SURGICAL VOICE REHABILITATION AFTER TOTAL LARYNGECTOMY AND STAFFIERI'S PROCEDURE — H.D. VUYK

SURGICAL VOICE REHABILITATION AFTER TOTAL LARYNGECTOMY AND STAFFIERI'S PROCEDURE

H.D. Vuyk

SURGICAL VOICE REHABILITATION AFTER TOTAL LARYNGECTOMY
AND STAFFIERI'S PROCEDURE

VRIJE UNIVERSITEIT TE AMSTERDAM

SURGICAL VOICE REHABILITATION AFTER TOTAL LARYNGECTOMY AND STAFFIERI'S PROCEDURE

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van
doctor in de geneeskunde
aan de Vrije Universiteit te Amsterdam,
op gezag van de rector magnificus
dr. P.J.D. Drenth,
hoogleraar in de faculteit
der sociale wetenschappen,
in het openbaar te verdedigen op
vrijdag 13 september 1985 te 15.30 uur
in het hoofdgebouw der universiteit,
De Boelelaan 1105

door

HERMANUS DIRK VUYK

geboren te Madrid (Spanje)

1985
DRUKKERIJ J.H. PASMANS B.V., 's-GRAVENHAGE

Promotor: Prof. dr. G.B. Snow

Copromotor: Dr. R.M. Tiwari

Referent: Prof. dr. G.J. Hordijk

This study has been carried out at the Departments of Otolaryngology, Physiology and Gastro-enterology of the Free University, Amsterdam, The Netherlands.

Part of this work was financially supported by:
Entermed B.V., Lameris Instrumenten B.V. and Hilekes B.V.

This manuscript was typed by Ms. G.C. Buys, Ms. P.M. Elswijk, Ms. O.C. von Freytag Drabbe and Ms. H.C. Starink.
Illustrations were made by R. de Haan.

To all who have contributed to this work, including our patients

CONTENTS

INTRODUCTION

The last 25 years have witnessed a growing interest in attempts at surgical rehabilitation of voice after total laryngectomy. These efforts should be judged against the background of the considerable variation of the successful rehabilitation of patients with the aid of esophageal speech. In 1975 Watts reported a success rate of 64% with esophageal voice in a series of 3000 patients. In the literature the reported percentages vary from 50 to 85 (Martin, 1963; Hunt, 1964; de Beule & Damste, 1972; Gilchrist, 1973; Sako et al 1974). According to Savary (1977) these variations may be the result of differences in the organization concerning the rehabilitation of laryngectomees.

The methods of surgical voice restoration can be classified basically into two groups: one, that is exclusively directed at the restoration of voice after total laryngectomy and the other which attempts to preserve the respiratory function of the larynx as well (Arslan & Serafini, 1972). The second group of methods is used only in very few centres in the world and will not be discussed in this thesis.

The object of all surgical methods for restoration of voice is to create a communication between the air- and the food passages in order to facilitate the expiratory volume of air to enter the pharynx, thereby bringing it into vibration. The upper esophageal sphincter is probably the main sound source, functioning in essentially the same way as in esophageal speech. The source of energy in surgical methods is provided by the lungs. In this respect the surgical method is more physiological. Although in the past functional voice has been achieved in a significant number of patients, these methods have failed to be generally accepted in surgical practice for two reasons. One was the frequent leakage of saliva and food into the trachea. The other was the possibility of stenosis of the tracheo-pharyngeal or tracheo-esophageal shunt. More recently some methods have become available which from reports in the literature appear to overcome these difficulties to a large extent. Firstly there is Staffieri's method (1969) where a so-called neoglottis is created immediately following total laryngectomy. A second group of techniques rely on a prosthesis which is placed in a tracheo-esophageal fistula with the object of overcoming the problems of salivary leakage through the fistula and stenosis of the fistula. The prosthesis serves as a "one-way valve" permitting the entry of air from the lungs into the pharynx only (Singer & Blom, 1980; Panje, 1981; Nijdam et al, 1982).

At the department of Otolaryngology of the Academic Hospital of the Free University of Amsterdam, during the period from May 1979 till July 1983, 42 patients underwent a surgical rehabilitation of voice following Staffieri's technique after total laryngectomy for cancer. The main purpose of the present study is the evaluation of the results of this technique in the above mentioned patients.

In Chapter I a review of the various methods of surgical rehabilitation of voice is presented. In Chapter II the method of Staffieri is described and the technique and patient selection criteria are discussed. In Chapter III the results and complications of Staffieri's method are discussed in relation to our patient material. These are compared with the results from other centers as reported in the literature.

In Chapter IV the voice obtained with the Staffieri method of surgical voice rehabilitation after total laryngectomy is objectively described in terms of selected acoustic and aerodynamic parameters. These data have been compared to data of normal speech, esophageal speech and speech through other methods of surgical voice restoration as mentioned in the literature. Previous investigators of alaryngeal voice focussed largely on quantifying either the acoustic measures for fundamental frequency, vocal intensity and/or duration or the aerodynamic measures for necessary pressure and airflow. Studies using both acoustic and aerodynamic parameters simultaneously registered are scarce (Damste, 1958; Snidecor, 1968; Jach et al, 1978, 1979). In our opinion the measurement of both acoustic and aerodynamic parameters simultaneously allows for a better understanding of the mechanism underlying the sound production. Besides, if the aerodynamic parameters are reported in relation to sound intensity a better comparison to other methods of alaryngeal speech should be possible.

In Chapter V the results of the manometric examination of the pharynx and upper esophagus in our group of patients are mentioned. This investigation was done to obtain information regarding the function of the pharynx and the upper esophagus in patients after laryngectomy with Staffieri's technique. The last investigation was especially directed to look for an answer to the problems of aspiration in some patients. As there is substantial evidence that the upper esophageal sphincter is the main sound source in Staffieri patients, we also studied the relation between the upper esophageal sphincter function and the aerodynamic parameters of speech.

REFERENCES

ARSLAN, M. & SERAFINI, I. Restoration of laryngeal function after total laryngectomy: Report of the first 25 cases. Laryngoscope 82: 1349-1360, 1972.

BEULE, G. de & DAMSTÉ, P.H. Rehabilitation following laryngectomy; the results of a questionnaire study. Br. J. Dis. Comm. 7: 141-147, 1972.

DAMSTÉ, P.H. Oesophageal speech after laryngectomy. Thesis Groningen, 1958.

GILCHRIST, A.G. Rehabilitation after laryngectomy. Acta Otolaryngol. 75: 511-518, 1973.

HUNT, R.B. Rehabilitation of the laryngectomee. Laryngoscope 74: 382-395, 1964.

JACH, K., MOZOLEWSKI, E., ZIETEK, E., TARNOWSKA, C. & MIKOSZA, H. Evaluation of physical parameters of shunt phonation in the laryngectomees. Ann. Ac. Med. Stetinensis suppl. 15, 24: 43-55. PZWL Warszawa (Poland), 1978.

JACH, K., MOZOLEWSKI, E. & ZIETEK, E. Physikalische kennwerte der vokalfistel-phonation bei laryngektomierten. HNO-Praxis 4: 276-283, 1979.

MARTIN, H. Rehabilitation of the laryngectomee. Cancer 16: 823-841, 1963.

NIJDAM, H.F., ANNYAS, A.A., SCHUTTE, H.K. & LEEVER, H. A new Prosthesis for Voice Rehabilitation after Laryngectomy. Arch. Otorhinolaryngol. 237: 27-33, 1982.

PANJE, W.R. Prosthetic vocal rehabilitation following laryngectomy — The voice button. Ann. Otol. Rhinol. Laryngol. 90: 116-120, 1981.

SAKO, K., CARDINALE, S., MARCHETTO, F.C. & SHEDD, D.P. Speech and vocational rehabilitation of the laryngectomized patient. J. Surg. Oncol. 6: 197-202, 1974.

SAVARY, P. Vocal and social situation of laryngectomees. Laryngoscope 87: 1516-1522, 1977.

SINGER, M.I. & BLOM, E.D. An endoscopic technique for restoration of voice after laryngectomy. Ann. Otol. Rhinol. Laryngol. 89: 529-533, 1980.

SNIDECOR, J.C. Speech rehabilitation of the laryngectomized. Second edition, Charles C. Thomas, Springfield, Illinois, 1968.

STAFFIERI, M. Laringectomia totale con ricostruzione di glottide fonatoria. Communicazione preliminare. Boll. Soc. Med. Chir. Bresciana, 1969.

WATTS, R.F. Total rehabilitation of laryngectomees. Laryngoscope 85: 671-673, 1975.

Chapter I

REVIEW OF PAST AND CONTEMPORARY TECHNIQUES

INTRODUCTION

Surgical attempts to restore speech after total laryngectomy, date back to 1873, when Billroth performed the first total laryngectomy for cancer, in Vienna (Gussenbauer, 1874). Up to the Second World War hardly any progress was made in the field of surgical voice rehabilitation after total laryngectomy, except for some individual attempts (Guttman, 1935).

This review of surgical voice rehabilitation techniques after total laryngectomy is confined to the postwar period. Details of the early history of this subject can be found in the monographs of Arnold (1960), Lebrun (1973) and Lowry (1981).

The methods of surgical voice rehabilitation after total laryngectomy can be categorized in two main groups:

1. Methods involving the creation of an external fistula.
   With these methods a prosthesis is used in every case to connect a pharyngo-cutaneous or esophago-cutaneous fistula to the tracheostoma.
2. Methods involving the creation of an internal fistula.
   Within this group a distinction is usually made between tracheo-hypopharyngeal fistulas and tracheo-esophageal fistulas, both with or without a prosthesis. Although this distinction is followed in this review, it is felt that this is somewhat arbitrary.

METHODS WITH AN EXTERNAL FISTULA

Briani (1952, 1958) might be considered a notable pioneer in developing controlled surgical fistulas to direct expired air from the trachea to the pharynx for purposes of phonation. His early technique involved a pharyngo-cutaneous fistula created by means of a tunneled anterior neck flap (figure 1 abc). In 1958 he published on a modification of his concept of voice rehabilitation which consisted of a direct fistula from the neck into the hypopharynx (figure 1d). By means of a sophisticated prosthesis, which externally connected the pharyngo-cutaneous fistula and the tracheostoma, the patient was able to divert pulmonary air into the hypopharynx during expiration. The expired air flow activated vibrations in the pharyngeal walls. The resultant sound, or voice, was articulated and resonated as it continued through the oral and nasal cavities (figure 2).

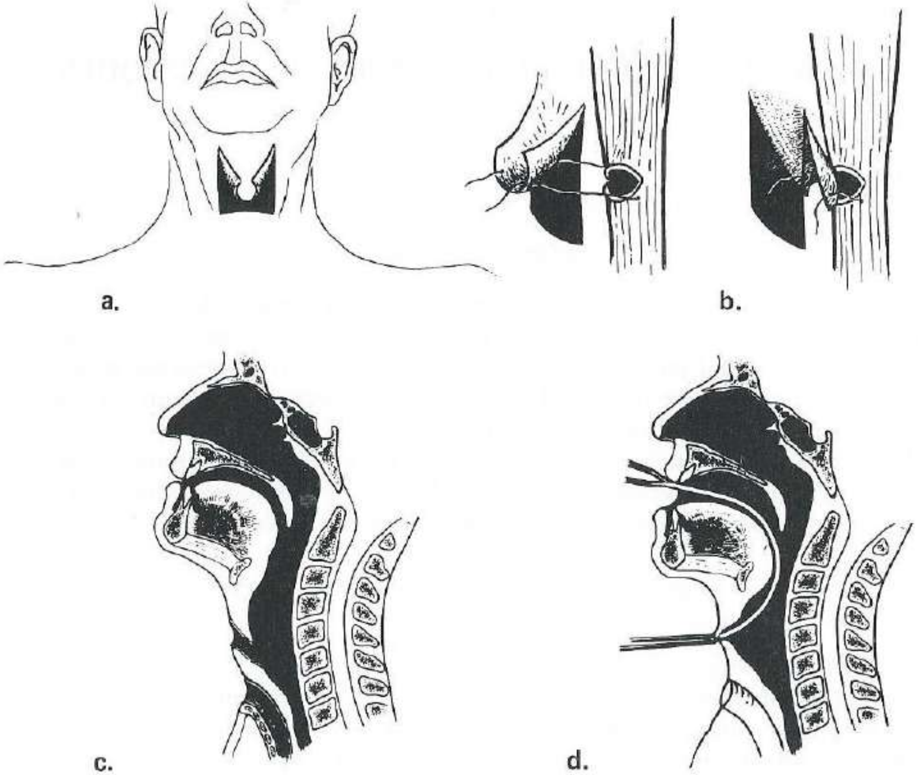


Figure 1. Briani's technique for voice rehabilitation.
a,b,c: Construction of skin-lined tube by anterior neck flap. The tubed neck-flap is connected to an opening in the esophagus.
d: Creation of a fistula by perforation through the neck onto a trockar positioned in the pharynx. Skin is approximated directly to mucous membrane.

Figure 2. Diagrammatic principle of sound production by means of a surgically created external fistula. The fistula walls as well as the mucosa and muscular remnants of the esophagus and/or pharynx can function as a vibratory source.

Conley (1958, 1959, 1969), another pioneer in the field of surgical voice rehabilitation, did not hesitate to report the frequent and troublesome problems which may be experienced after surgical voice rehabilitation. Conley felt that previous radiotherapy increased the risk of complications and was a relative contraindication to vocal rehabilitation. His results were adversely influenced by stenosis of the fistula, preventing adequate soundproduction, and leakage through the fistula which was above all extremely annoying. Moreover, the dependance on an often complicated prosthesis raises specific problems especially regarding the connection of the appliance to the pharyngo-cutaneous or esophago-cutaneous fistula.

In order to solve the above mentioned problems Conley et al (1958, 1959) developed various techniques which involved the construction of a fistula either of mucous membrane from the anterior cervical esophageal wall (figure 3) or by

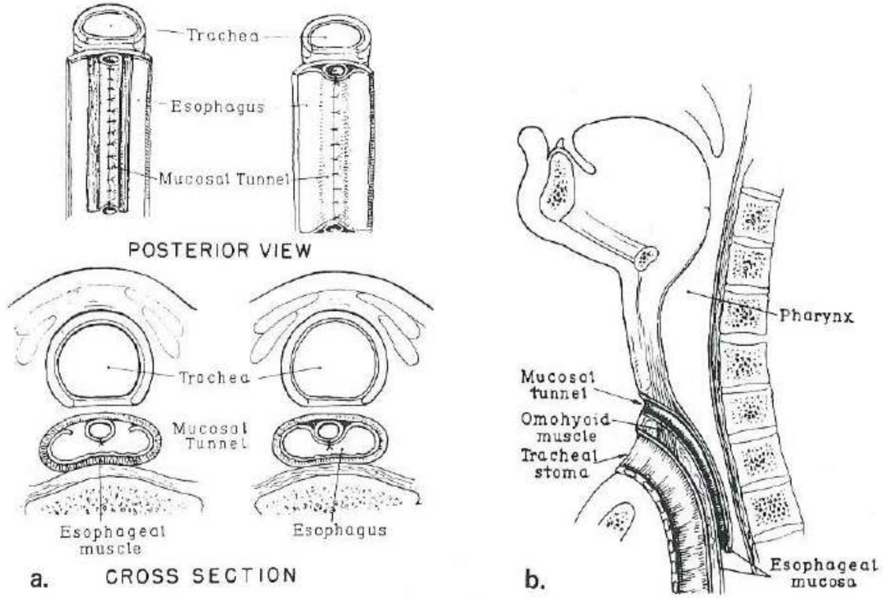


Figure 3. Conley's technique for surgical voice rehabilitation.
a: Mucosal tunnel made from reversed esophageal lining.
b: Mucosal tunnel opens just above tracheostoma and extends inferiorly along esophagus (used with permission from Annals of Otology, Rhinology & Laryngology, 67: 655-664, 1958).

means of an autogenous vein graft (figure 4). The basic principle of his technique was to create a passage which runs an oblique course from the neck down to the esophagus, so that the act of swallowing will close this tunnel automatically, thus preventing leakage. Conley further contrived the use of an omohyoid or scalene muscle sling or loop positioned under the upper segment of the tunnel in an attempt to assist in its compression upon swallowing. These procedures were ultimately abandoned because they failed to contain the problems of leakage and/or stenosis.

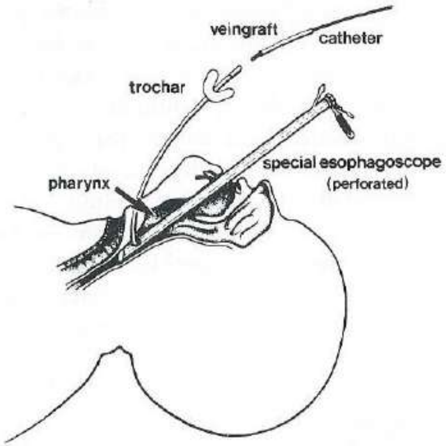
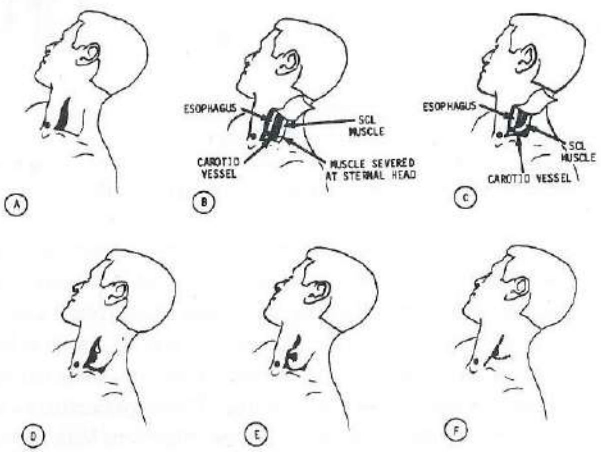


Figure 4. Conley's method of vocal rehabilitation by means of an autogenous vein graft. Special esophagoscope in position for cannulation with trocar and subsequent veingrafting (used with permission from Annals of Otology, Rhinology & Laryngology, 68: 990-995, 1959).

Taub et al (1972, 1973, 1974, 1975) described a combined surgical-prosthetic approach for postlaryngectomy voice rehabilitation. The surgical technique consists principally of a modified cervical esophagostoma. By means of a skin-platysma flap he constructed a fistula which ran from antero-lateral to caudo-medial (figure 5). In spite of the favourable course of the fistula and the ingenious prosthesis (figure 6) the problem of salivary leakage was not solved satisfactorily. Besides, the fistula crossed the common carotid artery which should be considered as a definite drawback of this technique. Wound infection coherent with salivary leakage has led to an erosion of the arterial wall with subsequent fatal bleeding.



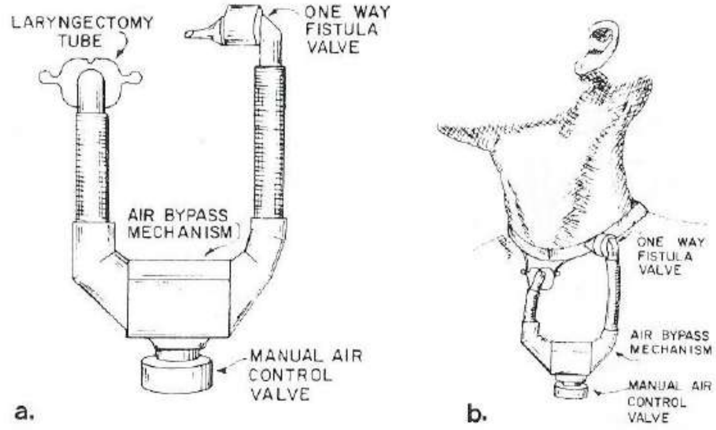


Figure 6. a,b: The air bypass mechanism as developed by Taub. Three main parts are depicted, the air bypass mechanism involves a manual air control valve to adjust the device for adequate air exchange and phonation. (used with permission from American Journal of Surgery, 124: 87-90, 1972).

Especially, patients who had been previously irradiated and/or had undergone a radical neck dissection were prone to this complication. It is recommended that a rotated flap of sternocleidomastoid muscle is used to provide additional carotid artery protection in all patients.

Edwards (1974, 1975, 1976) further modified Conley's (1958, 1959) technique which has been mentioned earlier, by using a full thickness myomucosal flap from the anterior esophageal wall for the creation of an oblique tract (figure 7). Apart from stenosis of the passage, narrowing of the remaining of the pharynx occurred. He later modified the technique (Edwards 1976) and suggested a cephalad oriented fistula constructed with a tunneled tongue flap or split skin. This concept, however, is not compatible with the principles of prevention of aspiration as suggested by Conley et al (1958), and has not been widely accepted.

Other authors (Shedd et al 1974ab, 1976a, Sisson et al 1975, McConnel et al 1977) also describe methods of postlaryngectomy voice rehabilitation involving a custom made external voice prosthesis connecting the tracheostoma and a hypopharyngeal fistula. These methods will not be discussed in detail as they do not essentially differ from the methods mentioned earlier.

Figure 5. Taub's technique for vocal rehabilitation.

a. Preparation of skinflap (including platysma).
b. Exposure of the esophagus; a small opening is made.
c. The sternocleidomastoid muscle is severed and rotated over the carotid vessels.
d. Suturing of the skinflap to the posterior margins of the esophagostoma.
e. Skinflap turned inwards and tubulated.
f. Wound at closure.

(used with permission from American Journal of Surgery, 125: 748-756, 1973).

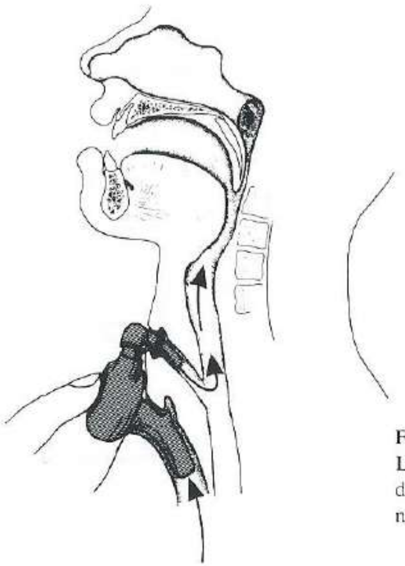


Figure 7. Edward's technique for vocal rehabilitation. Low type fistula with connecting prosthesis in place during phonation. (used with permission from Journal of Laryngology and Otology, 88: 905-918, 1974).

All the above mentioned methods involved the use of an external prosthesis which essentially consist of three parts: one that fits in the fistulous tract, another fitting in the tracheostoma and a connecting piece. The part which is connected to the fistula has in most prosthesis, for example those used by Shedd et al (1974ab, 1976a), Edwards (1974), Taub et al (1972, 1973) and McConnel et al (1977), a one-way valve to prevent the flow of saliva and food through the prosthesis. In most of the techniques a modified tracheal canula was used to fit the prosthesis into the tracheostoma. The connecting piece had an opening for respiration which can be closed digitally to shunt air into the hypopharynx for phonation. In the connecting piece of the prostheses of Taub (1972, 1973) and McConnel (1977) a variable pressure-sensitive valve was incorporated which renders the digital occlusion for phonation redundant. By means of a slight increase in the expiratory pressure the valve closed, thereby transferring air through the prosthesis to the hypopharynx. The valve remained open at the lower pressures which are needed for respiration. The valve could be adjusted to close at different expiratory pressures for the increased air demands of physical exertion.

