglottis and the arytenoid region (*asterisks*) alongside the aryepiglottic fold (*AEF*), the glottic part of the larynx is incised at the anterior midline and the vocal folds (*VF*) are orientated. *CC* cricoid cartilage, *PX* pharynx. **e** After removal of the central part of the larynx, the former laryngeal entrance is retained in front of the pharynx (*PX*) and closed using Gambee sutures (*green line*). **f** A drainage tube is placed, and a permanent tracheostoma is created at the first tracheal ring

The operation time ranged from 70 to 110 min. Individual activities of daily living recovered to those preoperatively within 3 days. There were no major complications such as worsening of the pneumonia and wound infection. Postoperative endoscopy demonstrated a simple suture line beneath the epiglottis and no artificial scarring at the entrance of the hypopharynx (Fig. 5a).

Videofluoroscopy was carried out on postoperative days 7–10. Swallowing function was not evaluated in three patients because of apraxia. In the other twelve patients, on the basis of individual preoperative swallowing dysfunction in the pharyngeal phase, there were various degrees of postoperative swallowing disability in the pharyngeal phase with a delayed swallowing reflex. However, safe passage of barium through the widened hypopharynx was achieved in all cases (Fig. 5b), with aspiration having been completely eliminated as a result of CPL. Even in the patients who had poor pharyngeal clearance, repeated swallowing finally moved all of the barium into the esophagus without aspiration. Currently, the esophageal phase is almost normal in these twelve patients, including those with spinocerebellar ataxia and amyotrophic lateral sclerosis.

After the videofluoroscopy, thirteen of the fifteen patients started to drink liquids, and then tried to take food orally. The remaining two patients, whose intension to take oral food had been unclear preoperatively, were unable to try oral intake. A patient suffering from dementia with Lewy bodies who had also shown little motivation in the preoperative period, tried to resume oral food intake after the operation due to strong encouragement from his family. The former thirteen patients were finally capable of oral food intake (Table 1). In ten cases, supply of total nutrition was possible by oral deglutition. In the other three, nutrition was supplied by a combination of oral deglutition and gastric tube feeding.

Discussion

The purpose of CPL is to create a simple pharyngeal tract by cutting the cricopharyngeal muscle, i.e., upper esophageal sphincter, while preserving the thyropharyngeal muscle, constriction of which generates the force for deglutition. To ease the passage of a swallowing bolus through the hypopharynx, this strategy needs to remove the anterior part of the thyroid cartilage and the entire cricoid and arytenoid cartilages, while preserving the lateral part of the thyroid cartilage and the entire hypopharyngeal mucosa. This allows not only easy passage of the swallowing bolus, but also reduces the length and tension of the pharyngeal sutures in comparison with previous narrow-field and ordinary total laryngectomy. The suture line corresponds to the previous laryngeal entrance, i.e., the diversion point between the air way and the digestive tract. In addition, this procedure allows formation of a stable permanent tracheostoma at the level of the first tracheal ring, irrespective whether or not a tracheotomy has been performed.

An additional merit of CPL in comparison with both narrow-field and ordinary total laryngectomy is that it preserves both the epiglottis and the superior laryngeal nerve. In the postoperative barium swallow test, thirteen