Shedd and co-workers (1972, 1976b) designed a so-called "reed fistula" prosthesis for patients who apart from a total laryngectomy also underwent a (sub)total pharyngectomy with reconstruction of the pharynx by means of a delto-pectoral flap. As the pharyngo-esophageal segment, which is an important prerequisite for alaryngeal speech, was missing, these patients practically remained voiceless. The above mentioned method of reconstructing the pharynx involved a planned fistula on which the prosthesis was fitted. In a pharynx reconstructed with a delto-pectoral skin flap vibrations are difficult to induce. Therefore Shedd et al

(1972, 1976b) incorporated a musical reed in the connecting piece of the prosthesis. A variable pressure-sensitive valve, as described above, could be added to the prosthesis. Difficult prosthetic fitting, salivary leakage and a mechanical voice remain problems to be solved.

Although, with time, more advanced prostheses have been developed, they remain awkward and unsatisfactory from a cosmetic point of view. Moreover the continuous drainage of saliva through the fistula creates problems of regional hygiene, which in combination with pressure of the appliance causes skin necrosis in some patients.

Although the quality of speech which could be attained with these methods was reported as being superior to the quality of esophageal speech (Blom 1972, Weinberg 1978) these methods have not been generally accepted because of the above mentioned reasons.

METHODS WITH AN INTERNAL FISTULA

TRACHEO-HYPOPHARYNGEAL FISTULA METHODS

Most of the techniques, for creating a tracheo-hypopharyngeal fistula for voice rehabilitation after total laryngectomy, do not involve the use of a prosthesis. Therefore, the techniques in which a prosthesis is actually applied will not be discussed separately.

Asai (1960, 1965, 1972) described his three stage method for the creation of an internal tracheo-pharyngeal fistula for voice rehabilitation after total laryngectomy. The first stage, performed at the time of laryngectomy, consists of the creation of a high tracheostoma. A second permanent tracheostoma is then made through the fourth and fifth tracheal ring with two centimeter of skin between it and the upper opening. After satisfactory healing a pharyngostoma is created in the second stage in the midline. In a final stage this is connected to the superior tracheostoma by a cervical skin tube ("dermal tube"), forming a long vertical internal shunt (figure 8). By occluding the lower tracheostoma, air could be shunted from the lungs through the skin tube into the pharynx. The expired air caused vibrations in the end of the newly created skin tube and consequently the air column in the pharynx was set in vibration. Like in Briani's technique, these voice vibrations formed the basis of speech.

In a review of 72 cases Asai (1972) reported generally good phonation, but there was disruption of the shunt in 10 cases, stenosis in 10 cases and aspiration pneumonia in 2 cases. Various patients had to use digital pressure over the skin tube during swallowing in order to prevent aspiration of saliva and food. It is reasonable to assume that especially in irradiated patients the use of neck skin in this technique carried a considerable risk for skin necrosis with disruption of the shunt and subsequent failure.

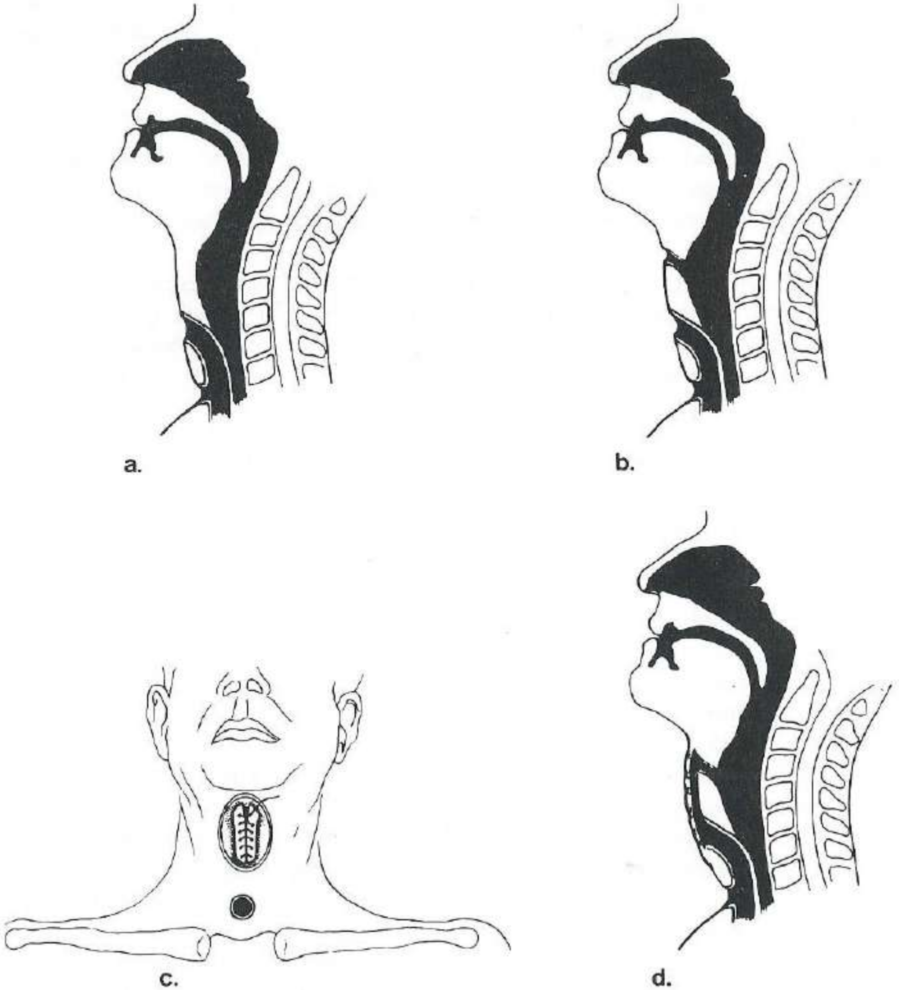


Figure 8. Asai's technique for vocal rehabilitation.
a. end of first stage — 2 tracheostomas.
b. end of second stage — 2 tracheostomas and pharyngostoma.
c. formation of skin-lined tube connecting the upper tracheostoma with the pharyngostoma.
d. completion of procedure.
(used with permission from Anals of Otology, Rhinology & Laryngology, 76: 829-833, 1967).

In view of these problems various authors modified this technique. Miller (1967, 1968, 1971, 1976) who had extensive experience with Asai's technique, suggested that the upper part of the fistula should slope obliquely down and enter the pharynx under the base of tongue. However, this did not solve the aspiration problem to a satisfactory degree.

Other authors (Minnigerode 1968, 1969, 1972; Yamamoto 1980) changed the technique of closing the cervical defect which arises from the creation of the skin tube. By using cranially or laterally based skin flaps they hoped to prevent traction on the suture lines which may have led to disruption of the shunt in a number of patients.

McGrail and Oldfield (1971, 1976) further modified Asai's technique by using a tubed deltopectoral flap to connect the pharyngostoma with the trachea (figure 9). However, tenacious salivary leakage and stenosis persisted in most patients. Other investigators (Fredrickson et al 1973; Maurer 1973) have reported on this modification. These authors used the hyoid which was preserved in order to support the upper part of the deltopectoral tube. The deltopectoral tube is angulated as it turns over the hyoidbone. Cineradiographic studies demonstrated that this technique prevented overflow of fluid and food into the deltopectoral tubes during deglutition. However, wound infection and deltopectoral tube-tracheal stenosis are reported to be distressing problems inherent in this technique.

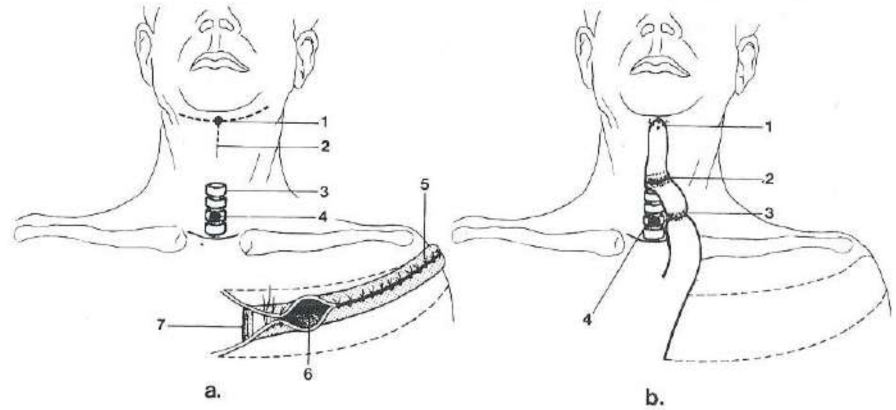


Figure 9. McGrail and Oldfield's technique for vocal rehabilitation.
a. suturing of skinflap
1. pharyngostoma
2. reconstituted pharyngeal mucosa
3. superior horizontal tracheal opening
4. permanent tracheostoma
5. epithelial-lined skin tube formed
6. inferior opening in skin tube
7. area of epithelial shave.

b. placing tube into position
1. superior end of skin tube sutured into pharyngostoma
2. inferior skin tube opening sutured to superior horizontal tracheal opening
3. epithelial shave area which creates a blind pocket
4. permanent tracheostoma.
(used with permission from the author. Transamerican Academy of Ophthalmology and Otolaryngology, 75: 510-512, 1971).

Montgomery (1972) described a technique which involves the creation of an obliquely placed mucosal tube communication between the hypopharynx and cervical skin as described earlier by Conley et al (1958). Although this procedure involves a tracheo-esophageal fistula, it is described here as a skin tube – reminiscent to Asai's technique – is used to connect the enlarged tracheostoma to the mucosal tube (figure 10). A specially designed silicone prosthesis was inserted into the trachea to facilitate funneling of air through the tube for phonation. In a series of 16 patients no stenosis of the tracheo-hypopharyngeal fistula is reported. However, Conley who used the first stage of this procedure in his external fistula method found stenosis of the mucosal tube to be a major problem.

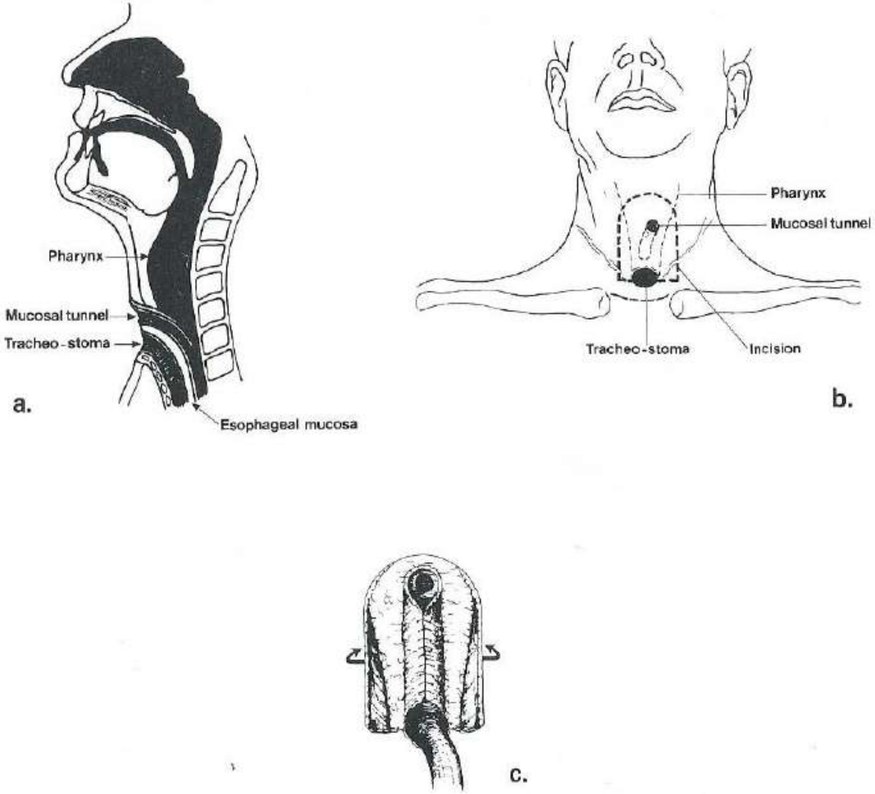


Figure 10. Montgomery's technique for vocal rehabilitation.
a. The creation of a mucosal tunnel from reversed esophageal lining.
b. Completion of the first stage. The flap for the construction of a skin tube to connect the esophagostoma to the tracheostoma is outlined.
c. Near completion of the skin tube construction.
(used with permission from "Postlaryngectomy vocal rehabilitation", Archives of Otolaryngology, 95: 76-83, 1972, American Medical Association).

In 1969 Staffieri proposed a simple single staged procedure which seemed to overcome the problems of aspiration and stenosis. A mucosa lined fistula, resembling a slit or buttonhole, was created in the anterior pharyngo-esophageal wall on top of the tracheal stump, which he called "Neoglottis Phonatoria" (figure 11). In the following chapters this technique will be dealt with in detail.

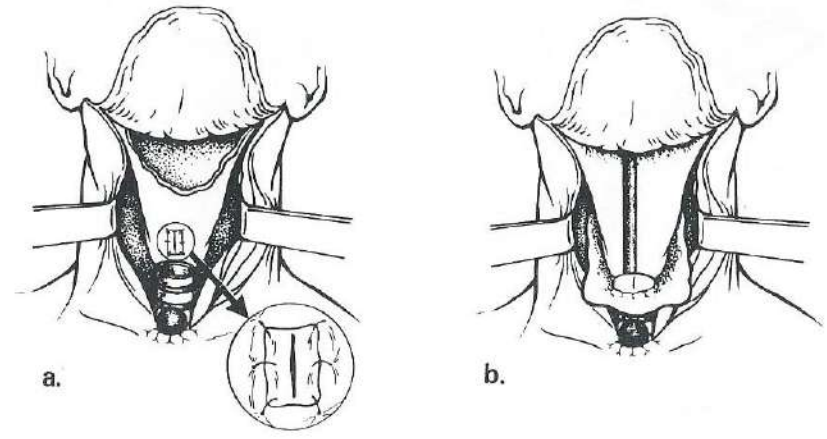


Figure 11. Staffieri's technique for vocal rehabilitation.
a. Construction of a neoglottis phonatoria in the anterior pharyngo-esophageal wall.
b. Reflection of pharyngo-esophageal wall over tracheal opening. Pharyngeal closure in usual three-layer "T" procedure.
(used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

In 1980 Brandenburg described a tracheo-hypopharyngeal fistula created from the posterior segment of the upper four tracheal rings in continuation with the anterior wall of the esophagus. He used omohyoid muscle in the area of the anterior esophagus to help support the opening of the neoglottis. A mucous membrane flap is created so as to overhang the neoglottis to help control aspiration (figure 12). There is a risk of postoperative oedema of the hypopharyngeal mucosa obstructing the upper esophagus in irradiated patients operated with this technique. Ten of thirteen patients reported by Brandenburg were listed as a success.

With certain reservation some methods of surgical voice rehabilitation which involve a subtotal laryngectomy will be discussed. The discussion will be limited to methods of subtotal laryngectomy which only intend to restore phonation but do not aim to maintain oral-nasal respiration.

Mozolewski et al (1972, 1975, 1979, 1980) used a pedicled mucosal flap rotated from the hypopharynx to create a mucosal tube connecting the trachea to the hypopharynx (figure 13). In most cases the cricoid and one arytenoid were preserved in order to support the adjacent tract and create an angulated course. If after resection of the tumor only the tracheal stump remained, the tube was supported by the tendon of the sternocleidomastoid muscle. Approximately 50% of the patients were

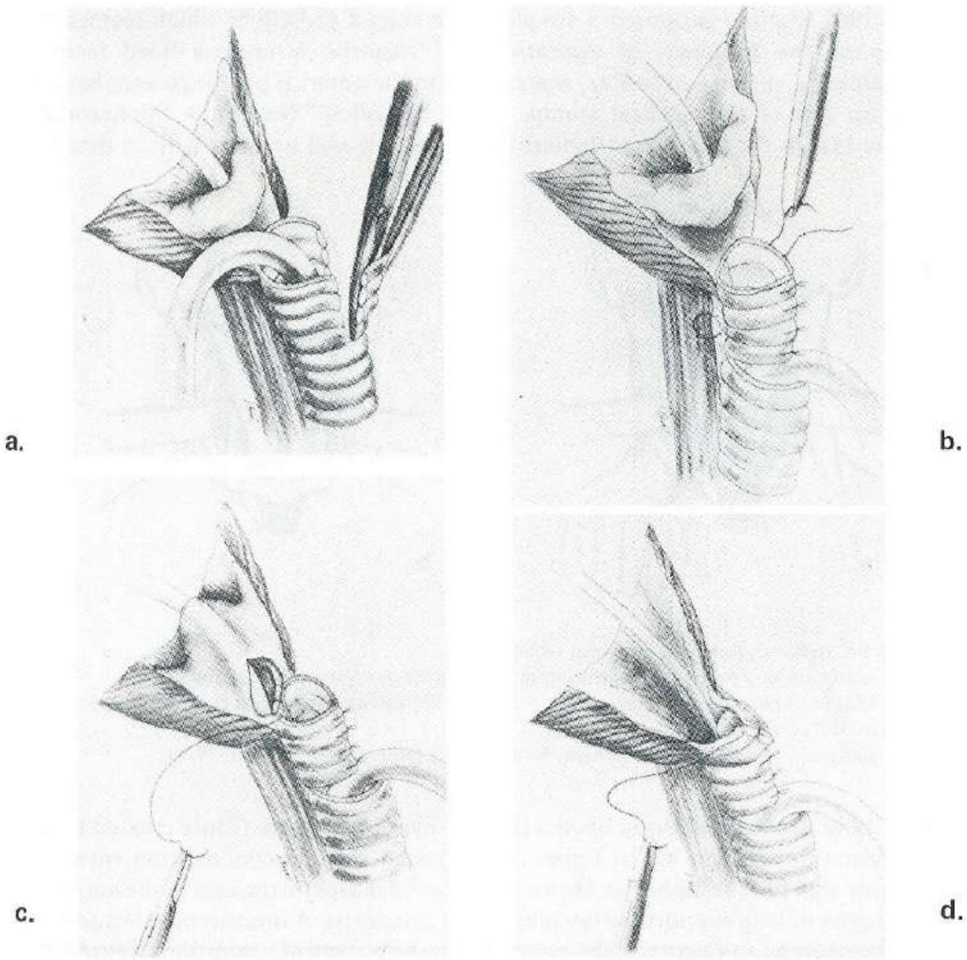


Figure 12. Brandenburg's technique for vocal rehabilitation.
a. Anterior segment of upper four tracheal rings is removed.
b. Reapproximation of walls of upper rings of trachea, creating triangular-shaped tube.
c. The margins of esophageal opening is sutured to the circumference of the triangular-shaped tube.
d. Reflection of lower margin of pharyngostoma on itself forms mucous membrane flap that partially covers opening into neoglottis. Closure of pharyngostoma begins with a running suture.

(used with permission from "Vocal Rehabilitation after Laryngectomy", Archives of Otolaryngology, 106: 688-691, 1980; copyright 1980 American Medical Association).

successfully rehabilitated. Of the patients who exhibited significant leakage, some could be treated with Teflon injection at the fistula site. Others used an elastic bandage or needed reoperation. Dietzel (1979) used an artificial stent to prevent stenosis of the fistula in his patients.

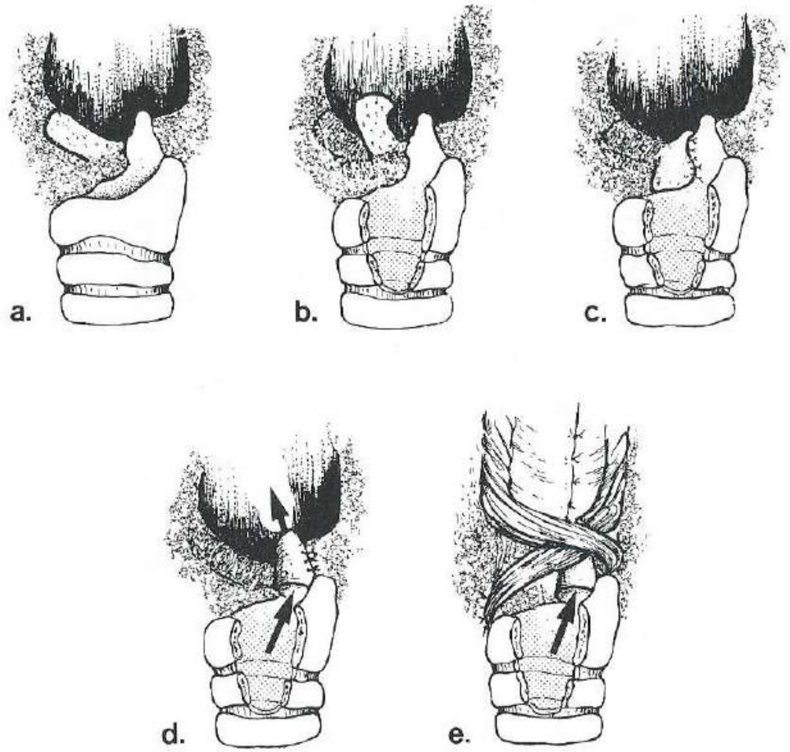


Figure 13. Mozolewski's technique for vocal rehabilitation.
a. Status of completion of the ablative part of operation.
b. Formation of mucosal pedicle flap of inferior pharynx. Cutting the anterior part of the cricoid cartilage.
c. Suturing of pharyngeal mucosal flap to the mucosal covering of the surface of the arythenoid.
d. Formation of shunt canal. The pharyngeal mucosal flap is turned over and sutured to the external border of mucosa covering arythenoid cartilage.
e. Pharyngeal mucosal suturing and superior position of strips of inferior constrictor muscle.
(used with permission from HNO-praxis, 4: 259-269, 1979).

Pearson et al (1980, 1981) reported on a surgical technique for glottic carcinoma involving an extended hemilaryngectomy with preservation of an endolaryngeal myomucosal segment, on the uninvolved side, in order to bridge the gap from the trachea to the pharynx (figure 14). If this segment itself is too narrow to tube into an adequate speaking shunt, its width can be increased by the addition of a pharyngeal flap. It is suggested that as the recurrent laryngeal nerve together with the myomucosal segment to which it is attached is preserved, a valved tracheo-pharyngeal shunt is created which functions as a neoglottis during phonation and constricts to close during swallowing. All the 16 patients were reported to achieve a good alaryngeal voice over varying periods of time. Six of the 16 patients experienced aspiration of varying degree without pulmonary complications. With a median follow-up of 14 months no local recurrences have been observed. Further experience has been gained with this method in case of limited lesions of the piriform sinus by Krespi and Sisson (1984).

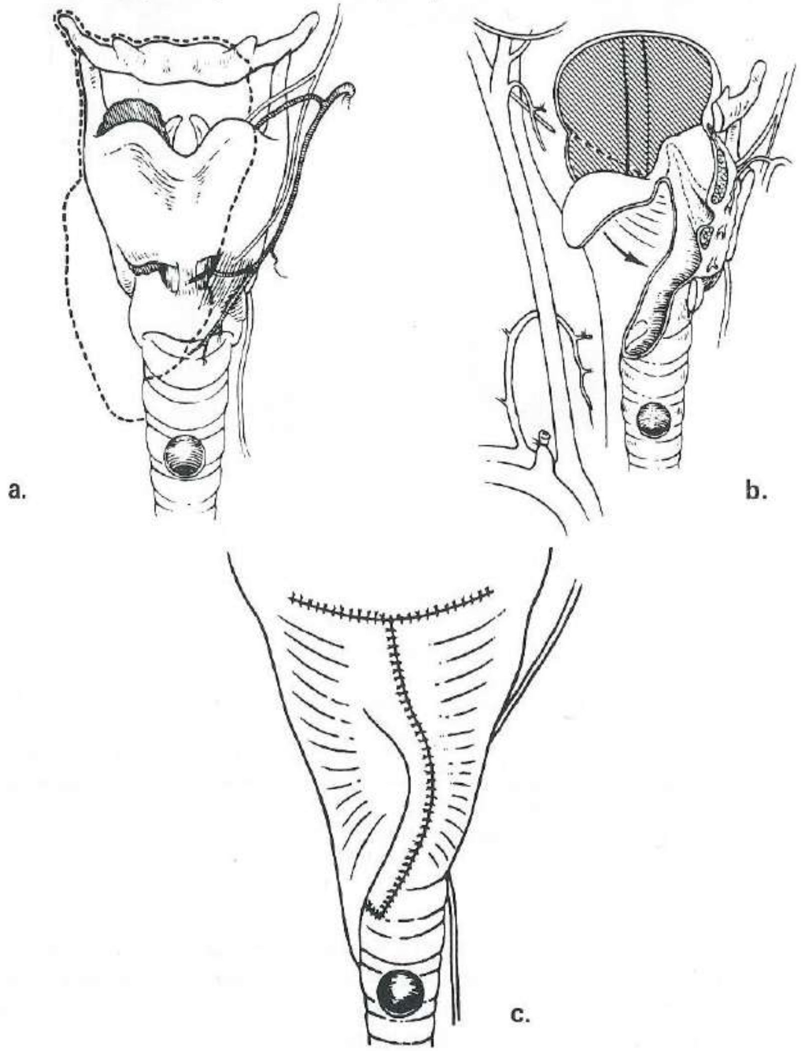


Figure 14. Pearson's technique for vocal rehabilitation.
a. The resection encompassed by an extended hemilaryngectomy.
b. The preserved endolaryngeal myomucosal segment bridges the gap from trachea to pharynx, but is too narrow to tube. Therefore, it is augmented with a pharyngeal flap.
c. The closure is completed. The airway will be maintained by the tracheotomy.
(used with permission from Laryngoscope, 90: 1950-1961, 1980).

TRACHEO-ESOPHAGEAL FISTULA METHODS

Most of Conley's work on surgical voice rehabilitation after total laryngectomy involved an external fistula with a prosthesis (Conley et al 1958, 1959, 1969). In his first publication on this subject, he described a few patients with a tracheo-esophageal fistula created by means of reversed esophageal mucosa. The reversed esophageal mucosa was tubed and sutured to an opening in the trachea (figure 15). This method eliminated the use of an external prosthesis for voice production. Stenosis more than leakage remained a problem in these patients.

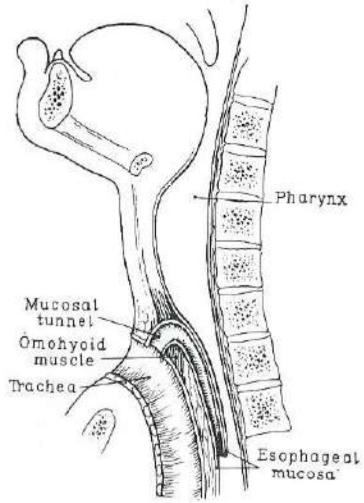


Figure 15. Conley's technique for vocal rehabilitation.
Retrograde esophageal mucosal shunt plicated by omohyoid muscle.
(used with permission from Annals of Otology, Rhinology & Laryngology, 67: 655-664, 1958).

In 1971 Calcaterra and Jafek experimented with dogs in an attempt to modify Conley's shunt procedure and overcome the problem of stenosis. They prefered using a full thickness esophageal flap to construct the fistula rather than use reversed mucosa alone as suggested by Conley et al (1958). Subsequently, reports have appeared of the application of this technique in humans, with varying success (Komorn et al 1973, 1974, 1976; Zwitman & Calcaterra 1973, Saito et al 1977) (figure 16). Stenosis of the fistula still occurred frequently especially where post-operative radiotherapy was administered. Leakage of saliva and food accompanied the shunts that maintained adequate patency for voice production. Because of these problems Calcaterra (1976) used this method only as a secondary procedure for laryngectomized patients who did not acquire esophageal speech.

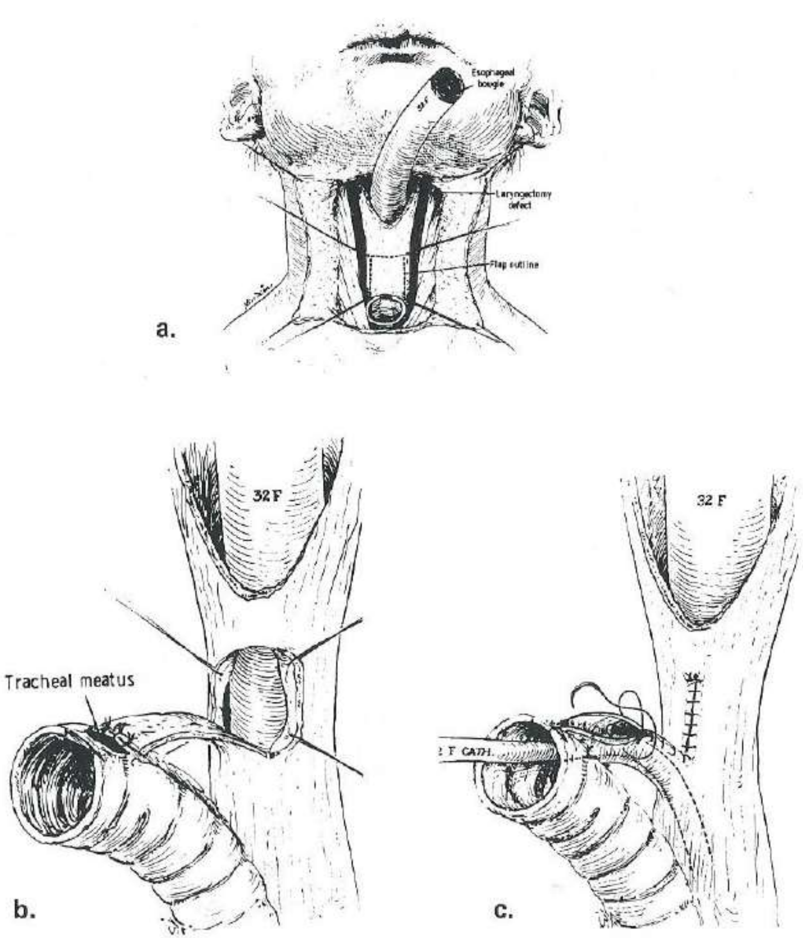


Figure 16. Calcaterra and Jafek's technique for surgical voice rehabilitation as applied in humans.
a. Full thickness inferior based esophageal flap outlined. A bougie inserted through the hypopharyngeal defect stabilises the esophagus.
b. Superior edge of the flap is sutured to the lower border of the tracheal meatus in the posterior wall of the trachea.
c. The flap is tubed around a catheter; the esophagal defect is closed.
(used with permission from Annals of Otology, Rhinology & Laryngology, 83: 445-451, 1974).

In 1977 Amatsu et al first reported on a new one-stage procedure for surgical voice rehabilitation after conventional total laryngectomy (Amatsu et al 1977, 1978, 1980). He did not separate the posterior wall of the trachea from the anterior wall of the esophagus and removed the anterior 2/3 of the cartilage from the first through fourth tracheal rings. Thus a tracheal mucosal flap was created to which a side-to-side tracheo-esophageal anastomosis was established (figure 17). The

tracheal flap was then tubed, as in Brandenburg's technique, forming a mucosal tunnel connecting the esophagus and the trachea. Aspiration more than stenosis is the limiting factor in this kind of shunt operation.

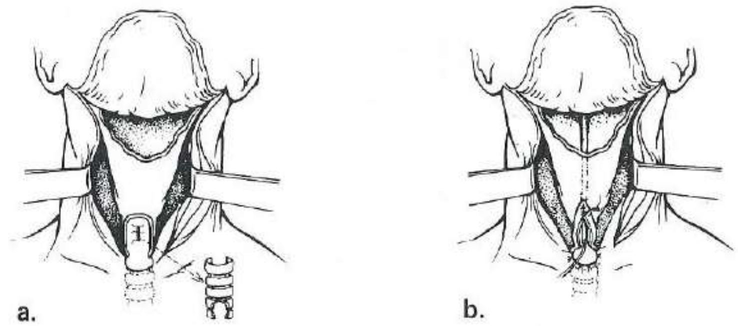


Figure 17. Amatsu's technique for vocal rehabilitation.
a. Construction of a posterior tracheal flap by removing the anterior two-thirds of the tracheal wall. A tracheo-esophageal side-to-side anastomosis is created in the remaining posterior tracheal flap.
b. By tunneling the tracheal flap, over a catheter, the tracheo-esophageal shunt is completed.

Based on the experience with Amatsu's technique, Singer and Blom (1980) described a simple, valved fistula tube to eliminate leakage during swallowing with preservation of voice. They further developed their procedure, which is essentially an endoscopic technique, using a simple tracheo-esophageal "puncture" for construction of a short midline communication between trachea and esophagus (figure 18). After the procedure a small silicone prosthesis is fitted in the fistula. The prosthesis has a one-way valve which is located at the esophageal end. The opposite end of the prosthesis is open and flanked by two flanges which are taped to the neck (figure 19ab). When the stoma is occluded, pulmonary air is shunted through the opening of the prosthesis into the esophagus. Vibrations of the air column in the pharynx produced by the airflow form the basis of voice sounds.

Singer et al (1981) reported an 88% success rate for voice aquisition. Similar results were reported by Wetmore et al (1981), Wood et al (1981) and Johns and Cantrell (1981); however, the number of patients who continue to use this method as their primary mode of communication has been reported to be considerably lower (Donegan et al 1981, Wetmore et al 1985). Leakage through the tracheo-esophageal fistula, dislodgement of the prosthesis with subsequent stenosis of the fistula, daily removal and reinsertion of the prosthesis for cleaning purposes and the need to use adhesives for fixation of the prosthesis, constitute some of the disadvantages.

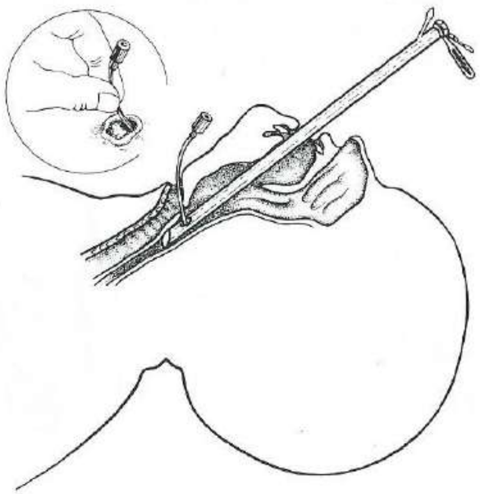


Figure 18. Blom-Singer technique for vocal rehabilitation.
The tracheo-esophageal puncture is made by inserting a trocart through the posterior wall of the tracheostoma into an esophagoscope. The tract is dilated until a catheter can be inserted in the tract as a stent. In due time a prosthesis with a one-way valve can be inserted in the fistula.
(used with permission from Annals of Otology, Rhinology and Laryngology, 89: 529-533, 1980).

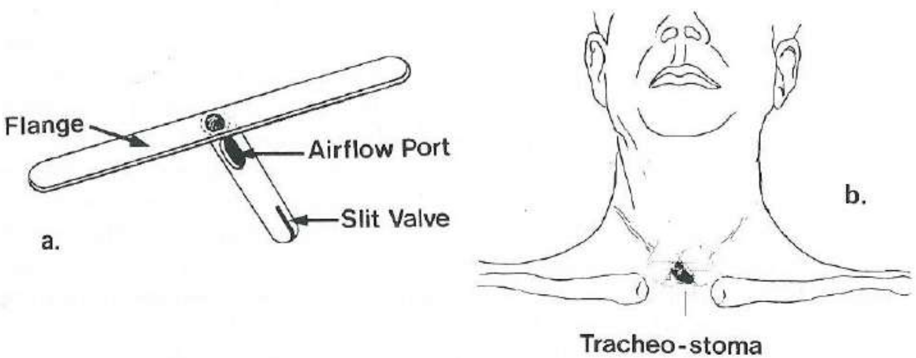


Figure 19.
a. Blom-Singer prosthesis with slit-like one-way valve.
b. Blom-Singer prosthesis fitted into the tracheo-esophageal puncture tract and taped to the peristomal skin.

There are several other types of voice prosthesis available today, each based on the same basic principle. The technique of insertion may vary. For example Panje (1981ab), who performed the tracheo-esophageal puncture under topical-local anaesthesia over a 34-36 F esophageal bougie, introduced a biflanged prosthesis for better fitting and prevention of dislodgement (figure 20). After insertion of the

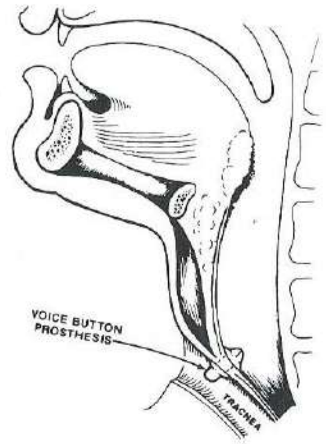


Figure 20. Panje prosthesis in situ.
The prosthesis is biflanged with a one-way valve at the esophageal end and open at the tracheal end. (used with permission from Annals of Otology, Rhinology & Laryngology, 90: 116-120, 1981).

prosthesis the flanges are situated on either side of the tracheo-esophageal partywall. In the new modified Blom-Singer prosthesis a retention collar on the esophageal side has been added in order to prevent its dislodgement. Fixation to the neck has been simplified, using one flange in the superior midline, instead of two on either side of the tracheostoma. A further modification of the Panje voice prosthesis by Nijdam et al (1982) resulted in a prosthesis with a flat valve which is incorporated in the flange on the esophageal side of the prosthesis (figure 21). These prostheses have an average life of 100 days and must then be renewed. Other modifications have been described by Henley-Cohn et al (1981, 1984), Perry et al (1982), Herrmann et al (1984), and Ossoff et al (1984).

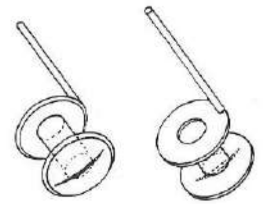


Figure 21. Groningen prosthesis.
A valve is incorporated in the flange of the esophageal side of the prosthesis. A small silicone string is attached to the flange on the tracheal side which is only employed during the insertion procedure.

Still the relative simplicity of these procedures do not preclude careful patient selection (Wetmore et al 1985). Selection criteria correspond with the selection criteria for the other methods of surgical rehabilitation of voice and should include age and general physical status especially the cardio-pulmonary status. It has been shown that the effort needed to speak through a vocal fistula is considerably greater than that necessary for phonation through a normal glottis (Weinberg 1982). Stoma size and site are important with respect to prosthetic fitting and digital occlusion. Other selection criteria involve manual dexterity and visual ability for adequate care for the prothesis. Patient expectation and motivation should be evaluated beforehand. Alcohol abuse has been shown to influence the success rate of prosthetic surgical voice rehabilitation techniques negatively (Schuller et al 1983). The relative simplicity of the procedure in combination with strict criteria for patient selection do not preclude an intensive logopaedic support.

SUMMARY

The last decade has known a considerable progress in methods of surgical voice rehabilitation after total laryngectomy. Initially, methods have been developed which involve an external fistula. The awkward prosthesis which is used in these methods have not found wide patient acceptance. In the last 10 years emphasis has shifted to methods with an internal fistula. Most of these techniques have been associated with problems such as stenosis of the fistula and leakage of saliva and food through the fistula. Subsequently, techniques have been developed involving an internal prosthesis with a one-way valve. Some of the disadvantages of those techniques have been mentioned above.

Of the current surgical or surgical-prosthetic procedures employed to rehabilitate the voice, the most frequently replicated techniques is that reported by Staffieri (1976), involving an internal fistula without a prosthesis, and that reported by Singer and Blom (1980), Panje (1981ab) and Nijdam et al (1984), involving an internal fistula with a prosthesis.

This thesis evaluates our results with Staffieri's technique.

REFERENCES

AMATSU, M., MATSUI, T., MAKI, T., KANAGAWA, K. Vocal rehabilitation after total laryngectomy: A new one-stage surgical technique. J. Otolaryngol. Jpn. 80: 779-785, 1977.

AMATSU, M. A new one-stage surgical technique for postlaryngectomy speech. Arch. Otorhinolaryngol. 220: 149-152, 1978.

AMATSU, M. A one-stage surgical technique for postlaryngectomy voice rehabilitation. Laryngoscope 90: 1378-1386, 1980.

ARNOLD, G.E. Alleviation of alaryngeal aphonia with the modern artificial larynx: I. Evolution of the artificial speech aids and their value for rehabilitation. Logos 3: 55-67, 1960.

ASAI, R. Laryngoplasty. J. Jap. Broncho-Esophagol. Soc. 12: 1-3, 1960.

ASAI, R. Asai's new voice production method. Substitution for human speech. Eighth International Congress of Otorhinolaryngology, Tokyo, 1965.

ASAI, R. Laryngoplasty after total laryngectomy. Arch. Otolaryngol. 95: 114-119, 1972.

BLOM, E.C. A comparative investigation of perceptual and acoustical features of esophageal speech and speech with the Taub prosthesis. Dissertation, University of Maryland, 1972.

BRANDENBURG, J.H. Vocal rehabilitation after laryngectomy. Arch. Otolaryngol. 106: 688-691, 1980.

BRIANI, A.A. Riabilitazione fonetica di laringectomizzati a mezzo della corrente aerea espiratoria polmonare. Arch. It. Otol. 63: 469-475, 1952.

BRIANI, A.A. Il ricupero sociale dei laringectomizzati attraverso un metodo personale operatorio. Medicina Sociale 8: 265-269, 1958.

CALCATERRA, T.C. & JAFEK, B.W. Tracheo-esophageal shunt for speech rehabilitation after total laryngectomy. Arch. Otolaryngol. 94: 124-128, 1971.

CALCATERRA, T.C. Tracheo-esophageal shunt for speech rehabilitation after total laryngectomy. In: Alberti, P.W. & Bryce, D.P. (eds) Workshops from the Centennial Conference on Laryngeal Cancer. Appleton-Century-Crofts New York: 576-578, 1976.

CONLEY, J.J., DeAMESTI, F. & PIERCE, J.K. A new surgical technique for the vocal rehabilitation of the laryngectomized patient. Ann. Otol. Rhinol. Laryngol. 67: 655-664, 1958.

CONLEY, J.J. Vocal rehabilitation by autogenous vein graft. Ann. Otol. Rhinol. Laryngol. 68: 990-995, 1959.

CONLEY, J.J. Surgical techniques for the vocal rehabilitation of the postlaryngectomized patient. Trans. Am. Acad. Ophthal. Otolaryngol. 73: 288-299, 1969.

DIETZEL, K. Erste Erfahrungen mit der Mozolewski-Technik bei der chirurgischen Rehabilitation der Stimme bei Laryngektomie. HNO-Praxis 4: 297-303, 1979.

DONEGAN, J.O., GLUCKMAN, J.L. & SINGH, J. Limitations of the Blom-Singer technique for voice restoration. Ann. Otol. Rhinol. Laryngol. 90: 495-497, 1981.

EDWARDS, N. Post-laryngectomy vocal rehabilitation. J. Laryngol. Otol. 88: 905-918, 1974.

EDWARDS, N. Post-laryngectomy vocal rehabilitation using expired air and an external fistula method: Further experiences. Laryngoscope 85: 690-699, 1975.

EDWARDS, N. New voices for old: Restoration of effective speech after total laryngectomy by the pulmonary air-shunt vocal fistula principle. Bristol Med. Chir. J. 90: 11-17, 1976.

FREDRICKSON, J.M., BRYCE, D.P. & WILLIAMS, G.T. Laryngeal reconstruction to prevent aspiration. Arch. Otolaryngol. 97: 457-460, 1973.

GUSSENBAUER, C. Ueber die erste durch Th. Billroth am Menschen ausgeführte Kehlkopf-Exstirpation und die Anwendung eines Künstlichen Kehlkopfes. Archiv. Clin. Chir. 17: 343-356, 1874.

GUTTMAN, M.R. Tracheohypopharyngeal fistulization (A new procedure for speech production in the laryngectomized patient). Trans. Am. Laryngol. Rhinol. Otol. Soc. 41: 219-226, 1935.

HENLEY-COHN, J.L. New technique for insertion of laryngeal prosthesis. Laryngoscope 91: 1957-1959, 1981.

HENLEY-COHN, J.L., HAUSFELD, J.N. & JAKUBCZAK, G. Artificial larynx prosthesis: Comparative clinical evaluation. Laryngoscope 94: 43-45, 1984.

HERRMANN, I.F., BUCHWALD, J. & ZENNER, H.P. Die Glottoplastik — eine neue Methode zur chirurgischen Stimmrehabilitation. HNO 32: 294-301, 1984.

JOHNS, M.E. & CANTRELL, R.W. Voice restoration of the total laryngectomy patient: The Singer-Blom technique. Otolaryngol. Head Neck Surg. 89: 82-86, 1981.

KOMORN, R.M., WEYCER, J.S., SESSIONS, R.B. & MALONE, P.E. Vocal rehabilitation with a tracheo-esophageal shunt. Arch. Otolaryngol. 97: 303-305, 1973.

KOMORN, R.M. Vocal rehabilitation in the laryngectomized patient with a tracheo-esophageal shunt. Ann. Otol. Rhinol. Laryngol. 83: 445-451, 1974.

KOMORN, R.M. Tracheo-esophageal shunt vocal rehabilitation. In: Alberti, P.W. & Bryce, D.P. (eds) Workshops from the Centennial Conference on Laryngeal Cancer. Appleton-Century-Crofts New York: 571-575, 1976.

KRESPI, Y.P. & SISSON, G.A. Voice preservation in pyriform sinus carcinoma by hemicricolaryngopharyngectomy. Ann. Otol. Rhinol. Laryngol. 93: 306-310, 1984.

LEBRUN, Y. The artificial larynx. Amsterdam. Swets & Zeitlinger BV, 1973.

LOWRY, L.D. Artificial larynges: A review and development of a prototype self-contained intra-oral artificial larynx. Laryngoscope 91: 1332-1355, 1981.