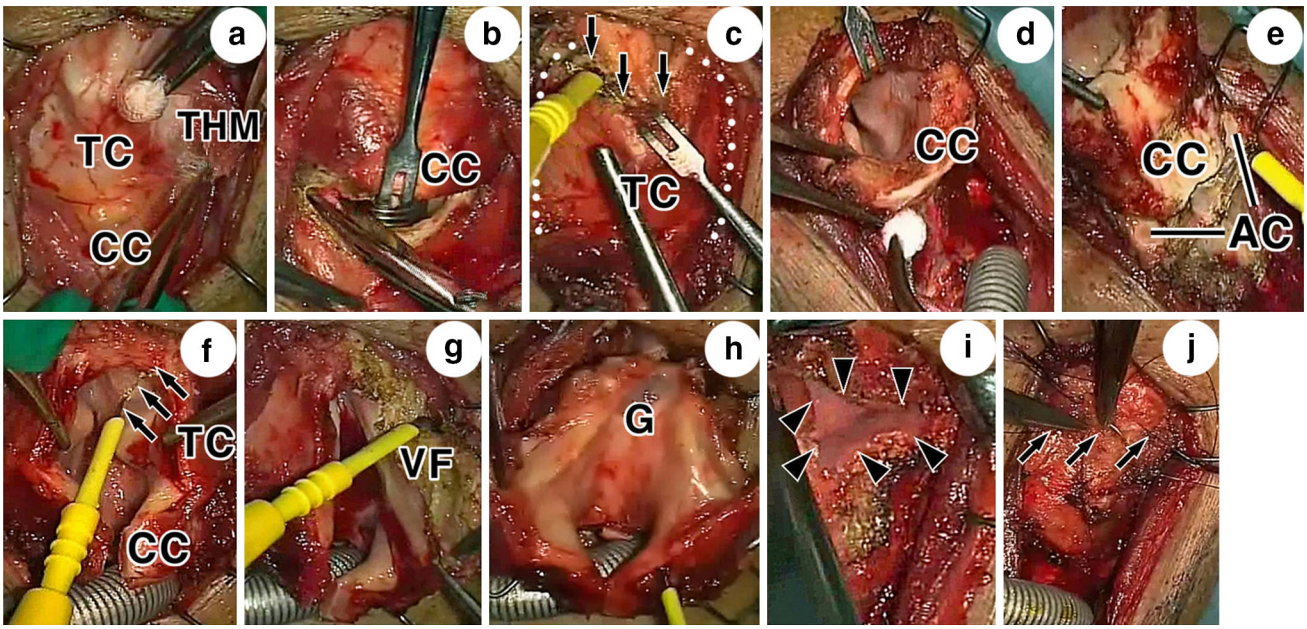

Fig. 2 Photographs of central-part laryngectomy (*CPL*). **a** The anterior aspect of the larynx is exposed and the thyrohyoid muscle (*THM*) is detached from the thyroid cartilage. *TC* thyroid cartilage, *CC* cricoid cartilage. **b** An incision is placed at the inferior edge of the cricoid cartilage as the caudal border of resection. **c** Incision lines are also marked at the superior edge (*arrows*) and medial region of the oblique line (*dotted line*) of the thyroid cartilage. **d** The cricoid cartilage is elevated and the postcricoid tissue is preserved with the perichondrium. **e** The arytenoid cartilages (*AC*) are also elevated together with the cricoid cartilage. **f** After cutting along the anterior midline of the cricoid and thyroid cartilages, the incision line is marked from the base of the epiglottis to the arytenoid region (*arrows*). **g** The incision is advanced into the fat tissue of the vestibular fold (*VF*) and thyroarytenoid muscle, but does not reach the pyriform sinus. **h** The central part of the larynx including the glottis (*G*) is ready to be removed. **i** After removal of the central part of the larynx, a small mucosal defect remains at the former laryngeal entrance (*arrowheads*). **j** Only three to four centimeters of mucosal suturing is needed to close the pharyngeal space (*arrows*)

patients who had achieved oral food intake had some degree of swallowing reflex. This finding suggests that supraglottic sensation using the epiglottis and superior laryngeal nerve can help to modulate the swallowing reflex after CPL.

Several surgical procedures for complete prevention of intractable aspiration have been established, namely laryngotracheal diversion and tracheoesophageal anastomosis [7, 8], glottal closure [10, 11], supraglottic closure [9], cricoidectomy [12, 13] and standard total laryngectomy [3, 4]. Among these procedures, the CPL reported here has the merits of both glottal closure and total laryngectomy, and is similar in concept to subepithelial cricoidectomy. For glottal closure, CPL can be carried out in a small surgical area and preserves both the superior laryngeal nerve and epiglottis with the expectation of retaining the ability to initiate a swallowing response. On the other hand, as is the case in standard total laryngectomy, CPL creates a simple pharyngeal tract by cutting the cricopharyngeal muscle, allowing easy passage of the swallowing bolus. In CPL, the resected portion of the larynx is larger than in cricoidectomy. However, the suturing at the former laryngeal entrance is simpler, and allows greater distension than suturing of the subglottic area in cricoidectomy.

Because surgery to prevent aspiration is not aimed directly at improvement of swallowing function, it is difficult to predict whether oral food intake will be achieved. The outcome in this respect will be influenced by not only motor and sensory palsy but also activities of daily living and the psychiatric condition of the patient. Under certain conditions, however, patients should be allowed to attempt oral food intake after surgery to separate the airway from the digestive tract. In the present series, ten of twelve patients who had hoped to resume oral food intake and underwent CPL achieved total oral deglutition and were able to stop using a gastrotomy tube; and other two also achieved a degree of oral deglutition of food and drink together with tube feeding. Oral food intake, however small, is important for gaining a sufficient quality of life, and as CPL offers this possibility, it is recommended.