MAURER, H. Tracheopharyngeale Interpositionsplastik mit zerviko-thorakalem Hautschlauch-einzeitiges Vorgehen zur sprachlichen Rehabilitation nach Kehlkopf-total-Exstirpation. Laryng. Rhinol. 52: 253-254, 1973.

McCONNEL, F.M.S., SISSON, G.A. & LOGEMANN, J.A. Three years' experience with a hypopharyngeal pseudoglottis for vocal rehabilitation after total laryngectomy. Trans. Am. Acad. Ophthalmol. Otolaryngol. 84: 63-67, 1977.

McGRAIL, J.S. & OLDFIELD, D.L. One-stage operation for vocal rehabilitation at laryngectomy. Trans. Am. Acad. Ophthalmol. Otolaryngol. 75: 510-512, 1971.

McGRAIL, J.S. Vocal rehabilitation at or following laryngectomy. In: Alberti, P.W. & Bryce, D.P. (eds) Workshops from the Centennial Conference on Laryngeal Cancer. Appleton-Century-Crofts New York: 560-562, 1976.

MILLER, A.H. First experiences with the Asai technique for vocal rehabilitation after total laryngectomy. Ann. Otol. Rhinol. Laryngol. 76: 82 9-833, 1967.

MILLER, A.H. Further experiences with the Asai technique of vocal rehabilitation after laryngectomy. Trans. Am. Acad. Ophthalmol. Otolaryngol. 72: 779-781, 1968.

MILLER, A.H. Four years experience with the Asai technique for vocal rehabilitation for the laryngectomized patient. J. Laryngol. Otol. 85: 567-576, 1971.

MILLER, A.H. Experiences with the Asai technique. In: Alberti, P.W. & Bryce, D.P. (eds) Workshops from the Centennial Conference on Laryngeal Cancer. Appleton-Century-Crofts New York: 557-559, 1976.

MINNIGERODE, B. Erste Erfahrungen mit der Methode von Asai zur Wiederherstellung der Stimme nach totaler Laryngektomie; zugleich Mitteilung einer vereinfachenden Modifikation der Verfahrens. Arch. Klin. Exp. Ohren, Nasen, Kehlkopf Heilk. 191: 751-754, 1968.

MINNIGERODE, B. Indikation und Technik eines modifizierten Verfahrens der plastischen Wiederherstellung der Stimme bei totaler Laryngektomie nach Asai. Pract. Oto-Rhino-Laryng. 31: 174-181, 1969.

MINNIGERODE, B. Five years' experience with a modified Asai-technique for voice rehabilitation after total laryngectomy. Acta Otolaryngol. 74: 279-282, 1972.

MONTGOMERY, W.W. Postlaryngectomy vocal rehabilitation. Arch. Otolaryngol. 95: 76-83, 1972.

MOZOLEWSKI, E. Surgical rehabilitation of voice and speech after laryngectomy. Otolaryngol. Pol. 26: 653, 1972.

MOZOLEWSKI, E., ZIETEK, E., WYSOCKI, R., JACH, K. & JASSEM, W. Arytenoid vocal shunt in laryngectomized patients. Laryngoscope 85: 853-861, 1975.

MOZOLEWSKI, E., ZIETEK, E. & JACH, K. Primäre muko-myoplastische Vokalfistel bei Laryngektomie. HNO-Praxis 4: 259-269, 1979.

MOZOLEWSKI, E., TARNOWSKA, C., JACH, K., ZIETEK, E., WYSOCKI, R., JASSEM, W. & LOBACZ, P. Primary mucoplastic vocal shunt. In: Shedd, D.P. & Weinberg, B. (eds) Surgical and Prosthetic Approaches to Speech Rehabilitation. G.K. Hall Medical Publishers, Boston, Massachusetts, Chapt. 11: 139-189, 1980.

NIJDAM, H.F., ANNYAS, A.A., SCHUTTE, H.K. & LEEVER, H. A new Prosthesis for Voice Rehabilitation after Laryngectomy. Arch. Otorhinolaryngol. 237: 27-33, 1982.

OSSOFF, R.H., LAZARUS, C.L. & SISSON, G.A. Tracheoesophageal puncture for voice restoration: Modification of the Blom-Singer technique. Otolaryngol. Head Neck Surg. 92: 418-423, 1984.

PANJE, W.R. Prosthetic vocal rehabilitation following laryngectomy – The voice button. Ann. Otol. Rhinol. Laryngol. 90: 116-120, 1981a.

PANJE, W.R., VANDEMARK, D. & McCABE, B.F. Voice button prosthesis rehabilitation of the laryngectomee – Additional notes. Ann. Otol. Rhinol. Laryngol. 90: 503-505, 1981b.

PEARSON, B.W., WOODS, R.D. II & HARTMAN, D.E. Extended hemilaryngectomy for T3 glottic carcinoma with preservation of speech and swallowing. Laryngoscope 90: 1950-1961, 1980.

PEARSON, B.W. Subtotal laryngectomy. Laryngoscope 91: 1904-1912, 1981.

PERRY, A., CHEESMAN, A.D. & EDEN, R. A modification of the Blom-Singer valve for restoration of voice after laryngectomy. J. Laryngol. Otol. 96: 1005-1011, 1982.

SAITO, H., MATSUI, T., TACHIBANA, M., NISHIMURA, H. & MIZUKOSHI, O. Experiences with the tracheo-esophageal shunt method for vocal rehabilitation after total laryngectomy. Arch. Oto-Rhino-Laryngol. 218: 135-142, 1977.

SCHULLER, D.E., JARROW, J.E., KELLY, D.R. & MIGLETS, A.W. Prognostic factors affecting the success of duckbill vocal restoration. Otolaryngol. Head Neck Surg. 91: 396-398, 1983.

SHEDD, D.P., BAKAMJIAN, V.Y., SAKO, K., MANN, M.B., BARBA, S. & SCHAAF, N.G. Reed-fistula method of speech rehabilitation after laryngectomy. Am. J. Surg. 124: 510-514, 1972.

SHEDD, D.P., BAKAMJIAN, V.Y., SAKO, K., SCHAAF, N.G. & MANN, M.B. Postlaryngectomy speech rehabilitation by a simplified, single-stage surgical method. Am. J. Surg. 128: 505-511, 1974a.

SHEDD, D.P. Surgical advances in rehabilitation of the laryngectomee. J. Surg. Oncol. 6: 269-276, 1974b.

SHEDD, D.P., SCHAAF, N.G. & KIELICH, M. A prosthetic device for air-tunnel speech rehabilitation. J. Prosthet. Dent. 36: 82-87, 1976a.

SHEDD, D.P., SCHAAF, N.G. & WEINBERG, B. Technical aspects of reed fistula speech rehabilitation followig pharyngolaryngectomy. J. Surg. Oncol. 8: 305-310, 1976b.

SINGER, M.I. & BLOM, E.D. An endoscopic technique for restoration of voice after laryngectomy. Ann. Otol. Rhinol. Laryngol. 89: 529-533, 1980.

SINGER, M.I., BLOM, E.D. & HAMAKER, R.C. Further experience with voice restoration after total laryngectomy. Ann. Otol. Rhinol. Laryngol. 90: 498-502, 1981.

SISSON, G.A., McCONNEL, F.M.S., LOGEMANN, J.A. & YEH, S. Jr. Voice rehabilitation after laryngectomy. Arch. Otolaryngol. 101: 178-181, 1975.

STAFFIERI, M. Laringectomia totale con ricostruzione di glottide fonatoria. Communicazione preliminare. Boll. Soc. Med. Chir. Bresciana, 1969.

TAUB, S. & SPIRO, R.H. Vocal rehabilitation of laryngectomees: Preliminary report of a new technic. Am. J. Surg. 124: 87-90, 1972.

TAUB, S. & BERGNER, L.H. Air bypass voice prosthesis for vocal rehabilitation of laryngectomees. Am. J. Surg. 125: 748-756, 1973.

TAUB, S. Voice prosthesis for speech restoration in laryngectomees. Trans. Am. Acad. Ophthalmol. Otolaryngol. 78: 287-288, 1974.

TAUB, S. Air bypass voice prosthesis for vocal rehabilitation of laryngectomees. Ann. Otol. Rhinol. Laryngol. 84: 45-48, 1975.

WEINBERG, B., SHEDD, D.P. & HORII, Y. Reed-fistula speech following pharyngolaryngectomy. J. Speech Hear. Dis. 43: 401-413, 1978.

WEINBERG, B., HORII, Y., BLOM, E. & SINGER, M. Airway resistance during esophageal phonation. J. Speech Hear. Dis. 47: 194-199, 1982.

WETMORE, S.J., JOHNS, M.E. & BAKER, S.R. The Singer-Blom Voice Restoration Procedure. Arch. Otolaryngol. 107: 674-676, 1981.

WETMORE, S.J., KRUEGER, K., WESSON, K. & BLESSING, M.L. Long-term Results of the Blom-Singer Speech Rehabilitation Procedure. Arch. Otolaryngol. 111: 106-10 9, 1985.

WOOD, B.G., RUSNOV, M.G., TUCKER, H.M. & LEVINE, H.L. Tracheoesophageal puncture for alaryngeal voice restoration. Ann. Otol. Rhinol. Laryngol. 90: 492-494, 1981.

YAMAMOTO, K. Vocal rehabilitation by a tracheopharyngeal shunt. Arch. Otolaryngol. 106: 70-73, 1980.

ZWITMAN, D.H. & CALCATERRA, T.C. Phonation using the tracheo-esophageal shunt after total laryngectomy. J. Speech Hear. Dis. 38: 369-373, 1973.

Chapter II

STAFFIERI'S TECHNIQUE AND PATIENT SELECTION CRITERIA

INTRODUCTION

In 1969 Staffieri first reported his method to the Italian Otolaryngological Society and in 1973 subsequently published his work in the German literature. His method essentially consists of a mucosal lined tracheo-hypopharyngeal fistula, created on top of the tracheal stump. The fistula resembles a slit or buttonhole which he called "Neoglottis Phonatoria". In our opinion the use of the term "Neoglottis Phonatoria" is not entirely justified as it is doubtful whether the glottic mechanism is restored as regards phonation and protection of the air way. However, Staffieri's innovation has been one of the most significant surgical advances in voice rehabilitation in the laryngectomized and to honour his effort in the field of surgical voice rehabilitation his term "Neoglottis Phonatoria" wil be used throughout this work.

In the first part of this chapter the technical aspects of Staffieri's method of surgical voice rehabilitation will be discussed. The second part deals with the criteria for patient selection pertaining to this technique. Except for a few minor variations, the technique which has been used at the Academic Hospital of the Free University Amsterdam, is identical to the technique as described by Staffieri (1976). These differences will be noted and some other variations as described in the literature will be mentioned. Furthermore some aspects of the postoperative course will be considered.

SURGICAL TECHNIQUE

The neoglottis phonatoria is created after completion of the total laryngectomy. A few modifications of the standard total laryngectomy procedure are necessary in order to facilitate vocal rehabilitation following Staffieri's method. The ablative procedure with its modifications will be discussed, followed by a detailed description of the creation of the "Neoglottis Phonatoria".

For the tracheostomy, which precedes the laryngectomy, a horizontal incision is made approximately 1 cm above the sternum. After surgical dissection the trachea is incised between the fourth and fifth ring. A tracheal canula is introduced. It is only after the laryngectomy that the ventral part of the fourth or fifth ring is removed and a permanent tracheostoma formed.

The horizontal tracheostomy incision is extended to a modified Glück Sörensen-incision and to the mastoid if a neck dissection is to be included. The technique of laryngectomy does not essentially differ from the traditional method except a few details. The trachea is transected below the level of the cricoid thus saving the superior part of the trachea above the tracheostoma. If the tumor extends to the subglottic region for not more than one centimeter, one can resect the first tracheal ring without excluding Staffieri's procedure. This is especially true in patients with a relatively longer neck. The integrity of at least two cartilage rings above the tracheostoma is essential to ensure that the neoglottis will not be occluded by the patients attempt to close the stoma with a finger.

The surgical dissection is carried out from below upwards between the trachea and the esophagus and a myomucosal flap of the anterior pharyngo-esophageal wall is developed (figure 1). Once the dissection is completed the hypopharynx is entered on the site located at the greatest distance from the margins of the carcinoma. The point of entry into the hypopharynx is then extended horizontally to the oposite side along the upper border of the cricoid cartilage. The larynx is removed including the hyoidbone. The remaining portion of the myomucosal flap inferiorly from the site of incision over the cricoid is then used in neoglottic reconstruction.

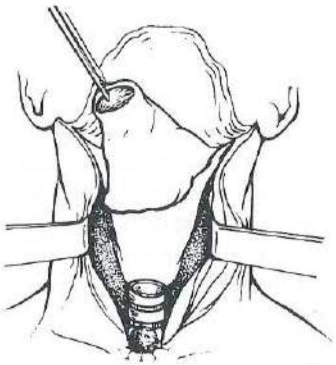


Figure 1. Detachment of larynx from trachea.
(used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

Attention is then directed to the myomucosal flap and the posterior wall of the trachea. The posterior tracheal wall should be sutured to the adjacent anterior esophageal wall in order to maintain stability and a constant relationship between these two layers. This will aid in the accurate positioning of the neoglottis and permit the surgeon to place a slight amount of tension on the flap in the anterior-posterior direction. The point at which the neoglottis is to be created in the myomucosal flap is carefully marked. Ideally the neoglottis should come to lie close to the anterior border of the tracheal stump. With a sharp-pointed scalpel blade (No. 11 blade), an incision is made through the muscle and submucosa of the

pharyngo-esophageal wall until the mucous membrane can be seen. The muscle incision is never more than 10 mm long. This step is facilitated by placing the opposite index finger into the lumen of the hypopharynx and upper-cervical esophagus, as shown in figure 2. A centimeter scale and a pair of callipers are useful tools in the exact assessment of the length of the neoglottis.

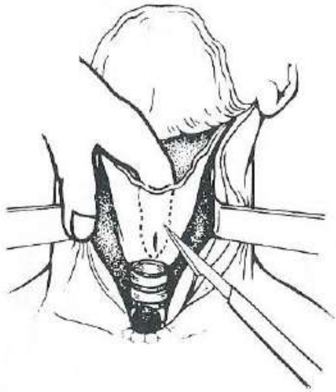


Figure 2. Making the neoglottis. Midline incision through the anterior pharyngo-esophageal wall. The index finger of the left hand is placed in the pharynx.
(used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

The intact mucosa of the pharyngo-esophageal flap is then grasped through this small incision with a fine non-traumatic forceps and drawn out towards the surgeon between the delicate muscle fibers. An incision of 5 mm at its maximum is made through the mucosa, so that a fistula is formed. The 6 sutures (Vicryl 5×0) to stabilize the mucosal edges should be very carefully placed. Lateral pull on the sutures is avoided. This prevents undue enlargement of the fistula in the lateral direction. Furthermore the sutures at the upper and lower ends are angled at 45°C which tend to assert a longitudinal pull so that the neoglottis results in a slit and not in an opening (figure 3).

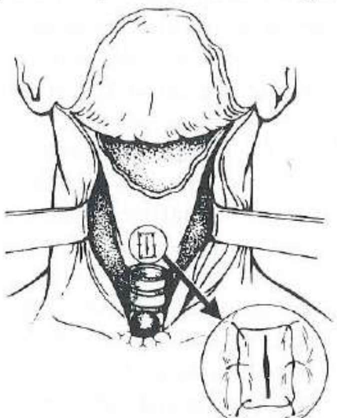


Figure 3. Neoglottis constructed in anterior pharyngo-esophageal wall.
(used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

After completing the neoglottic reconstruction, the flap is sutured carefully into position over the superior margin of the tracheal stump with Dexon 3×0 (figure 4). When suturing the flap to the lateral border of the tracheal stump tension is deliberately avoided. However, while suturing the flap to the anterior margin of the tracheal stump, a slight amount of tension is applied. Again, it is important that the neoglottis does not gape upon completion, since gaping will frequently promote postoperative aspiration. A standard T-shaped three-layer closure of the pharynx is then performed (figure 5).

Fig. 4

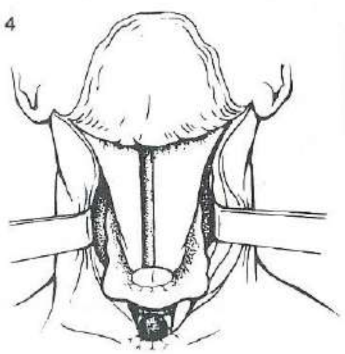


Fig. 5

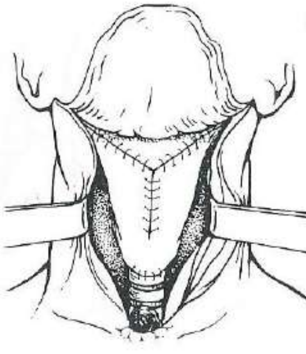


Figure 4. Reflexion of anterior pharyngo-esophageal wall with neoglottis over the tracheal stump. (used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

Figure 5. Pharynx closed in three layers.
(used with permission from Laryngologie, Rhinologie & Otologie, 57: 812-817, 1978).

Staffieri (1976) uses a separate incision for the tracheostomy. After completion of the neoglottis he advocates the placing of a silk thread through the neoglottis and pharynx which is brought out through the nasal passage. The silk thread serves to maintain the patency of the neoglottis in the postoperative period. Furthermore it can be used as a guide in case revision or dilatation is necessary. In our opinion the constant presence of this thread can cause microtrauma to the delicate mucosal lining of the fistula which subsequently may result in stenosis. We have therefore refrained from using it. The corner sutures which in our technique have been used to stabilize the reversed esophageal mucosa are angled at 45° rather than 90° as described by Staffieri. Contrary to Staffieri's technique we prefer a standard T-shaped three-layer closure of the pharynx in order to avoid tension on the suture lines, especially at the base of the tongue.

In an attempt to prevent stasis of saliva above the neoglottis, thus eliminating the bubbly characteristic of voice, Leipzig et al (1980), Griffiths (1980) as well as Calearo and Caroggio (1981) advocated oblique sectioning of the trachea, from front to back, at an angle of approximately 45°. In our experience beveling of the upper end of the trachea is not beneficial.

Other modifications have been reported by Heermann (1978 a,b) as well as by Sisson and Goldman (1980). The first modification involves implantation of a cartilage plate to close off part of the tracheal stump thus creating a valve to prevent aspiration. However Heermann's technique has been reported in only a small series of patients. Sisson's technique involves the attachment of the superior belly of the omohyoid muscle to the everted esophageal mucosa to support the shunt, thus preventing prolaps of the esophageal mucosa. Aspiration of saliva and stenosis of the fistula has been a problem in 10 out of a reported series of 26 patients.

The immediate postoperative care of our patients has been as follows. The patient is fed by a nasogastric tube for 10 days. We begin feeding a soft diet after removal of the nasogastric tube if the wound has healed satisfactorily. Patients may have some initial difficulty with liquids and, when this occurs, they are maintained on semisolids. Speech therapy is commenced only after the third postoperative week, to allow sufficient time for the pharynx to heal, and to withstand the pressure within its lumen during speech. Speech therapy consists mainly of the co-ordination of breathing and voice production and of the use of adequate intrathoracic pressure while speaking. Excessive intrathoracic pressure produces bulging and tension in the tissues around the neoglottis. By learning to control respiratory movements in the expiratory phase, the duration of speech can be increased. Emphasis is laid on articulation, rate of speech (i.e. slowing down speed if necessary to aid clarity of voice) and phrasing (so that good phrasing is achieved without the patient running out of air before he finishes speaking).

PATIENT SELECTION CRITERIA

The criteria for patient selection includes: the site and extent of the tumor; individual build of the patient with reference to the neck (patients with a longer neck have a longer length of trachea available); state of lungfunction; age; presence or absence of systemic illness; and motivation as well as manual dexterity. Chronic alcoholics are not considered suitable.

In the presence of gross subglottic extension of the tumor, it is not possible, in our opinion, to do a radical excision and yet to preserve a good length of the trachea for reconstruction. In case of piriform sinus involvement we do not perform this procedure as the remaining pharyngeal mucosa and musculature is inadequate and one can expect problems in healing. However, Sisson and Goldman (1980) as well as some others have extended their indication for the creation of a neoglottis to tumors restricted to the apex of the piriform sinus. The postcricoid and inter-arytenoid area should be free of tumor as the anterior pharyngo-esophageal flap is developed in this area. Accompanying neckdissection is not a contra-indication for this technique. Only the presence of pre-tracheal and/or paratracheal positive lymph nodes is considered to be a contra-indication. Histopathologically, poorly differentiated tumors are best irradiated and such patients are not considered at all for surgery. In our series of patients previous radiotherapy has not been considered to be a contra-indication for this procedure. However, we will discuss the role of previous radiotherapy extensively in relation to neoglottis reconstruction in chapter III.

In subjects with a short neck, an adequate length of the trachea for neoglottis reconstruction is not available. Generally, 75 years is the upper age limit. Our own studies (chapter IV) and the studies of Jach et al (1979) regarding Mozolewski's procedure for voice rehabilitation, have shown that the effort needed to speak through a vocal fistula is considerably greater than that necessary for phonation through a normal glottis. Patients with poor lungfunction are at risk with regard to the possible infection of the lungs due to aspiration. Furthermore patients with diabetes mellitus are known to have a more complicated post-operative course and therefore should be excluded from neoglottic surgery. Patient's expectation and motivation should be evaluated beforehand. A certain degree of manual dexterity is needed to close the tracheostoma for phonation.

REFERENCES

CALEARO, C.V. & CAROGGIO, A. Total laryngectomy with tracheopharyngeal fistula (neoglottis). Ann. Otol Rhinol. Laryngol. 90: 217-221, 1981.

GRIFFITHS, C.M. Experience with Staffieri's neoglottic technique. In: Shedd, D.P., Weinberg, B. (eds) Surgical and prosthetic approaches to speech rehabilitation. G.K. Hall, Medical Publishers, Boston: 119-129, 1980.

HEERMANN, J. Ventilneoglottis auf eingeklappter seitlicher Trachealwand mit Ohrmuschelknorpel und Mukosa nach Trink-insuffizienz der Staffieri-Fistel. Laryng. Rhinol. 57: 972-974, 1978a.

HEERMANN, J. Ventilneoglottis nach Laryngektomie durch Knorpelimplantat in die Trachea. Laryng. Rhinol. 57: 489-493, 1978b.

JACH, K., MOZOLEWSKI, E. & ZIETEK, E. Physikalische Kennwerte der Vokalfistel-Phonation bei Laryngektomierten. HNO-Praxis 4: 276-283, 1979.

LEIPZIG, B., GRIFFITHS, C.M. & SHEA, J.P. Neoglottic reconstruction following total laryngectomy. The Galveston experience. Ann. Otol. Rhinol. Laryngol. 89: 204-208, 1980.

SISSON, G.A. & GOLDMAN M.E. Pseudoglottis procedure: Update and secondary reconstruction techniques. Laryngoscope 90: 1120-1129, 1980.

STAFFIERI, M. Laringectomia totale con ricostruzione di glottide fonatoria. Communicazione preliminare. Boll. Soc. Med. Chir. Bresciana, 1969.

STAFFIERI, M. Funktionelle totale laryngektomie. Mschr. Ohr. Hk., Wien 107: 77-89, 1973.

STAFFIERI, M. La chirurgia riabilitativa della voce dopo laringectomia totale. In: Staffieri, M., Serafini, I. (eds) La riabilitazione chirurgica della voce e della respirazione dopo laringectomia totale. Relazione ufficiale del 29° congresso nationale AOOI Bologna: 1-222, 1976.

Chapter III

STAFFIERI'S PROCEDURE, REVISITED

H.D. Vuyk, MD, R.M. Tiwari, MS, FRCS, DLO, PhD and G.B. Snow, MD, PhD

From the Department of Otolaryngology, Free University Hospital, Amsterdam, The Netherlands

(accepted for publication in Head and Neck Surgery)

ABSTRACT

Our long term experience with Staffieri's procedure in 42 patients is presented. Our results were evaluated regarding voice production, aspiration problems and pharyngo-cutaneous fistula formation. Approximately 50% of the patients were successfully rehabilitated. 25% of the patients did not use the neoglottis for speech production, mostly because of stenosis of the neoglottis. The remaining 25% had serious aspiration problems which needed treatment. It was striking that half of these patients initially benefitted from the Staffieri procedure and had no aspiration problems at all. These 42 patients were compared to a group of 43 patients who underwent a conventional total laryngectomy in about the same period. After a total laryngectomy and Staffieri's procedure more than 35% of the patients had a pharyngo-cutaneous fistula, while after a conventional total laryngectomy the fistula rate was less than 20%. The average postoperative stay in the hospital was longer in the Staffieri group, especially in those patients who were previously treated with radiotherapy. In our opinion the results of this surgical technique in the long run do not justify its further use.

INTRODUCTION

During the past 2 decades there has been a renewed interest in surgical voice rehabilitation after total laryngectomy (1-6). The creation of an internal or external connection between the trachea and hypopharynx or esophagus forms the basis of all surgical voice rehabilitation techniques. These surgically created fistulas permit shunting of air from the trachea to the hypopharynx. Through the expired air, vibrations of the air column in the pharynx are produced which form the basis of speech. In spite of a considerable amount of work and research that has been done, stenosis of the fistula and leakage of saliva and food through the fistula still occur frequently with most of the techniques.

Staffieri (7, 8) developed a simple single stage procedure which seemed to overcome these problems. A mucosa lined fistula is created between the trachea and hypopharynx following laryngectomy (Fig. 1). Our early results with this technique (9) were encouraging. However, in the long run we have come across problems such as late aspiration, and a high incidence of immediate pharyngo-cutaneous fistulas which severely limit the usefulness of this method.

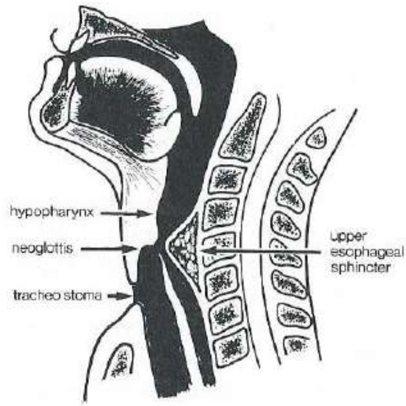


Figure 1. Tracheo-hypopharyngeal shunt (Staffieri's neoglottis) in sagital section — diagrammatic.

This paper reports our long term experiences with Staffieri's procedure in 42 patients. Our results were evaluated regarding voice prodution, aspiration problems and pharyngo-cutaneous fistula formation. Regarding the pharyngo-cutaneous fistula formation, a group of 43 patients who underwent a conventional total laryngectomy is included in this study for comparison.

MATERIAL AND METHODS

Since May 1979, when we began to use Staffieri's procedure, until July 1983, 42 patients have undergone this procedure. Forty of these patients were male and 2 females. They varied in age from 42 to 74 years, the average age being 58.1 years. One patient had latent diabetes, which was not known at the time of surgery. Twenty-two of these patients were radiation failures. They developed a recurrence between 4 and 31 months (average of 11 months) after radiotherapy. There were 18 patients who were irradiated at the department of Radiotherapy of the Free University Hospital, Amsterdam. They were all treated using individual shell masks, simulator set-ups, computerized dosimetry and shrinking fields. The field sizes varied from 6×6 cm^2 to 8×8 cm^2 but most patients received 7×7 cm^2 as initial field with shrinkage at 58 Gy to a smaller and at 64 Gy to the smallest (4×4 or 5×4 cm^2) fields. The cumulative dose varied from 68 to 72 Gy in about 7 weeks with a daily dose of 2 Gy. All of them underwent photon radiotherapy using a linear accelerator. Not only the initial simulator set-up but all of the smaller fields were controlled by computerized dosimetry and port-film checks.

The tumor site was either glottic or supraglottic. Only in 3 patients, subglottic extensions of the tumour were present. These were never more than 1 cm. In none of these patients the pyriform sinuses were involved clinically, however, in one patient radiological asymmetry was noted in a pyriform sinus. None of these tumours were suitable for partial laryngectomy procedure. Of the 20 patients who had had no previous treatment and thus could be classified according to TNM classification system of the UICC (1982), 19 presented with lesions classified as T_3 or T_4.

In 25 out of 42 patients a radical neck dissection was carried out. In 17 patients the radical neck dissection was performed together with total laryngectomy as a primary procedure. In two of them a bilateral radical neck dissection was done. Four of these 17 patients were treated with postoperative radiotherapy. In 8 patients the radical neck dissection was done as a secondary procedure, 5 to 35 months (average of 14.9 months) after total laryngectomy. Seven of these 8 patients had subsequent radiotherapy.

These patients were operated according to the technique described by Staffieri (7). We adhered to Staffieri's recommendation of not creating a fistula larger than 5 mm. At no time the oncological principles of cancer irradiation were compromised.

For the purpose of comparison 43 patients who underwent a conventional total laryngectomy at this department in about the same period were included in this study at random. None of these 43 patients had tumor involvement of the hypopharynx or were treated for a recurrence after partial laryngectomy. Forty of these patients were men and only 3 women. They varied in age from 52 to 84 years, the average age being 66.7 years. Five patients were known to have diabetes. Approximately half of these 43 patients had previously been treated with radiotherapy, all of them in the Free University Hospital. In 14 patients a radical neck dissection was performed together with a laryngectomy. In one of them a bilateral procedure was done.

The follow-up period of the Staffieri patients varied from one to five years with an average of approximately two years.

In our evaluation of this surgical voice rehabilitation technique a patient is categorised as a success if he uses his Staffieri voice as a primary method of communication and if he has no or only slight discomfort from aspiration, which does not need treatment. Regarding the evaluation of the voice obtained with this method and the possible aspiration problems we laid emphasis on the patients own opinion. Thus a subjective study was undertaken by means of a questionnaire. Patients were asked to rate their Staffieri voice from 1 to 10, 1 being the worst and 10 being the best. Other questions with regard to voice production pertain to fatigue during phonation and problems in closing the tracheostome during phonation. Five phrases were used to quantify aspiration symptoms: "not at all"; "slight"; "moderate"; "quite a bit" and "extreme". We chose this method as röntgenographic studies did not prove to be useful in this respect, especially because of a discrepancy between the röntgenographic results and the patient's own opinion.

Regarding the risk of postoperative pharyngo-cutaneous fistula formation we studied the incidence of pharyngo-cutaneous fistulas as well as their severity. A salivary fistula is regarded as severe, if spontaneous closure does not occur and it needs to be closed surgically. The period of hospitalisation after the operation has also been used as a parameter for the severity of the fistula. A distinction is made between patients who recieved previous full course radiotherapy and patients who underwent surgery as primary treatment. However, only those patients who were irradiated in our hospital were considered suitable for comparison. Patients with diabetes are known to have a more complicated postoperative course. They will be discussed separately. Patients were selected for neck dissection either because of the presence of a metastatic node on the ipsilateral side or as an elective procedure in a T_3 or T_4 laryngeal carcinoma. Because of these criteria most of the patients who underwent a radical neckdissection in combination with a total laryngectomy and Staffieri's procedure did not have previous radiotherapy. Only 3 patients underwent a radical neckdissection in combination with a total laryngectomy and Staffieri's procedure, having received previous radiotherapy in this hospital. These 3 patients will not be evaluated separately.

RESULTS

After an average follow-up period of two years 19 of the 42 patients who have undergone a laryngectomy with Staffieri's procedure were successfully rehabilitated. Because of a temporary deterioration or loss of speech through the neoglottis, 4 of these 19 patients underwent a minor procedure like endoscopic dilatation of the fistula or removal of polypoid tissue from the neoglottis region. In these 4 patients adequate voice was established.

Ten of the 42 patients failed to acquire speech through the neoglottis. Only in one patient it was clear that granulation tissue prevented the flow of air through the neoglottis. Another patient had an unexplained paroxysm of coughing for nearly 12 hours in the immediate postoperative phase which may have led to damage of the neoglottis. As all the subjects who failed to acquire speech through the neoglottis did acquire esophageal speech in the mean time, no further attempt of revision surgery was made.

It must be stated, that initially 3 patients used their neoglottis for phonation without aspiration problems. At some date after the laryngectomy one of these three patients underwent a radical neck dissection with postoperative radiotherapy, after which he lost his Staffieri voice presumably due to sequelae of mucositis. Another patient found phonation through his neoglottis more tiring than his esophageal speech while the third patient, who had latent diabetes, preferred esophageal speech because he needed the use of both his hands in his daily work. Incidentally this last patient developed aspiration problems at a later stage. He is included in the group of 11 patients mentioned hereafter.

This retrospective analysis showed that 11 patients had aspiration problems for which they needed treatment. The neoglottis itself had been established in the same manner in all of our patients. However, in 4 patients the trachea was transected obliquely in an anterior to posterior direction in order to avoid stasis of saliva, thus improving the quality of voice. Remarkably, 3 of these 4 patients had aspiration problems for which they needed treatment. Six of these 11 patients initially benefitted from the Staffieri procedure and had no aspiration problems, but developed aspiration later in the course of this evaluation. In none of our patients the aspiration problems caused pulmonary complications after discharge from the hospital.

The influence of radiotherapy on the success rate has been studied. Nineteen of the total 42 patients were successfully rehabilitated, of these 8 (42%) were previously irradiated. Ten of the 42 patients failed to acquire speech through the neoglottis. Of these 6 (60%) had undergone surgery for a recurrence after radiotherapy. Of the 11 patients who had aspiration problems 7 (64%) were primarily treated with radiotherapy and operated for recurrence. These figures suggest that previous radiotherapy does influence the success rate negatively. Four patients received postoperative radiotherapy after laryngectomy and Staffieri's procedure. Three of these 4 patients have been successfully rehabilitated. One of these lost his Staffieri voice during radiotherapy, but regained fully without treatment 3 months after completion of radiotherapy. The last of the 4 patients had troublesome aspiration in the immediate postoperative phase, for which he needed treatment.

The aspiration problems in the 11 patients were difficult to treat. Revision surgery, carried out in 4 patients, did not help in solving the aspiration problems. Closure of the neoglottis entails a much larger surgical procedure than would appear to be the case. Instead of attempting to close the neoglottis surgically we have subsequently used the Groningen type of voice prosthesis (10). In the 8 patients in whom this prosthesis was inserted this not only solved their aspiration problem but also preserved their voice. Normally these prostheses are supposed to have a life of 100 days and need to be replaced at the end of this period or earlier in

case they get extruded. These prostheses certainly offer a good alternative to surgical closure.

A subjective study was done regarding the results of the operation on 19 patients who used their Staffieri voice as a primary method of communication and did not need treatment for aspiration problems. Of the 19 patients only 17 patients were included in this study, since 2 had died of disease in the meantime. Of each returned list nearly all the questions were answered. The patients were asked to rate their Staffieri voice from 1 to 10 in ascending order of quality. The average rating was 7.7 varying from 6 to 10. In general the loudness of the voice and understandibility of speech was being rated as satisfactory or good. Three of these patients found phonation tiring. Three patients had problems in closing the tracheostoma for phonation. This problem is related to the size and position of the stoma, the height of the necessary pressure and the mobility of the arm, which is often restricted after radical neck dissection. Having to close the tracheostoma with the finger during speech was regarded a disadvantage of neoglottic speech by more than half of the patients. Most of the 17 patients studied had no or seldom any aspiration. Five patients experienced aspiration only if they drank too much and too fast at the time. Only 5 of the 17 patients said to have regular aspiration problems, but even these could manage by drinking carefully and did not need to be reoperated.

Table I shows the incidence of pharyngo-cutaneous fistulas and duration of hospital stay after conventional total laryngectomy as well as after total laryngectomy and Staffieri's procedure. The patients are grouped according to primary surgery and surgery for recurrence after radiotherapy. Not tabulated are 4 Staffieri patients who received their previous radiotherapy elsewhere and a total of 6 patients with diabetes mellitus. It can be noted that a higher frequency of salivary fistulas is seen in patients with a laryngectomy after Staffieri compared to patients with a conventional total laryngectomy. However, these differences are not statistically significant (Fischer test, $p > 0.05$). For the group of patients with a conventional total laryngectomy a higher frequency of pharyngo-cutaneous fistulas can be noted after surgery and previous radiotherapy, compared to surgery alone, but these differences did not reach statistical significance either (Fischer test, $p > 0.05$). After a total laryngectomy and Staffieri's procedure for irradiation failure the postoperative pharyngo-cutaneous fistula rate is also higher than after surgery as a primary treatment. Again, this too is not a statistically significant difference (Fischer test, $p > 0.05$). However, the incidence of pharyngo-cutaneous fistulas which needed surgical closure in patients who underwent a total laryngectomy and Staffieri's procedure for irradiation failure is significant. Moreover, the one patient who underwent a conventional total laryngectomy and died after an excessive wound breakdown, was previously treated with radiotherapy. The figures mentioned above suggest that previous radiotherapy is closely related to the seriousness of the fistula rather than the incidence alone.

Not tabulated are 5 patients with a conventional total laryngectomy and one patient with a total laryngectomy according to Staffieri with diabetes mellitus. This patient group is not homogenous regarding the seriousness of the diabetes. The

Table I. Pharyngo-cutaneous fistula formation and duration of hospital stay after conventional total laryngectomy and following total laryngectomy with Staffieri's procedure.

Mode of treatment		Total no. of patients	No. of patients with fistulas	No. of fistulas requiring surgical closure	Hospital stay of patients without fistulas*	Hospital stay of patients with fistulas*	Hospital stay of total group*
A. Conventional total laryngectomy	Primary surgery	23	3(13%)	1(33.3%)	18(14-48)[2]	42(40-74)	19(14- 74)[1]
	Surgery for recurrence after radiotherapy	15	3(20%)	1(33.3%)	18(13-38)	47(36-58)	21(13- 58)[3]
B. Laryngectomy after Staffieri	Primary surgery	19	7(36,8%)	1(14.3%)	28(15-46)[2]	39(30- 72)[4]	35(15- 72)[1]
	Surgery for recurrence after radiotherapy	18	8(44.4%)	6(75.0%)	23(16-49)	78(51-142)[4]	41(16-142)[3]

*Median value and range in days. Significant differences between groups are indicated with symbols:
[1] = $p < 0.01$; [2,3] = $p < 0.02$; [4] = $p < 0.05$ (Wilcoxon's two sample test).

patient with a total laryngectomy according to Staffieri had a latent diabetes with postoperative high blood glucose levels and was treated with insulin. This patient and another with a conventional total laryngectomy were not previously irradiated and had no salivary fistula. The remaining 4 patients of this group were previously irradiated and had a conventional total laryngectomy with radial neck dissection. All 4 patients developed a pharyngo-cutaneous fistula. One died of haemorrhage from the carotid artery.

A late complication associated with pharyngo-cutaneous fistula formation is the occurrence of a stenosis of the hypopharynx which was seen in 5 Staffieri patients and in 1 patient with a conventional total laryngectomy. Four of these Staffieri patients suffered a serious pharyngo-cutaneous fistula. In one Staffieri patient the stenosis developed after a secondary radical neck dissection with postoperative radiotherapy.

Table 1 also compares the period of hospital stay after conventional total laryngectomy and total laryngectomy with Staffieri's procedure. Median value and variations are given. Regarding the patients who were not previously irradiated a significant difference in the length of postoperative stay in hospital could be found between patients after conventional total laryngectomy and patients after total laryngectomy and Staffieri's procedure (Wilcoxon's two sample test; $p < 0.01$). This is consequent to the higher incidence of salivary fistulas in patients after Staffieri's procedure. For patients, not previously irradiated who did not develop a pharyngo-cutaneous fistula, a significant difference was found (Wilcoxon's two sample test; $p < 0.02$). This may reflect the time required for initial voice therapy and rehabilitation of swallowing in Staffieri patients. Surgery performed in previously irradiated patients is associated with a much longer hospitalisation period after Staffieri's procedure than after total laryngectomy alone (Wilcoxon's two sample test; $p < 0.02$). This is mainly due to the number of fistulas and to the seriousness of the fistulas in the Staffieri group. There were no deaths from complications in this group.

We studied the influence of previous radiotherapy on the length of postoperative stay in the hospital, in the group of patients who underwent a conventional total laryngectomy as well as in the group of patients who underwent a total laryngectomy and Staffieri's procedure. We could not find a statistically significant difference in hospital stay between the patients who had surgery as a primary mode of treatment and those who were operated for a radiation failure (Wilcoxon's two sample test $p > 0.05$). However, those Staffieri patients who developed a fistula after surgery and previous radiotherapy were hospitalized much longer than those Staffieri patients who had a fistula after surgery alone (Wilcoxon's two sample test $p < 0.05$). These figures suggest a relation between previous radiotherapy and the seriousness of the fistulas.

DISCUSSION

As the number of patients who underwent a Staffieri procedure after total laryngectomy has grown, there has been an increasing awareness of the problems and complications associated with this surgical procedure.

Approximately 50% of the patients were successfully rehabilitated. These patients did actually appreciate the quality of their new voice. Twentyfive percent of the patients did not use the neoglottis for speech production, mostly because of a stenosis of the fistula. Since it has been our policy to teach esophageal speech as well, all the patients who did not use the neoglottis could still communicate without further intervention. The remaining 25% had serious aspiration problems which had to be corrected. It was striking that 6 of these 11 patients initially benefitted from the Staffieri procedure and had no aspiration problems at all. Another problem we encountered in our patients who underwent a total laryngectomy and Staffieri's procedure is the high fistula rate compared to the patiens who underwent a conventional total laryngectomy.

There were no pulmonary complications in our patients. A few of our successfully rehabilitated patients noticed some aspiration from time to time. However, they could manage this problem by not drinking too fast. Studies conducted with regards to manometric pressure measurements suggest that in some patients the problem of aspiration may be related to a dysfunction of the upper esophageal sphincter and a lack of coordination between the pharyngeal musculature and the upper esophageal sphincter, leading to stasis of the bolus above the neoglottis (12). These studies were performed using a low-compliance pneumohydrolic perfusing system with a triple-lumen catheter assembly and are elaborately discussed in Chapter V.

In Table 2 the results of Staffieri's technique as reported in the literature have been summarized. Overall success rates are given which include a certain number of reoperated cases. It is noteworthy that not only the number of reoperations but also the success thereof varied considerably among these studies. Without these reoperations most authors (14-16, 22) claim success rates of about 50% which is comparable to the results of this study. As, in other studies, our attempts to establish adequate voice with a secondary procedure has been far more successful than our reoperations to eliminate aspiration.

There are more factors which should be borne in mind when a comparison between the various studies mentioned in Table 2 is made. The patient groups are by no means homogenous regarding stage of cancer, and the extent of the surgical procedure, previous radiotherapy, neck dissections, etc. For example Staffieri (8) as well as Calearo and Caroggio (15) only rarely perform a laryngectomy in combination with Staffieri's procedure for radiation failures, because of a possible negative effect on the function of the neoglottis. Others (23-25) did not consider radiotherapy a contraindication for Staffieri's procedure. More than half of our patients who underwent a Staffieri's procedure had previous radiotherapy. Although not convincingly, our figures do suggest that previous radiotherapy influences the success rate negatively.

Table 2. Results of total laryngectomy and Staffieri's procedure.

Author		No. of patients	No. of revisions	Success rate (%)
Staffieri	(1979)[8]	105	36	91
Sisson & Goldman	(1980)[13]	26	8	65
Steiner	(1980)[14]	50	?	43
Calearo & Caroggio	(1981)[15]	63	14	68
Gatti et al	(1981)[16]	10	4	70
Kuske	(1981)[17]	19	4	65
Navratil	(1981)[18]	12	?	50
Bailey et al	(1982)[19]	50	21	50
Hybásek	(1982)[20]	28	8	65
McConnel & Teichgraeber	(1982)[21]	13	7	50

It is not clear whether the authors of the studies in Table 2 have evaluated the aspiration problems in the same critical way. Bailey (19) stressed the importance of grading the amount of aspiration. But even if a usable objective method of grading is found, that is not a complete answer to the problem. From our own experience, we know that sometimes a discrepancy can be noted between the investigator's opinion and the opinion of the particular patient regarding the amount of aspiration. Therefore a subjective evaluation by means of a questionnaire is included in this study.

Moreover, in a comparison of the results of studies on surgical voice rehabilitation, the time interval between primary surgery and the time of evaluation should be taken into account. Various authors (14, 21) have shown that in time, after the operation, the success rate diminishes significantly. This is mainly due to the development of late aspiration problems, which has also been found in this study. However, in most of the studies mentioned in Table 2 the follow-up period is not stated.

It is clear from this study that a total laryngectomy in combination with Staffieri's procedure is associated with a higher number of pharyngo-cutaneous fistulas, compared to that after conventional total laryngectomy alone. After a conventional total laryngectomy the frequency of pharyngo-cutaneous fistulas in this study compares favourably with the 7.4-69% reported in other studies (26-35). In our patients the frequency of pharyngo-cutaneous fistulas after Staffieri's procedure, especially in previously irradiated patients, is higher than the percentages mentioned in the literature, which vary from 8 to 31 (13, 16, 24, 25, 36, 37). However, differences in patient material make various series difficult to compare.

Most surgeons who operated on previously irradiated patients, have long recognised that these patients do less well in terms of wound healing. However, there is a disagreement concerning the possible relationship between radiotherapy and salivary fistulae. Some authors (29, 31, 33, 35) found a relation between radiotherapy and the incidence of postoperative pharyngo-cutaneous fistulas. This study nor other studies (26, 28, 32, 38) showed such a relationship. Yet the relationship between radiotherapy and the severity of salivary fistulas, which was also found in this study, is well documented (26-28, 32, 33, 35). The high percentage of failures in patients with history of previous radiotherapy as well as the prolonged hospitalstay of some of these patients, lead us to consider previous radiotherapy a significant contraindication for Staffieri's procedure in our patients.

We learned from this experience that like in any surgical technique strict selection of cases is important. Proper preoperative evaluation and preparation are essential. It must be mentioned that our approach to the therapy of laryngeal cancer in general is conservative (39). As a result patients who were subjected to Staffieri's technique were only those with recurrence after radiotherapy or those with large tumors. When large tumors are removed and the remaining pharyngeal mucosa and musculature are limited one can expect problems in healing.