Among surgical procedures for prevention of aspiration, laryngotracheal diversion with tracheoesophageal anastomosis is, like CPL, similarly less invasive. However, CPL has an advantage in allowing easy access to the surgical area, which is located more superficially in the upper region of the anterior neck. Especially in elderly patients, the hyoid bone assumes a more inferior position with increasing age [18] and the positions of the larynx and trachea tend to become more caudal. This makes it more

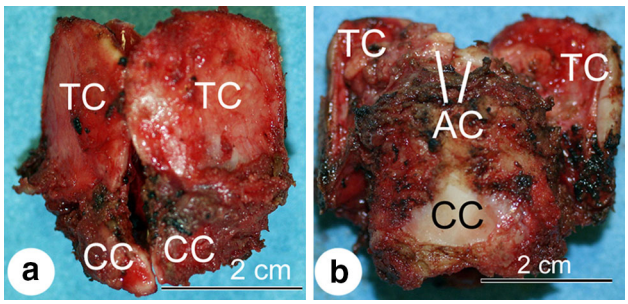

Fig. 3 Photographs showing anterior (**a**) and posterior (**b**) views of the resected central part of the larynx. The resected central part of the larynx with the glottis is composed of the whole cricoid cartilage (*CC*), arytenoid cartilages (*AC*) and medial part of the thyroid cartilage (*TC*)

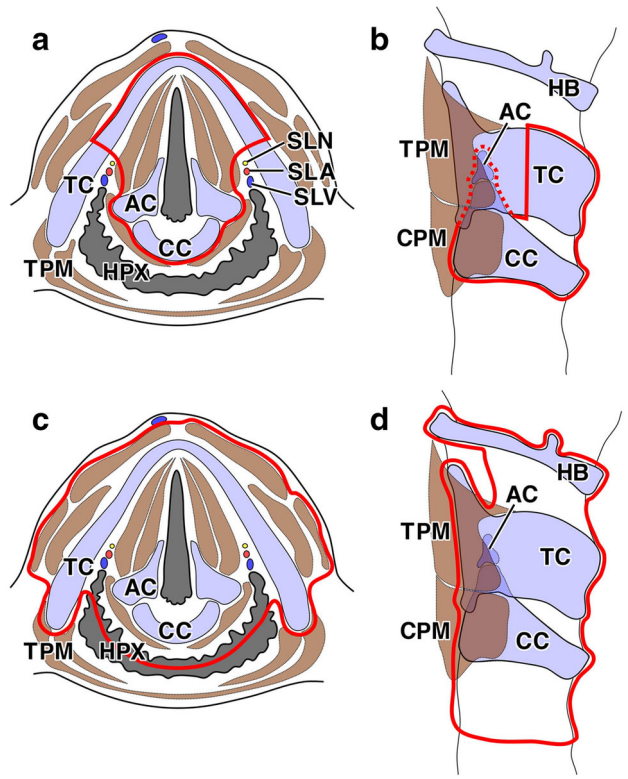

Fig. 4 Tissues removed in central-part laryngectomy (**a**, **b**) and standard total laryngectomy (**c**, **d**). **a**, **c** Horizontal cut views through the glottic plane. **b**, **d** Lateral view diagrams. **a**, **b** Tissue removed in central-part laryngectomy is encircled by a *red line*. The whole hypopharynx (*HPX*), lateral part of the thyroid cartilage (*TC*), and thyropharyngeal muscle (*TPM*) are preserved. The superior laryngeal nerve (*SLN*), artery (*SLA*) and vein (*SLV*) are also preserved. The whole cricoid cartilage (*CC*) and arytenoid cartilages (*AC*) are removed, and the cricopharyngeal muscle (*CPM*) is cut. *HB* hyoid bone. **c**, **d** Tissue removed tissue in standard total laryngectomy is encircled by a *red line*. All of the cartilages in the larynx (TC, CC, AC) are removed, along with part of the hypopharynx (*HPX*). Both the thyropharyngeal muscle (*TPM*) and cricopharyngeal muscle (*CPM*) are cut