Based on the results of this series, Staffieri's technique is a questionable alternative to total laryngectomy and esophageal speech for rehabilitation. Post-operative complications are higher than with a total laryngectomy alone. Apart from the early complications a number of patients developed late aspiration problems. This series substantiates the necessity of long term follow-up of a surgical voice rehabilitation procedure after total laryngectomy before any conclusions can be drawn on the preference to esophageal speech.

REFERENCES

1. CONLEY, J.J., DeAMESTI, F., PIERCE, J.K. A new surgical technique for the vocal rehabilitation of the laryngectomized patient. Ann. Otol. Rhinol. Laryngol. 67: 655-664, 1958.
2. CALCATTERA, T.C., JAFEK, B.W. Tracheo-esophageal shunt for speech rehabilitation after total laryngectomy. Arch. Otolaryngol. 94: 124-128, 1971.
3. ASAI, R. Laryngoplasty after total laryngectomy. Arch. Otolaryngol. 95: 114-119, 1972.
4. TAUB, S., SPIRO, R.H. Vocal rehabilitation of laryngectomees: Preliminary report of a new technic. Am. J. Surg. 124: 87-90, 1972.
5. EDWARDS, N. Post-laryngectomy vocal rehabilitation. J. Laryngol. Otol. 88: 905-918, 1974.
6. AMATSU, M. A new one-stage surgical technique for postlaryngectomy speech. Arch. Otorhinolaryngol. 220: 149-152, 1978.
7. STAFFIERI, M. La chirurgia riabilitativa della voce dopo laringectomia totale, in Staffieri M., Serafini I. (eds): La riabilitazione chirurgica della voce e della respirazione dopo laringectomia totale. Relazione ufficiale del 29° congresso nationale AOOI Bologna,1976, pp. 1-222.
8. STAFFIERI, M. Neue chirurgische Möglichkeiten zur Rehabilitation der Stimme nach totaler Laryngectomie. HNO-Praxis 4: 243-253, 1979.
9. TIWARI, R.M., SNOW, G.B., LECLUSE, F.L.E., GREVEN, A.J., BLOOTHOOFD, G. Observations on surgical rehabilitation of the voice after laryngectomy with Staffieri's method. J. Laryngol. Otol. 3: 241-250, 1982.
10. NIJDAM, H.F., ANNYAS, A.A., SCHUTTE, H.K., LEEVER, H. A new prosthesis for Voice Rehabilitation after Laryngectomy. Arch. Otorhinolaryngol. 237: 27-33, 1982.
11. BLOM, E.D., SINGER, M.I., HAMAKER, R.C. Tracheostoma valve for postlaryngectomy voice rehabilitation. Ann. Otol. Rhinol. Laryngol. 6: 576-578, 1982.
12. VUYK, H.D., KLINKENBERG-KNOL, E., TIWARI, R.M. The role of the upper esophageal sphincter in voice rehabilitation after laryngectomy and Staffieri's procedure. J. Laryngol. Otol. (in press).

13. SISSON, G.A., GOLDMAN, M.E. Pseudoglottis procedure: Update and secondary reconstruction techniques. Laryngoscope 90: 1120-1129, 1980.
14. STEINER, W. Chirurgische rehabilitation der stimme nach laryngektomie (derzeitiger stand). Therapeutische Umschau 37: 1117-1127, 1980.
15. CALEARO C.V., CAROGGIO, A. Total laryngectomy with tracheopharyngeal fistula (neoglottis). Ann. Otol. 90: 217-221, 1981.
16. GATTI, W.M., LUCCHINETTI, M., THINAKKAL, R. Creation of the phonatory neoglottis. Preliminary experience with ten cases. Acta Otolaryngol. 91: 305-312, 1981.
17. KUSKE, I. Erfahrungen mit der methode von Staffieri zur wiederherstellung der stimme nach totaler laryngektomie. Laryng. Rhinol. 60: 373-375, 1981.
18. NAVRATIL, J. Our experience with laryngectomy according to Staffieri (neoglottis phonatoria). Cesk. Otolaryng. 30: 28-31, 1981.
19. BAILEY, B.J., LEIPZIG, B., GRIFFITHS, C.M. Neoglottic reconstruction: The Staffieri technique, in Sekey, A. (ed): Electroacoustic analysis and enhancement of alaryngeal speech. Charles C Thomas, Springfield Illinois, 1982, pp 282-301.
20. HYBÁSEK, I. Neoglottis phonatoria, own experiments, in Novák, A., Sram F. (eds): Abstracta congressus decimus societatis phoniatricae Europaeae, Prague, Czecoslovak Medical Society, 1982, pp 78-80.
21. McCONNEL, F.M.S., TEICHGRAEBER, J. Neoglottis reconstruction following total laryngectomy: The Emory experience. Otolaryngol. Head and Neck Surg. 90: 569-575, 1982.
22. DRAF, W. Die rekonstruktive laryngektomie nach Staffieri. Ein neuer Weg der stimmlichen Rehabilitation. Laryng. Rhinol. 57: 812-817, 1978.
23. GRIFFITHS, C.M., LOVE, T.J. Neoglottic reconstruction after total laryngectomy: A preliminary report. Ann. Otol. 87: 180-184, 1978.
24. GRIFFITHS, C.M. Experience with Staffieri's neoglottic technique, in Shedd, D.P., Weinberg, B. (eds): Surgical and prosthetic approaches to speech rehabilitation. G.K. Hall, Medical Publishers, Boston, 1980, pp 119-129.
25. LEIPZIG, B., GRIFFITHS, C.M., SHEA, J.P. Neoglottic reconstruction following total laryngectomy. The Galveston experience. Ann. Otol. 89: 204-208, 1980.
26. LAVELLE, R.J., MAW, A.R. The aetiology of postlaryngectomy pharyngocutaneous fistulae. J. Laryng. Otol. 86: 785-793, 1972.
27. JOSEPH, D.L., SHUMRICK, D.L. Risks of head and neck surgery in previously irradiated patients. Arch. Otolaryngol. 97: 381-384, 1973.
28. BRESSON, K., RASMUSSEN, H., RASMUSSEN, P.A. Pharyngocutaneous fistulae in totally laryngectomized patients. J. Laryngol. Otol. 88: 835-842, 1974.
29. STELL, P.M., COONEY, T.C. Management of fistulae of the head and neck after radical surgery. J. Laryngol. Otol. 88: 819-834, 1974.
30. PONCET, P. Total laryngectomy for salvage in cancers of the glottic region. Laryngoscope 85: 1430-1434, 1975.
31. LUNDGREN, J., OLOFSSON, J. Pharyngocutaneous fistulae following total laryngectomy. Clin. Otolaryngol. 4: 13-23, 1979.
32. CUMMINGS, C.W., JOHNSON, J., CHUNG, C.K., SAGERMAN, R. Complications of laryngectomy and neck dissection following planned preoperative radiotherapy. Ann. Otol. 86: 745-750, 1977.
33. WEI, W.I., LAM, K.H., WONG, J., ONG, G.B. Pharyngocutaneous fistula complicating total laryngectomy. Austr. NZ J. Surg. 50: 366-369, 1980.
34. LAM, K.H., WEI, W.I., WONG, J., ONG, G.B. Surgical salvage of radiation failures in cancer of the larynx. J. Laryngol. Otol. 97: 351-356, 1983.
35. ARORA, M.M.L., YANDE, R.D., GOLHAR, S., PANDHI, S.C., MANN, S.B.S. Critical evaluation of eighty laryngectomees for the possible causes of postoperative complications: A prospective study. Indian J. Otolaryngology 35: 5-8, 1983.

36. RUDERT, H. Erste Erfahrungen mit den Shunt-Operationen nach Staffieri und Amatsu. Zur Rehabilitation der Stimme nach Laryngektomie. Hat der tracheo-ösophageale Shunt eine Zukunft? Laryng. Rhinol. 58: 476-481, 1979.
37. McCONNEL, F.M.S., WHITMIRE, R. Neoglottic reconstructive laryngectomy: A preliminary report, in Shedd D.P., Weinberg, B. (eds): Surgical and prosthetic approaches to speech rehabilitation. G.K. Hall, Medical Publishers, Boston, 1980, pp 131-137.
38. HORGAN, E.C., DEDO, H.H. Prevention of major and minor fistulae after laryngectomy. Laryngoscope 89: 250-260, 1979.
39. SNOW, G.B., KARIM, A.B.M.F. Behandeling van larynxcarcinoom. Ned. T. Geneesk. 126, 24: 1096-1100, 1982.

ADDENDUM TO CHAPTER III

THE ONCOLOGICAL RESULTS OF TOTAL LARYNGECTOMY AND STAFFIERI'S PROCEDURE

Whatever method of surgical voice restoration is applied, at no time the oncological principles of cancer irradication should be compromised. The oncological results, especially regarding local tumor control, should therefore be included in an evaluation of a surgical voice restoration method. We have studied our patient material consisting of 42 patients who have undergone a total laryngectomy and Staffieri's procedure in this respect after a mean follow-up period of 3 years, varying from 2 to 6 years.

Of the 42 patients 17 underwent a radical neck dissection at the time of their total laryngectomy. In two of these 17 patients a bilateral procedure was done. In another 8 patients a radical neck dissection was carried out as a secondary procedure some time after their laryngectomy.

Histopathological examination of the larynx specimens showed that the margins were free of tumor in all cases. The neck specimens contained metastatic nodes in 13 out of 25 cases. In 12 of these 13 cases either three or more nodes were involved or extra nodal spread was found on histopathological examination. As one patient refused further irradiation, only 11 of these 12 patients had postoperative irradiation to their necks.

RESULTS

One of the 42 patients developed a stomal recurrence 16 months after the total laryngectomy and Staffieri's procedure. He had been previously irradiated. A radical neck dissection had been performed as a secondary procedure 7 months after the total laryngectomy on the side opposite to the side of the stomal recurrence. His stomal recurrence has been treated with radiotherapy in combination with chemotherapy consisting of a multidrug schedule of Vincristin, Bleomycin and Methotrexate. The initial response of the tumor recurrence is favourable, but follow-up is only 6 months.

Another patient developed a stomal recurrence 20 months after total laryngectomy and Staffieri's procedure. He has been irradiated primarily 10 months before the total laryngectomy. His stomal recurrence is presently under treatment following the lines of treatment outlined above.

A third patient developed a recurrence in the base of tongue after a radical resection – confirmed on histopathological examination – of a supraglottic tumor which had been treated previously with radiotherapy. He died of a carotid haemorrhage 7 months after the total laryngectomy.

A fourth patient underwent a primary resection of a T_3N_0 glottic/supraglottic carcinoma (TNM classification of the IUCC, 1982). Twenty months after the total laryngectomy he developed a large subdigastric metastatic lymph node on the right side, for which a radical neck dissection was done. The tumorous mass appeared to be fixed to the pharynx. In spite of postoperative radiotherapy the tumor locally persisted, forming a non-healing pharyngo-cutaneous fistula. This patient died three years after the initial surgical treatment.

In summary, 27 patients are alive without evidence of disease. Two patients are alive possibly with local disease. These are the two patients who developed a stomal recurrence. Seven patiens have died of their disease: 1 with local disease, 1 with regional disease and 5 with distant metastases.

Five patients developed a second primary tumor in the lung. Four of them have died. One is still being treated for the lung tumor.

One patient died in a car accident.

DISCUSSION

In this series of 42 patients who underwent a total laryngectomy and Staffieri's procedure two stomal recurrences and one recurrence in the base of tongue have occurred (7.1%). Leipzig (1982) and Staffieri A. (1979) reported similar percentages. In the literature the incidence of stomal recurrence after conventional total laryngectomy has been reported to be 3 to 40%, with an average of 7.4% (Davis & Shapshay, 1980). While comparing these figures to those concerning total laryngectomy and Staffieri's procedure mentioned above, one can say that the frequency of local recurrence after total laryngectomy and Staffieri's procedure is not greater than that after conventional total laryngectomy alone. However, one should adhere strictly to the criteria for the selection of patients for this type of surgery, such as these have been laid down earlier in chapter II.

REFERENCES

DAVIS, R.K. & SHAPSHAY, S.M. Peristomal Recurrence: Pathophysiology, Prevention, Treatment. Otolaryng. Clin. N. Am. 13: 499-508, 1980.

LEIPZIG, B. Neoglottic Reconstruction Following Total Laryngectomy: a reappraisal. In: Sekey, A. (ed) Electroacoustic analysis and enhancement of alaryngeal speech. Charles C. Thomas, Illinois: 297-298, 1982.

STAFFIERI, A. Katamnestische Erhebungen über funktionelle Resultate der Rehabilitation von Stimme und natürlicher Atmung nach Laryngektomie bei über 1000 von verschiedenen Chirurgen operierten Patienten. HNO-Praxis 4: 304-309, 1979.

Chapter IV

ACOUSTIC AND AERODYNAMIC DATA OF SPEECH AFTER LARYNGECTOMY AND STAFFIERI'S PROCEDURE

H.D. Vuyk, MD*, J.M. Festen, PhD*, A.J.G. Spoelstra, MD, PhD°, R.M. Tiwari, MS, FRCS, DLO, PhD*

From the Department of Otolaryngology* and Physiology°, Free University, Amsterdam, The Netherlands

(submitted for publication in Journal of Speech- and Hearing Disorders)

ABSTRACT

The voice obtained with the Staffieri method of surgical voice rehabilitation after total laryngectomy is studied in 20 patients and objectively described in terms of selected acoustic and aerodynamic parameters. For evaluation purposes, the results are compared with the data of normal speech, esophageal speech and speech as a result of other methods of surgical rehabilitation of voice as mentioned in the literature. Because acoustic and aerodynamic parameters are related they should be registered simultaneously. We studied intensity, fundamental frequency as well as pressure and airflow necessary to sustain phonation of the vowel /a/. From these data resistance and efficiency of the Staffieri sound source were calculated. Moreover the maximum phonation time and speaking rate were measured. In order to compare fundamental frequency and aerodynamic data among subjects, we suggest to use data interpolated to a 65 dBA intensity level. In the acoustic data no significant differences could be found between our patients and patients using various other alaryngeal speech forms. The air-flow differences between Staffieri speech and speech after other surgical voice rehabilitation methods and esophageal speech mainly reflects the difference in the driving force mechanism for voice production. Pressure data do not vary much among the different alaryngeal speech forms. Our findings support the notion that the upper esophageal sphincter is the main sound source in all forms of surgical voice rehabilitation and performs this function in essentially the same way as in esophageal voice.

INTRODUCTION

During the past two decades several methods of surgical voice rehabilitation after total laryngectomy have been described (Conley, de Amesti & Pierce, 1958; Calcaterra & Jafek, 1971; Asai, 1972; Taub & Spiro, 1972; Edwards, 1974; Amatsu, 1978). These techniques essentially consist of the creation of an internal or external connection between the trachea and the hypopharynx or esophagus. These surgically created fistulas permit shunting of air from the trachea to the hypopharynx. Through the expired air, vibrations of the air column in the pharynx are produced, which form the basis of speech. In spite of a considerable amount of work and research that has been done, stenosis of the fistula and leakage of saliva and food through the fistula still occurs frequently with most of the techniques.

Staffieri (1976) developed a simple single staged procedure which seemed to overcome these problems. A mucosa lined fistula is created between the trachea and hypopharynx following laryngectomy (Fig. 1). After Staffieri's procedure and also after most other procedures of surgical voice rehabilitation it is necessary to occlude the tracheostoma in order to divert pulmonary air into the hypopharynx. Worldwide more than 500 patients experienced a Staffieri procedure (Staffieri, 1979). However, recent studies (Steiner, 1980; McConnel & Teichgraeber, 1982) on long term follow-up suggest that the neoglottis phonatoria is eventually not able to prevent aspiration.

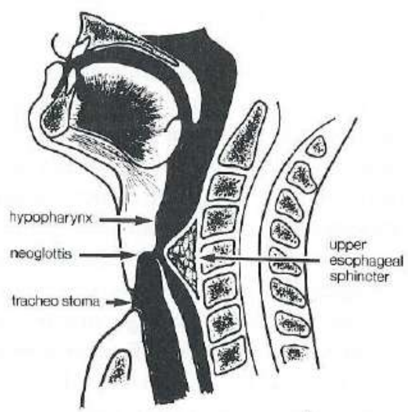


Figure 1. Tracheo-hypopharyngeal shunt (Staffieri's neoglottis) in sagital section – diagrammatic.

Singer and Blom (1980) developed a prosthesis with a one way valve which is inserted in a fistula created in the posterior wall of the trachea. The prosthesis is meant to prevent aspiration and stenosis without hindering the shunting of air into the hypopharynx. We, however, chose to rehabilitate the voice of our patients with the Staffieri procedure with the object of simultaneous rehabilitation without dependence on prosthetic material.

The phonatory process of the Staffieri method of voice rehabilitation is studied in 20 of our patients using both acoustic and aerodynamic parameters. For evaluation purposes, the results are compared with the data of normal speech, esophageal speech and speech as a result of other methods of surgical rehabilitation of voice as mentioned in the literature.

In Table I the results on physical parameters of voice production from various studies are summarized. Three main categories can be distinguished: studies on normal speech, studies on esophageal speech, and studies on speech after surgical rehabilitation of voice. Within the scope of this study we included the following parameters: intensity and fundamental frequency of the produced sound, pressure and airflow necessary to sustain phonation, and the maximum phonation time as well as the speaking rate.

Weinberg, Horii, Smith (1980) as well as Robbins, Fisher, Blom and Singer (1984) studied both esophageal speakers and laryngeal speakers. They showed that esophageal speech has a lower intensity than normal speech with differences up to 10 dB. The fundamental frequency is about one octave below the fundamental frequency of normal speech. Some voice rehabilitation methods seem to permit higher frequencies (Curry, Snidecor & Isshiki, 1973; Weinberg, Shedd & Horri, 1978; Tarnowska, Mozolewski, Lobacz, Jassem & Wysocki, 1979; Tarnowska, Jach & Mozolewski, 1982). The high frequencies measured in speech with the reed fistula method however are artificially raised as a reed is incorporated in the external prosthesis (Weinberg et al, 1978). The intensity levels measured by Jach, Mozolewski, Zietek, Tarnowska and Mikosza (1978) in patients after Mozolewski's procedure and by Robbins et al (1984) in patients after Blom-Singer procedure are higher than the intensity levels of the esophageal speakers. Remarkably, they are also higher than the values for phonation in normal adults. Because it is not likely that the surgically-constructed sound producing system is more efficient than the complex normal laryngeal system, these differences must be associated with a higher energy input (subneoglottic pressure and/or airflow).

In general, the pressure necessary to sustain speech after laryngectomy – esophageal speech as well as speech after surgical voice rehabilitation – is ten times higher than for normal phonation. On an average, pressure is about 30 cm H_2O, but with a considerable interindividual variation. For laryngeal speech Schutte (1980) found a lower pressure between 1.5 and 6 cm H_2O. The airflow values for esophageal speech are considerably lower than for normal speech or speech after surgical voice rehabilitation. This lower flow is not surprising considering the differences in the mechanism of speech production. The near normal values of airflow in speech after surgical voice rehabilitation reflect the use of a pulmonary driving source for speech production, analogous to the situation in normal speech.

The values for maximum phonation time and speaking rate are also mentioned in Table I. The maximum phonation time after surgical voice rehabilitation attains near normal values and contrasts favourably with the maximum phonation time of esophageal speech. The differences regarding the speaking rate are not as conspicuous. The use of pulmonary air for speech production apparently permits more favourable temporal values.

For various reasons the results of the studies mentioned in Table I are difficult to compare. The experimental conditions used vary among these studies. In most of the studies patients are phonating either at comfortable loudness and pitch while sustaining the vowel /a/ or at conversational loudness and pitch while reading a standard passage. Some studies use quite deviant conditions; Zinner and Fleschler (1972) studied esophageal speakers who sustained a vowel either as long as possible or as loud as possible. Schultz-Coulon, Sybrecht and Pilavakis (1980) studied Staffieri speakers, measuring pressure and airflow, but those patients were asked to phonate as loud as possible. Mahieu and Schutte (1984) studied patients with a Groningen internal voice prosthesis, who spoke as loud as possible. In Table I the various experimental conditions are mentioned (see Legends). Robbins et al (1984) studied normal subjects, esophageal speakers and patients phonating after a Blom-Singer procedure, while reading a standard passage and sustaining a vowel /a/. Intensity levels registered were lower while reading a standard passage than the values measured while sustaining a vowel /a/ for all three groups of patients. But even when studies using the same conditions are compared, a considerable variation can be found. As there is no evidence that comfortable loudness and pitch can be characterized by the same intensity and frequency for various subjects a certain variation can be expected. If comfortable loudness would mean phonation with a maximum result for a minimum effort, an efficiency optimum should be found for a certain intensity and frequency. In normal subjects no such optimum seems to exist (van den Berg, 1956; Cavagna & Margaria, 1965, 1968; Schutte, 1980). Only in one study (Perkins & Yanagihara 1968) an efficiency optimum was found for a certain frequency but this frequency varied among speakers.

Some relations among acoustic and aerodynamic parameters of speech have been studied for normal and esophageal speakers. Few of these are mentioned here in order to stress the importance of simultaneous registration of acoustic as well as aerodynamic parameters in studies on normal and alaryngeal speech. In normal speech pressure and airflow are related to intensity (Schutte, 1980). Phonetograms of normal speakers show a simultaneous variation of intensity and frequency (Seidner, Wendler, Wagner & Rauhut, 1981). Van de Berg et al (1958, 1959) reported that in esophageal speech pitch is linked with intensity. A high intensity is produced by an increased contraction of the upper esophageal sphincter accompanied by a higher subneoglottic pressure. As a consequence of this contraction fundamental frequency also increases with the production of a higher intensity. These examples show that a study including both acoustic and aerodynamic parameters, simultaneously registered, can be expected to provide critically important data for better understanding of voice production. However, in most of the studies on alaryngeal speech sofar, including those on Staffieri speech, only one or two of the variables mentioned in Table I have been studied. Some authors (van den Berg, 1956; Cavagna & Margaria, 1956, 1958; Schutte, 1980) have reported data regarding intensity, pressure and airflow simultaneously registered in normal speakers. From these data the authors have calculated the efficiency of normal voice production. In the study of Schutte (1980) the efficiency is defined as the ratio

Table 1. A survey of data from the literature concerning experimental data for intensity, frequency, pressure, airflow, maximum phonation time and speaking rate of laryngeal and alaryngeal speech production. The average value and range are given as well as the number of tested persons. Various experimental conditions are used, see text. Microphone — mouth distance varies in these studies from 15-30 cm, only Jach et al (1978, 1979) as well as van Heusden, Plomp and Pols (1979) used a distance of 100 cm. No corrections for these distances were applied. Various experimental conditions are indicated with symbols: [a]standard passage; [b]sustaining /a/; [c]maximum duration task; [d]maximum intensity task; [e]for airflow of 150 cc/sec.; [f]for 65 dB Sound Pressure Level.

Speech method	1st author		No. test persons	Intensity (dB)	Frequency (Hz)	Pressure (cm H_2O)	Air flow (ml/sec)	Max. phonation time (sec)	Speaking rate (words/min)
Oesophageal	Damsté	1958	22	58.5	<185(67.5)	18-59(32)			
	Snidecor	1959	6		17.2-135.5(62.8)				
	Isshiki	1964	6				25- 72		
	Berlin	1965	56					0.42-5.53(1.96)	
	Shipp	1967	33		40-185(74.9)				
	Snidecor	1968	6						85-129(113)
	Hoops	1969	22	62.4[a]SPL	42.9- 85.8(65.6)				65-169(114)
	Blom	1972	6						143-190(157)
	Weinberg	1972	33		33-200(69)				
	Zinner	1972	11			16.0- 93.4(54.7)[c]		0.44- 3.43(1.45)	
						28.0-113.4(70.7)[d]			
	Filter	1975	20		45-125(71.8)				36-129(100)
	Curry	1977	6		27.2-110.0(60.8)				
	Weinberg	1980	10	65.1[a]SPL					
	Bloothooft	1983	9	65[b]SPL					
	Robbins	1984	15	59.3[a]A	77.1				99
				73.8[b]SPL	65.3			1.9	
Surgical									
Asai	Snidecor	1968	5	72-80[b]	99-214		94.7-504.9(302.7)	3.3-13.1(7.35)	89-215(133)
	Curry	1973	5		40.8-149.0(97.1)				
	Iwai	1973	2			20.2-28.3(24.3)			
Calcaterra	Zwitman	1973	1		65			20	
	Komron	1974	8					7.2	133
	Saito	1977	6					7-35(20)	
Iwai	Iwai	1973	4			30.0-37.4(33.0)	43.0-382.5(156.7)		
Mozolewski	Jach	1978/79	30	72-92[b]		15.0-80.0(36.6)	50-300(120)		
	Tarnowska	1979			80-200			7-25(13)	
		1982			60-160(110)				
McConnel (ext.prosth.)	McConnel	1977	13	70	106				
	Schulz	1980	4			60-145(89)[d]	80-1480(533)[d]		
	Graner	1982	8						30-158
	Hybasek	1982	23			25-65			
	Novak	1982			70-110				
	Robbins	1982	2	63.5[a]SPL	48.5			11.0-15.5(13.3)	125
	Unger	1982	16					7-14	
	Bloothooft	1983	9	65[b]SPL	49-116(78)				
Amatsu	Amatsu	1980	25					5-28(15)	
		1984	16					6-30(15)	95-271(151)
Pearson	Pearson	1980/81	7			16-63(43)			
Taub (ext.prosth.)	Blom	1972	6		46.3-90.5(69.2)				
	Taub	1973/80	1			24-40			130-152(141)
Reed fistula (ext.prosth.)	Shedd	1972	1					14.6	99
	Weinberg	1978	4		107-204(148)				
	Shedd	1980	2				106-251(203)		
Blom-Singer (int.prosth.)	Wetmore	1981	13					3-30(14)	
	Weinberg	1982b	5			20-35(28)	104-182(133)		
	Robbins	1984	15	79.4[a]A	101.7				128
				88.1[b]SPL	82.8			12.2	
Blom Singer (int.prosth.only)	Weinberg	1982c	88			9.2-14.5(11.9)[e]			
	Moon	1983	15			17.9-19.5(18.6)[e]			
Groningen (int.prosth.)	Manni	1984	10	74-102[d]				3-31(10.5)	
	Mahieu	1984	17	74-88[d]A					
Panje (int.prosth.only)	Weinberg	1982a	4			54 -68 (60)[e]			
	Moon	1984	10			22.5-37.5(30)[e]			
Bivona (int.prosth.only)	Weinberg	1984	20			5.3- 6.8(6.0)[e]			
Laryngeal	Franke	1939							140-185
	Rollin	1962			132.1				
	Ptacek	1963	40♀					9-35(17)	
			40♂					13-50(25)	
	Hollien	1972			118.4				
	van Heusden	1979		50[a]A					
	Schutte	1980	63	58-106[b]SPL		1.5-6.0(2.5)[f]	30-300(140)[f]		
	Weinberg	1980	5	74.5[a]SPL					
	Robbins	1984	15	69.3[a]A	102.8				173
				76.9[b]SPL	103.4			21.8	

Table 2. Individual subject data: (a) age, (b) sex, (c) lungfunction parameters such as vital capacity [VC] and forced expired volume in one second [FEV_1], (d) previous radiotherapy, (e) postoperative pharyngo-cutaneous fistula formation, (f) length of time since discharge from hospital after surgery.

	(a)	(b)	(c)		(d)	(e)	(f)
Subject number	age	sex	VC (ml)	FEV_1 (%)*	Previous radiotherapy	Pharyngo-cutaneous fistula	Time since discharge from hospital (months)
S1	56	m	3300	67	—	+	24
S2	51	m	3870	41	+	—	23
S3	46	m	4470	54	—	+	28
S4	41	m	3810	82	+	+	20
S5	58	f	3520	75	—	—	17
S6	67	m	4040	64	—	—	18
S7	62	m	4500	47	+	+	14
S8	59	m	3890	72	+	—	3
S9	58	m	4580	74	—	—	6
S10	63	m	4250	70	—	—	9
S11	41	m	4780	77	+	+	9
S12	50	m	—	—	+	+	1
S13	64	m	4070	67	+	—	4
S14	67	m	3520	58	+	—	3
S15	60	m	4690	69	—	—	6
S16	68	m	2600	67	+	+	5
S17	52	m	2850	75	+	—	3
S18	56	m	4120	60	—	—	4
S19	50	m	4050	63	—	+	3
S20	70	m	4280	68	+	—	2
mean	57		3960	66			10

*percentages of normative values
— not known at time of surgery.

between the power of the sound produced integrated over a half sphere with radius r in front of the speaker ($2 \pi r^2 \times I$) and the generated aerodynamic power ($p \times \dot{V}$). Efficiency measurements combine both acoustic and aerodynamic parameters and may offer interesting data on other methods of voice production as well. The resistance of the airway is denoted by the ratio between pressure and flow and has been extensively studied for various voice prostheses (Weinberg et al 1982a,b,c, 1984; Moon et al 1983, 1984). As these studies were conducted in vitro, no acoustic measurements could be done.

In the present study intensity, frequency, subneoglottic pressure and airflow (of the voice) were simultaneously registered during phonation of a sustained vowel /a/ after surgical rehabilitation of voice with Staffieri's technique. Relationships between the measured parameters were studied. From the data obtained airway resistance and efficiency of the sound generating system can be calculated. Moreover the maximum phonation time and speaking rate were measured.

In comparing aerodynamic data with the results of other studies we suggest using the subneoglottic pressure and airflow for phonation at 65 dBA intensity level, which is approximately the middle of the intensity range in these patients (Bloothooft & Tiwari, 1983). However, esophageal speakers (Angemeier & Weinberg, 1981) as well as Staffieri neoglottis speakers are often unable to produce and sustain a vowel at a given intensity and frequency. We therefore studied the whole range of intensity and frequency levels and subsequently interpolated our data to a 65 dBA intensity level. The results will be evaluated further in relation to clinical data, which will be mentioned hereafter. Lastly, the relationship of the acoustic and aerodynamic data to the quality of voice as judged by these patients is studied.

SUBJECTS

Twenty patients who underwent a Staffieri procedure participated as subjects in the investigations. These patients (19 male, 1 female) used neoglottic speech as their primary method of communication. To a certain degree aspiration of liquid was experienced by 11 of these patients. Table 2 shows the individual subject data with respect to age, sex, lungfunction characteristics, radiotherapy, postoperative pharyngocutaneous fistula formation and length of time since discharge from hospital after surgery. All subjects in this group had received speech therapy to enhance neoglottic speech for an average period of 4 months, ranging from 3 to 6 months.

METHODS

The recording sessions were carried out in an anechoic room. During the measurements a mouth piece with a pneumotachograph (Fleisch nr. 2 reaching up to 3000 ml/sec) was inserted into the subject's mouth for airflow ($\dot{V}$) measurements.

Airflow was deduced from the pressure difference across the heated flowhead of the pneumotachograph using a differential pressure transducer (Statham PM 15 TC). A nose clip was used to prevent nasal airflow. The subneoglottic pressure (p_s) was measured under the Staffieri neoglottis in the tracheostoma using a silicon plug, which closed the tracheostoma during phonation. This plug was penetrated by a teflon tube (length 5 cm; internal diameter 2 mm). As a reference to the subneoglottic pressure the oral pressure was used, measured in the mouth piece before the connected flowhead. The pressure changes both from the tracheostoma and of the lumen of the mouth piece were conveyed to a differential pressure transducer of the type Valedyne MP245 reaching up to 100 cm. H_2O, using 2 PVC-tubes 60 cm. in length and with an internal diameter of 3 mm. The sound pressure level was measured by means of a sound level meter (Brüel & Kjaer type 2218) at a distance of 20 cm from the end of the pneumotachograph. We have measured fundamental frequency by means of an electroglottograph (Frøkjaer, Jansen type EG-830), similar to the study of Lecluse, Tiwari and Snow (1981) regarding the fundamental frequency of Staffieri speech. Signals representing intensity (I), fundamental frequency (f), subneoglottic pressure (p_s) and the airflow ($\dot{V}$) were registered on a Gould-Godart graphic recorder with a calibrated scale.

While studying the whole range of intensities and frequency levels the subjects were asked to phonate at their lowest and highest intensities and frequency levels as well as to phonate at various intermediate intensities and frequencies. Only when a tight seal of the tracheostoma was achieved, were the curves evaluated. In figure 2 an example is given of the simultaneous registered curves. Each set of measurements composed 15 to 30 phonations. During each investigation the data were accumulated at a time when the various parameters were in a steady state. Five such observations were made in each individual patient. For every measuring point the efficiency was calculated as $\mathrm{Eff} = 2\pi r^2 \times I/p_s \times \dot{V}$.

The gathered data were processed in a scatter diagram with intensity on the X-axis taken as independent variable and the values represented on the Y-axis as dependent variables. From our own preliminary studies on Staffieri speakers and from the literature regarding laryngeal speakers (van den Berg 1958 & Schutte 1980) it appeared that the relation can be described fairly well by a straight line if the logarithms of the dependent variables are used. The mean f, p_s and $\dot{V}$ as well as Eff for phonation at 65 dBA intensity level, is calculated using the regression of f, p_s, $\dot{V}$ and Eff on intensity. The pressure and flow obtained for 65 dBA determine the airway resistance ($R = p_s/\dot{V}$) of the Staffieri sound source for this intensity level.

The maximum phonation time and speaking rate were obtained in each subject while performing the following two tasks: (1) sustain the vowel /a/ with a minimum intensity of 65 dBA on a single deep breath for as long as possible (three trials) and (2) read a standard paragraph in their native dutch language at a conversational pace and level of loudness. The first task was performed in the experimental set-up described above. The second task was performed under the supervision of a speech therapist. Only six patients participated in this investigation, as the importance of measuring speaking rate in the evaluation of alaryngeal speech was realised at a later stage during this study.

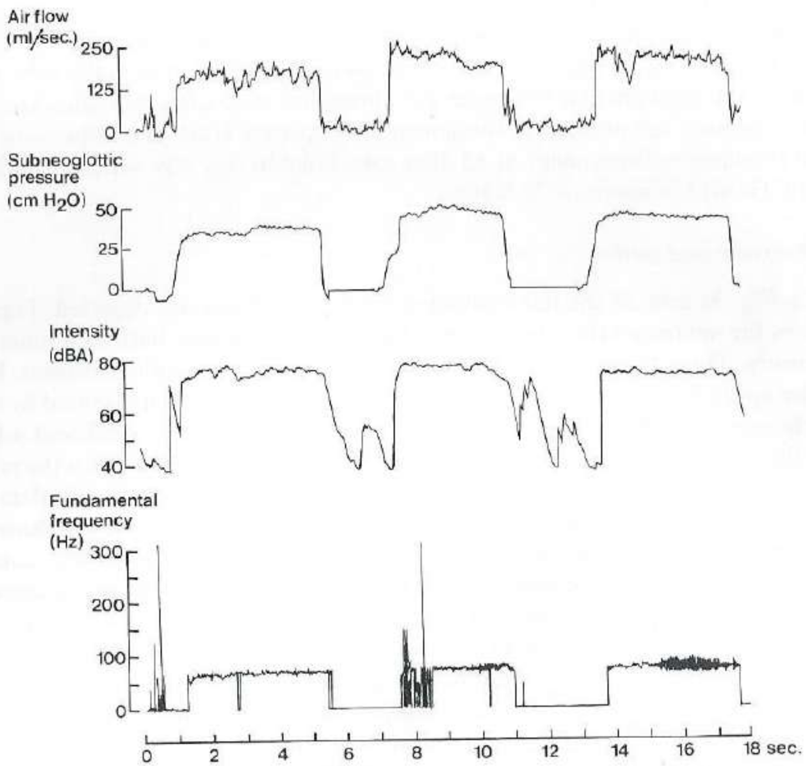


Figure 2. Example of simultaneous registration of airflow, subneoglottic pressure, sound intensity and fundamental frequency in a patient phonating with a Staffieri neoglottis.

RESULTS

a. Intensity and frequency

In the 20 patients examined, the maximum vocal intensity varied from 66 to 87 dBA and the minimum range was from 44 to 65 dBA. In 19 patients the fundamental frequency could be registered. In one patient the electrode of the electroglottograph could not be placed without causing a leak when closing the tracheostoma during phonation. For the 19 subjects the highest fundamental frequency ranged from 75 to 280 Hz and the lowest fundamental frequency range was from 15 to 130 Hz. For some speakers the determination of the lowest possible fundamental frequency was hindered by a type of phonation by which incidently very low values were obtained. As only a few data points were actually registered at 65 dBA the fundamental frequency for phonation at 65 dBA was calculated using the regression for predicting fundamental frequency from sound-pressure level. The fundamental frequency at 65 dBA calculated in this way varied from 25.2 to 110.6 Hz with a mean of 70.5 Hz.

b. Pressure and airflow

In Fig. 3a and 3b the data obtained from one subject are depicted. Figure 3a shows the subneoglottic pressure and Figure 3b the airflow both as a function of intensity. These figures are representative for the data from other subjects. In first order approximation the variations with sound intensities is represented by means of the regression lines. In 17 of the 20 patients the correlation coefficient is higher for the relation between subneoglottic pressure and intensity than for the relation between airflow and intensity. High pressures were noted during the initial unstable portion of sustained vowel utterances in some patients. Frequency is shown in 6 categories for the individual points. Although a certain frequency could be produced for various intensities in our patients, a covariation between intensity and frequency was found in most of them. In 13 of the 19 patients in whom both frequency and intensity could be measured, the relation between frequency and intensity reached statistical significance ($p < 0.05$; Spearman's rank correlation test). Because of this close relationship between frequency and intensity, we refrained from studying pressure and airflow and their relations to intensity for different frequency categories (Fig. 3a and 3b).

Fig. 4a and 4b depict for 20 patients the regression lines, predicting subneoglottic pressure and air flow upon intensity. As a reference area for normal phonation we used the data collected by Schutte (1980). These data clearly show that the pressure necessary to sustain the vowel /a/ in neoglottis speakers always exceeds the values measured in normal subjects and shows large interindividual differences. On the other hand nearly all the regression lines calculated for airflow fall within the reference area of normal subjects. The subneoglottic pressure at 65 dBA varied from 17.1 to 68.6 cm H_2O (mean value 38.5 cm H_2O). The airflow at 65 dBA varied from 35 to 260 ml per sec. (mean value 107 ml/sec).

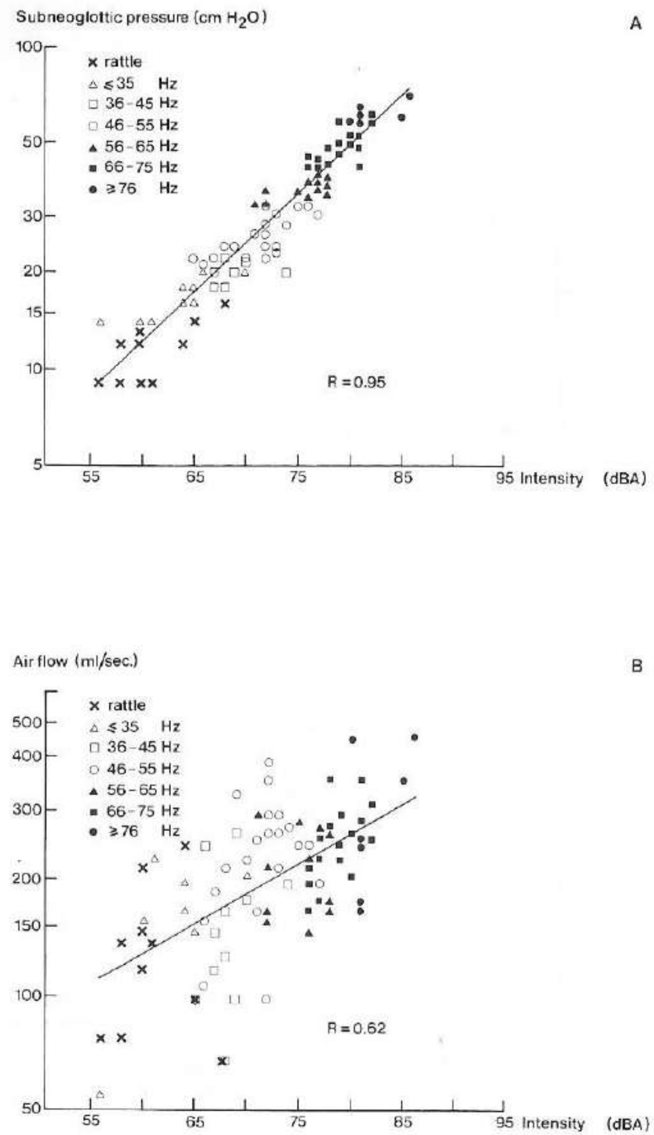


Figure 3. Subneoglottic pressure (panel a) and airflow (panel b) measured at various intensities for a sustained vowel /a/ produced by one Staffieri speaker. Six symbols indicate different ranges of fundamental frequency. The regression for predictions upon the intensity is shown with a straight line.

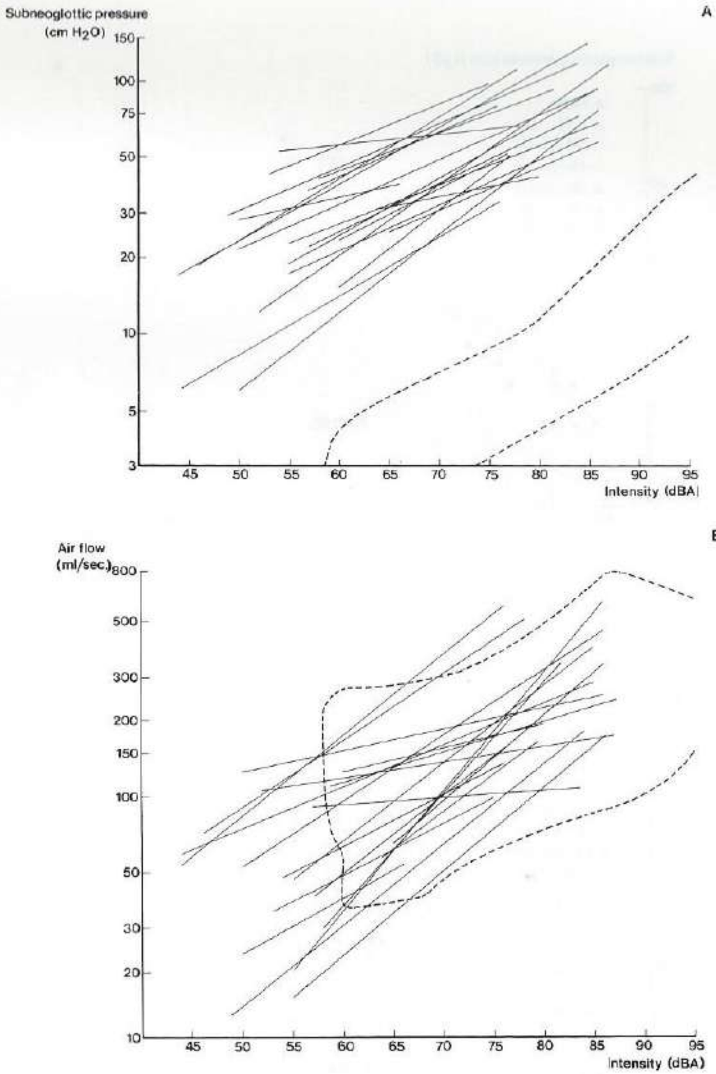


Figure 4. The set of regression lines for 20 Staffieri speakers predicting pressure (panel a) and airflow (panel b) from sound intensity. A reference area for normal speakers is indicated with dashed lines (after Schutte, 1980).

c. *Resistance*

The pressure and air flow values at 65 dBA were measured to calculate the resistance of Staffieri's sound source. Fig. 5a shows the results as a function of airflow. Although resistance and airflow are related measures they are depicted

together in order to be able to compare our data to the results from other studies on alaryngeal speech (Jach, Mozolewski, Zietek, Tarnowska & Mikosza, 1978; Jach, Mozolewski & Zietek, 1979; Weinberg et al 1982b) and normal speech (Smitheran & Hixon, 1981). The data in figure 5a show that airway resistance of the Staffieri sound source during phonation at 65 dBA ranged from about 0.072 to 1.248 cm H_2/ml/sec (mean value 0.505 cm H_2O/ml/sec). For comparable airflow a substantial variation in resistance among patients is evident.

In figure 5b the in-vitro resistance of various alaryngeal voice prosthesis are depicted (Weinberg, 1982a; Weinberg & Moon, 1982c, 1984; Moon & Weinberg, 1984; Henley-Cohn, 1984). In comparing the results of different studies on Panje prosthesis a substantial variation can be noted as well. From the study of Weinberg et al (1982b) it is known that the airway resistance measured during phonation with a Blom-Singer prosthesis is higher than the airway resistance of the Blom-Singer prosthesis alone.

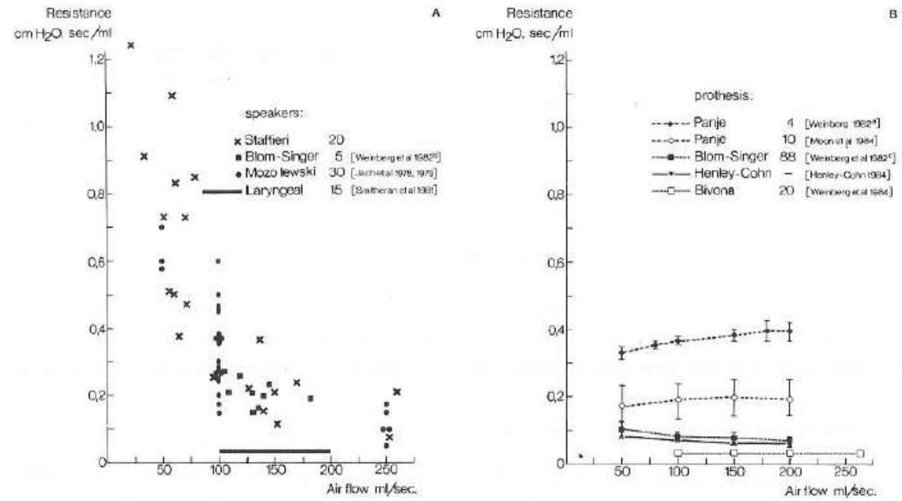


Figure 5. Panel a) shows the resistance as a function of airflow for the Staffieri sound source compared with resistance for various other alaryngeal sound sources and the normal human larynx during vowel production (see inset).
Panel b) shows the resistance of various alaryngeal voice prostheses studied in vitro (see inset).

d. *Efficiency*

Figure 6 shows the regression lines for predicting the efficiency of the sound source from sound intensity for our subjects. The efficiency of the Staffieri sound generating system for phonation at 65 dBA varied from 0.54×10^{-6} to 7.3×10^{-6} (average of 2.86×10^{-6}). Nearly all the regression lines lie below the lower border of the reference area for normal speakers, as established by Schutte (1980). The regression lines of patients who in our opinion had the best voice quality are depicted by heavy lines.