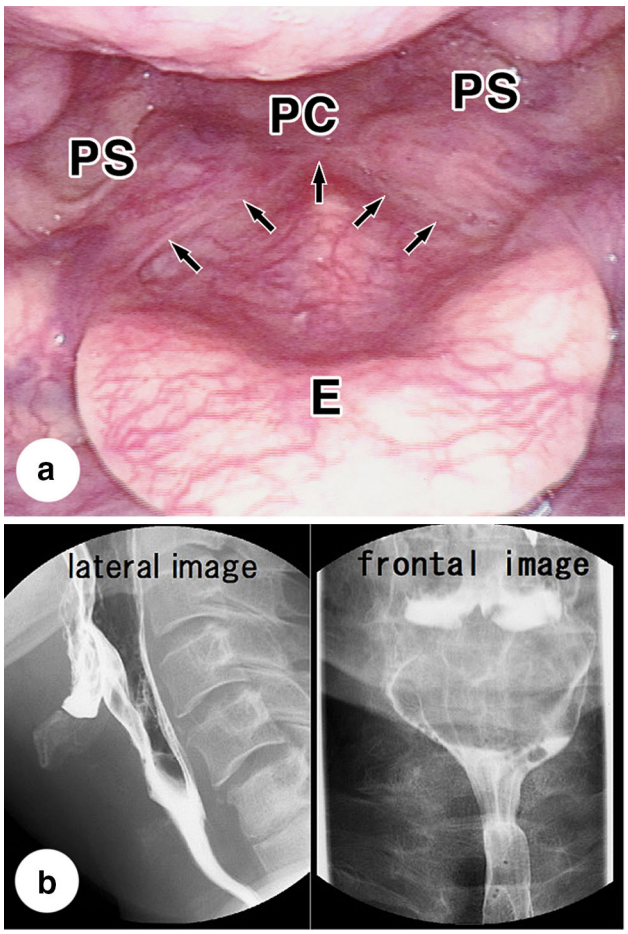

Fig. 5 Fiberoptic views of the entrance of the hypopharynx (**a**) and videofluoroscopy (**b**) after central-part laryngectomy. **a** The suture line at the former laryngeal entrance is seen (*arrows*). The postcricoid (*PC*) and pyriform sinus (*PS*) of the hypopharynx are preserved. *E* epiglottis. **b** Videofluoroscopy shows smooth passage of barium and a wide hypopharyngeal space

difficult to access the surgical area for laryngotracheal diversion in comparison with CPL. CPL also has an advantage over laryngotracheal diversion with regard to passage of the swallowing bolus because the cricopharyngeal muscle is cut, along with removal of the cricoid cartilage. Especially in the case of the tracheal blind pouch created by laryngotracheal diversion without tracheoesophageal anastomosis, the barium swallowing test shows residual liquid in the blind pouch until drainage has been completed [19]. On the other hand, CPL is not a reversible procedure and thus vocal function is permanently lost. For this reason, laryngotracheal diversion is more suitable for younger patients who may recover from aspiration [14].

Postoperative vocal loss is an anticipated demerit of narrow-field laryngectomy including CPL. For patients without aphasia and dysarthria, post-laryngectomy voice rehabilitation should be considered to allow some quality of life to be regained [20]. We have considered vocal

rehabilitation for patients treated by CPL in this series. Up to the time of writing, however, only three patients have been able to start vocal rehabilitation using electrolaryngeal speech. Because of their poor general condition, including several forms of motor palsy or mental problems, twelve patients have been unable to start vocal rehabilitation. However, vocal rehabilitation for these patients may still become possible after their general condition has improved and intractable pneumonia resolved. If this proves possible, we will likely select electrolaryngeal speech because it is easier to learn and no additional surgical procedure is necessary. As a secondary choice, tracheoesophageal shunt speech also has the benefit of being easily achievable, and is suggested to be equivalent to esophageal speech that is also available after the CPL, being better than electrolaryngeal speech in terms of voice-related quality of life [21]. Furthermore, establishment of a combination of CPL and tracheoesophageal voice restoration; namely, performing the tracheal esophageal puncture and inserting a speech valve at the end of the procedure of CPL, may overcome the demerits of CPL and rescue many patients from intractable pneumonia with preservation of their vocal functions.

Conclusion

CPL is a safe and useful procedure for prevention of intractable pneumonia. Because the surgical area is limited in comparison with other laryngectomy methods and minimal pharyngeal suturing is needed, complications related to surgery are expected to be decreased. The technique also offers the possibility of oral food intake by preserving the thyropharyngeal muscle and superior laryngeal nerve and removing the cricopharyngeal muscle. This surgery is not reversible for laryngeal structures but is preferable in adult cases of intractable aspiration when recovery of laryngeal protective function is not anticipated.

Conflict of interest The authors have no conflicts of interest to declare.

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