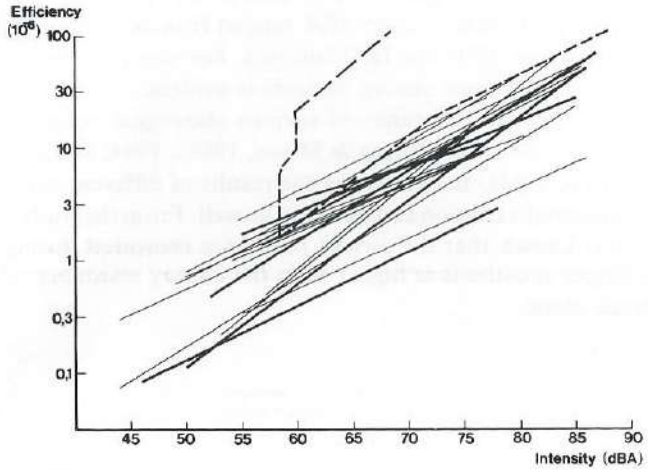


Figure 6. The set of regression lines for 20 Staffieri speakers predicting efficiency from sound intensity. The regression line for 5 patients with the most agreeable and easy resonant voice is indicated with a thick line. A reference area for normal speakers is indicated with a dashed line (after Schutte, 1980).

e. Maximum phonation time and speaking rate

The maximum phonation time of these 20 Staffieri speakers varied from 4 to 24 sec. with an average of 14 sec. In 6 patients the speaking rate was established. The number of words spoken per minute ranged from 67 to 166 with an average of 138.

f. Relation between measured and clinical data

Concerning the influence of the clinical data on physical parameters we found previous radiotherapy to be of importance in relation to fundamental frequency and airway resistance. As only a few patients were treated with radiotherapy post-operatively, these patients were not included in this part of the study. The maximum fundamental frequency of patients who had preoperative radiotherapy (mean 170 Hz; 100-280 Hz) was significantly higher ($p < 0.02$; Wilcoxon's two sample test) than in patients not previously irradiated (mean 119.3; 75-190 Hz). The airway resistance during phonation of patients with preoperative radiotherapy was 0.378 cm H_2O sec/ml (0.072-0.832); significantly less than the 0.744 cm H_2O.sec/ml (0.221-1.240) for patients who had no radiotherapy at all ($p < 0.05$; Wilcoxon's two sample test). A clinical feature related to the intensity range (the difference between maximum and minimum intensity) appears to be the period of time the patients have used their neoglottic voice. The intensity range is significantly higher in

patients who have been using their Staffieri speech for a longer period of time ($p < 0.05$; Wilcoxon's two sample test). To study the influence of air-volume we investigated relations between lung function parameters, such as vital capacity (VC), forced expired volume in one second (FEV_1) and the maximum phonation time as well as the speaking rate. However, no significant relation was found ($p > 0.05$; Spearman's rank correlation test).

g. Relation between subjective opinion and the measured data

In order to assess the clinical importance of the data measured in this study, the results were evaluated in relation to the subjective opinion about this method of speech. A questionaire was sent to the patients. Among other questions they were asked to rate their voice from 1-10 in terms of satisfaction and whether voice production was tiring. The mean rating was 7,5 varying from 4 to 10. For only 4 patients phonation was tiring. The significance of the relations between subjective opinion and aerodynamic parameters (p_s, $\dot{V}$, R, Eff) for phonation at 65 dBA are given in table 3. It is apparent that the subjective opinion about the voice rehabilitation bears close relationship to the pressure necessary to sustain phonation. Airflow values for phonation at 65 dBA had no relation with the subjective variables, probably because they fall within the normal range. The significant correlations between the subjective rating on one hand and both resistance and efficiency on the other hand are brought about by the afore mentioned correlation with the subneoglottic pressure.

Table 3. Data showing the relation between subjective opinion and measured parameters. The subjective evaluation was done in terms of voice quality rating from 1-10 and in terms of tiring or non tiring phonation. The difference between the aerodynamic parameters of the group of patients who found their phonation tiring and the group who did not find phonation tiring, is given.

	Voice quality rating*; (1-10)		Tiring phonation**; +/—		
	rank correlation	significance	difference (tiring, non-tiring)		significance
pressure	-0,65	$p < 0,01$	26.7	cm H_2O	$p < 0,01$
flow	0,09	$p > 0,05$	34,2	ml/s	$p > 0,05$
resistance	-0,46	$p < 0,05$	0,153	cm H_2O.s/ml	$p > 0,05$
efficiency	0,49	$p < 0,05$	-1,93		$p > 0,05$

*Spearman's rank correlation test.
**Wilcoxon's two sample test.

DISCUSSION

This study is meant to describe selected acoustic and aerodynamic features of the phonatory process after laryngectomy and Staffieri's procedure. In this fairly large group of patients a substantial variation in the measured acoustic as well as aerodynamic parameters was found. We sought to point out the factors responsible for this variation and to compare data of speech after Staffieri's procedure to the data concerning laryngeal speech, esophageal speech and speech after surgical voice rehabilitation procedures.

The maximum and minimum values of the vocal intensities show a substantial variation. A factor related to an increased intensity range is the period of time the subjects have used their neoglottic voice. This finding suggests that patients learn to optimize their alaryngeal voice and it stresses the importance of a long term follow-up. It is however true that each patient was not repeatedly examined at specified time periods.

Regarding the variations in fundamental frequencies it is remarkable that in some patients a very low fundamental frequency (< 20 Hz) was registered. Probably, these borderline phonations are caused by an irregular airflow through stasis of saliva in the hypopharynx. Part of the variability of the fundamental frequency is a result of radiotherapy. It is possible that the maximum fundamental frequency in irradiated patients is higher because of an increased stiffness of the tissues involved in sound production as a result of radiation fibrosis.

The ranges of other data, like pressure, airflow, resistance and efficiency and also of pressure and airflow values for phonation at 65 dBA show large interindividual differences as well. The interindividual differences in resistance of the phonatory mechanism may be related to previous radiotherapy. The reason for this observation, however, is not clearly understood. It is noteworthy that in the long run we encountered more problems of postoperative pharyngo-cutaneous fistula formation, stenosis of the neoglottis and aspiration in patients who were previously irradiated than in patients who had no previous radiotherapy (Vuyk et al, 1985a). We, therefore, consider previous radiotherapy a contra-indication for this procedure in spite of the more favourable resistance and fundamental frequency values registered in patients operated after previous radiotherapy. The measured ranges of pressure, airflow, efficiency, as well as their values for phonation at 65 dBA, appeared not to be influenced by clinical data such as previous radiotherapy, postoperative occurrence of pharyngo-cutaneous fistula and the age and time the patients had used their neoglottic voice before testing.

In normal speakers the maximum phonation time is related to the age and sex (Ptacek & Sander, 1963; Ptacek, Sander, Maloney & Jackson, 1966). Although our group of subjects under study was nearly homogeneous with regard to age and sex, a variation in the maximum phonation time and speaking rate was found among our patients. The assumption that patients, who use a greater amount of air for phonation would have a shorter maximum phonation time, could not be confirmed. Nevertheless, lung function parameters, such as vital capacity (VC) and forced expired volume in one second (FEV_1), did not bear any relation to maximum phonation time and speaking rate indicating that the results are not influenced by differences in the ventilation system itself. Analogous to normal subjects (Isshiki, Okamura & Morimoto, 1967) patients probably used their vital capacity only partly for maximum phonation time. Therefore lung function parameters within

certain limits, are not significant as to the indication for surgical voice rehabilitation with the Staffieri procedure especially as regards the maximum phonation time. This is consistent with the findings of Blechsmidt, de l'Espine, Brugger and Herrmann (1982) concerning other surgical voice rehabilitation methods using prosthesis.

Regarding the variation in acoustic, as well as aerodynamic parameters the upper esophageal sphincter plays an important role in voice production in these patients. Roentgenological studies (McCurtain, Noscoe, Berry, Snow, Tiwari, Lecluse & Rouma, 1982; Novak, Hlava, Hybàsek & Prsîkova, 1982) have shown a constriction of the lumen at the transition of the esophagus into the pharynx, above the neoglottis with an adequate air column below. Endoscopic examination in our patients with a neoglottis phonatoria leads one to think that the neoglottis functions as an inlet of air and that the pharyngeal mucosa above this level develops a form and pattern which may be reminiscent of the original vocal folds. The calculation of the resistance value represents in this group of patients the combined resistance of the Staffieri neoglottis and the pharyngo-esophageal segment which is identical with the upper esophageal sphincter. Considering the wide variation in the amount of residual pharyngeal musculature among these patients and as confirmed on roentgenological studies, it is not surprising to find large interindividual differences in the measured acoustic and aerodynamic characteristics of voice production.

In collaboration with the department of gastro-enterology we studied the pressure in the upper esophageal sphincter in our patients at rest as well as the pressure-waves during swallowing by means of intraluminal pressure recordings (Vuyk et al, 1985b). The variation in postlaryngectomy anatomy and physiology is reflected in the large interindividual differences found in this study. Patients who showed a normal relaxation and coordination of the upper esophageal sphincter needed significantly lower subneoglottic pressures, measured in the tracheostoma, to sustain phonation at 65 dBA than patients who did not show a relaxation or coordination of the upper esophageal sphincter ($p < 0.05$; Wilcoxon's two sample test). After dilatation of the esophagus, produced by the inflow of air, a reflex rise of the pressure in the upper esophageal sphincter occurs and is denoted by a constriction appearing in the roentgenograms. This reflex mechanism is known to exist in normal persons (Creamer & Schlegel, 1957). The pressure necessary to sustain phonation in our patients depended on the extent to which this reflex mechanism occurs and on the ability of the patient to induce a relaxation of the upper esophageal sphincter before air expulsion. A definite one to one relationship between intensity and pressure necessary to sustain phonation was found in this study (Figure 4a). A patient probably produces a higher intensity as the upper esophageal sphincter contracts as a result of a rise in the subneoglottic pressure. And as a consequence of this contraction, the fundamental frequency increases with a subsequent higher intensity of voice in most patients. No relation between upper esophageal sphincter function and previous radiotherapy was found, which could explain the more favourable resistance values obtained in patients operated after previous radiotherapy.

For evaluation purposes we have compiled data from the literature concerning the acoustic and aerodynamic characteristics of laryngeal, esophageal and surgical (after laryngectomy) voice. However, the comparison of data from different studies – including our own – can only be made with certain reservations. For instance there is no uniformity regarding the experimental conditions used in the various studies. Moreover, in our opinion phonation at comfortable loudness and pitch which is extensively used, is not very valuable in studying acoustic and aerodynamic parameters of speech production. There is no evidence that comfortable loudness and pitch can be characterized by the same intensity and frequency. Therefore reproducebility is marginal even within the same subjects. In the introduction we suggested that if comfortable phonation would mean phonation with a maximum result for a minimum effort, an optimum efficiency should be found for a certain intensity and frequency. Analogue to normal voice production, we found a clear one to one relationship with intensity and efficiency in our patients, which did not show any optimum (Fig. 6). In a comparison of acoustic parameters of various methods of voice production, probably only maximum and minimum values of intensities and frequencies are of importance.

Regarding the evaluation of physical parameters of voice production a simultaneous registration of aerodynamic as well as acoustic parameters is of importance. Our results show that a higher intensity is related to an increased pressure and airflow (Fig. 4) as in normal speech production (Schutte, 1980). Regarding the co-relation between pressure and intensity a similarity can be noted with esophageal speech (van den Berg et al, 1958). As alaryngeal speakers are often unable to produce and sustain a vowel at a given intensity and frequency, and as comfortable loudness and pitch are of no use in this respect, we suggest studying the whole range of at least the intensity. For comparison purposes one can interpolate the data to a fixed intensity. We suggest using 65 dBA in this respect as this level of intensity falls within the range of most types of alaryngeal speech. In our patients a co-variation between intensity and frequency can be noted which is known to exist in normal and esophageal speech as well (Fig. 3). Therefore frequency measurements are of secondary importance when aerodynamic parameters of voice production are studied.

Within the above mentioned limitations we have evaluated our results in a comparative way. The results of our study are similar to the results of other studies on Staffieri's speech mentioned in Table 1. Compared to normal speakers the fundamental frequency is approximately one octave lower. The maximum intensity in our patients is at least 10 dB lower than in normal subjects. On the contrary the pressure necessary to sustain phonation is about 10 times greater for Staffieri speakers than for the normal voice (Fig. 4a). The mean airflow at 65 dB in our patients is lower than the mean value in normal subjects, but the airflow values of our group of patients fall within the normal limits (Fig. 4b). Consequently the resistance of the Staffieri sound source, being the ratio of pressure to airflow, is much larger than the normal laryngeal airway resistance during the production of a vowel (Fig. 5). It is encouraging that the efficiency of the sound source in some of

our patients approaches normal values. However, our hypothesis that patients with efficient voice production would have a more agreeable and "easy resonant" voice than other patients could not be confirmed. Schutte (1980) did not find high quality trained singer voices to be more efficient than non-trained voices. It is possible, however, that for singers the efficiency of the voice is only of secondary importance after esthetic demands.

In a comparison of the acoustic characteristics of Staffieri speech, found in this study, to the acoustic characteristics of esophageal speech, reported in the literature, no differences were observed. The similarity between Staffieri and esophageal speech was observed earlier by Bloothoofd and Tiwari (1983) in a study with 9 subjects in each of the categories. Furthermore in our patients subneoglottic pressure measured during phonation is within the same order of magnitude as in esophageal speakers. These findings are not surprising considering the similarity of the sound source in both methods of speech. This is well illustrated on xeroradiographic studies, showing the constriction of the upper esophageal sphincter in the same patient during esophageal as well as Staffieri speech (McCurtain et al, 1982). However, esophageal speakers use different mechanisms to initiate and sustain speech which consequently result in lower airflow values. Since the airway resistance is calculated from the ratio of pressure to airflow, the lower airflow values in esophageal speech lead to higher resistant values. Staffieri speakers are able to sustain speech for substantially longer periods of time than esophageal speakers. The primary reason for this is that they may draw upon the considerably larger respiratory volume. Vital capacity of the lungs is about 4000 cc, compared to 80 cc for a fully inflated esophagus (Diedrich, 1968).

Comparing our results with the results of studies on other surgical voice rehabilitation methods, only Robbins et al (1984) and Jach et al (1978, 1979), who respectively studied patients with a Blom-Singer prosthesis and after Mozolewski procedure found higher intensity and frequency levels. As Robbins et al (1984) did not study acoustic parameters simultaneously with aerodynamic parameters we can only compare intensity and frequency ranges but as regards the efficiency of the sound source, for example at 65 dBA, it is not possible to draw a conclusion. The information in the study of Jach et al (1978, 1979) is too concise to make a complete comparison possible. Aerodynamic values are reported for comfortable phonation which varies considerably among these patients. We have pointed out, that a comparison of our results to the results of studies of other surgical voice rehabilitation methods can only be made to a limited extent. It is however fair to say that as regards the pressure and airflow as well as the maximum phonation time and speaking rate our patients do not differ from patients using other surgical voice rehabilitation methods for speech production. The sound source in nearly all alaryngeal forms of speech except those using an artificial larynx, consist of the upper esophageal sphincter, which lead to similar subneoglottic pressures during phonation. The near-normal airflow, maximum phonation time and speaking rate of Staffieri speech and of speech after other surgical voice rehabilitation methods reflect the use of the normal physiological driving mechanism for voice production.

Some of our patients show a very high resistance during phonation compared to the values found in patients phonating after other surgical voice rehabilitation methods (Fig. 5a). Studies on patients with a Groningen voice prosthesis (Nieboer & Schutte, 1984) showed that the prosthesis itself accounts for approximately 1/3 of the total resistance during phonation and that the upper esophageal sphincter accounts for the complementary part. Although the slit forming the neoglottis in our patients is only very small, we think that the upper esophageal sphincter determines the airway-resistance during phonation to a large extent.

An important observation in this study is the relationship between the subjective opinion about the Staffieri voice and the subneoglottic pressure, resistance and efficiency. These findings stress the importance of striving for more favourable values. Crico-pharyngeal myotomy has been proposed to enhance voice production after laryngectomy and tracheo-esophageal puncture with considerable success (Singer & Blom, 1981; Chodosh, Giancarlo, Goldstein, 1984). However, as regards the aerodynamic parameters the positive effect has only been demonstrated by an increased maximum phonation time. Further aerodynamic studies need to be done in order to be able to appreciate the value of crico-pharyngeal myotomy in surgical voice rehabilitation.

REFERENCES

AMATSU, M. (1978). A new one-stage surgical technique for postlaryngectomy speech. Archives of Oto-Rhino-Laryngology, 220, 149-152.

AMATSU, M. (1980). A one-stage surgical technique for postlaryngectomy voice rehabilitation. Laryngoscope, 90, 1378-1386.

AMATSU, M., KINISHI, M., & JAMIR, J.C. (1984). Evaluation of speech of laryngectomees after the Amatsu tracheoesophageal shunt operation. Laryngoscope, 94, 696-701.

ANGERMEIER, C.B., & WEINBERG, B. (1981). Some aspects of fundamental frequency control by esophageal speakers. Journal of Speech and Hearing Research, 46, 85-91.

ASAI, R. (1972). Laryngoplasty after total laryngectomy. Archives of Oto-Rhino-Laryngology, 95, 114-119.

BERG, J.W. van den (1956). Direct and indirect determination of the mean subglottic pressure. Folia Phoniatrica, 8, 1-24.

BERG, J.W. van den, MOOLENAAR-BIJL, A.J., & DAMSTÉ, P.H. (1958). Oesophageal Speech. Folia Phoniatrica, 10, 65-85.

BERG, J.W. van den & MOOLENAAR-BIJL, A.J. (1959). Crico-pharyngeal sphincter, pitch, intensity and fluency in oesophageal speech. Practica Oto-Rhino-Laryngologica, 21, 298-315.

BERLIN, C.I. (1965). Clinical measurement of esophageal speech III. Performance of non-biased groups. Journal of Speech and Hearing Disorders, 30, 174-183.

BEUKELMAN, D.R., CUMMINGS, C.W., DOBIE, R.A. & WEYMULLER jr., E.A. (1980). Objective assessment of laryngectomized patients with surgical reconstruction. Archives of Otolaryngology, 106, 715-718.

BLECHSCHMIDT, M., DE L'ESPINE, Th., BRUGGER, E., & HERRMANN, I.F. (1982). Untersuchung der Korrelation zwischen Lungenfunktion und Stimmverhalten nach Gottoplastik oder Blom-Singer-Punktion. Laryngologie, Rhinologie, Otologie, 61, 263-266.

BLOM, E.D. (1972). A comparative investigation of perceptual and acoustical features of esophageal speech and speech with the Taub voice prosthesis. Doctoral dissertation, University of Maryland.

BLOOTHOOFT, G., & TIWARI, R. (1983). Phonetograms of alaryngeal voices. Progress report institute of phonetics University of Utrecht, 8, 2, 24-43.

CALCATERRA, T.C., & JAFEK, B.W. (1971). Tracheo-esophageal shunt for speech rehabilitation after total laryngectomy. Archives of Otolaryngology, 94, 124-128.

CAVAGNA, G.A., & MARGARIA, R. (1965). An analysis of the mechanics of phonation. Journal of Applied Physiology, 20, 301-307.

CAVAGNA, G.A., & MARGARIA, R. (1968). Airflow rates and efficiency changes during phonation. Annals New York Academy of Sciences, 144, 152-164.

CHODOSH, P.L., GIANCARLO, H.R. & GOLDSTEIN, J. (1984). Pharyngeal myotomy for vocal rehabilitation postlaryngectomy. Laryngoscope, 94, 52-57.

CONLEY, J.J., DeAMESTI, F., & PIERCE, J.K. (1958). A new surgical technique for the vocal rehabilitation of the laryngectomized patient. Annals of Otology Rhinology and Laryngology, 67, 655-664.

CREAMER, B., & SCHLEGEL, J. (1957). Motor responses of the esophagus to distention. Journal of Applied Physiology, 10, 498-504.

CURRY, E.T., SNIDECOR, J.C. & ISSHIKI, N. (1973). Fundamental frequency characteristics of Japanese Asai speakers. Laryngoscope, 83, 1759-1763.

CURRY, E.T. (1977). Some acoustical aspects of alaryngeal speech. Ear Nose Throat Journal, 56, 288-292.

DAMSTÉ, P.H. (1958). Oesophageal speech after laryngectomy. Thesis Groningen.

DIEDRICH, W.M. (1968). The mechanism of esophageal speech. Annals New York Academy of Sciences, 303-317.

EDWARDS, N. (1974). Post-laryngectomy vocal rehabilitation. Journal of Laryngology and Otology, 88, 905-918.

FILTER, M.D., & HYMAN, M. (1975). Relationship of acoustic parameters and perceptual ratings of esophageal speech. Perceptual and Motor Skills, 40, 63-68.

FRANKE, P. (1939). A preliminary study validating the measurement of oral reading rate in words per minute. Thesis, Iowa State University.

GRANER, D., KANTER, A., KLOR, B.M. & MILLIANTI, F.J. (1982). Speech and swallow following Staffieri voice restoration procedure. Journal of Speech and Hearing Disorders, 47, 146-149.

HENLEY-COHN, J.L. (1984). Biomaterials. In: Proceedings of the International Workshop on Voice Prosthesis Würzberg, W. Germany (in press).

HEUSDEN, E. van, PLOMP, R., & POLS, L.C.W. (1979). Effect of ambient noise on the vocal output and the preferred listening level of conversational speech. Applied Acoustics, 12, 31-43.

HOLLIEN, H. & SHIPP T. (1972). Speaking fundamental frequency and chronologic age in males. Journal of Speech and Hearing Research, 15, 155-159.

HOOPS, H.R. & NOLL, J.D. (1969). Relationship of selected acoustic variables to judgements of esophageal speech. Journal of Communication Disorders, 2, 1-13.

HYBÁSEK, I. (1982). Neoglottis phonatoria, own experiments. In: Novák, A., Sram, F. (Eds). Abstracta congressus decimus societatis phoniatricae Europaeae, Prague, Czecoslovak Medical Society, 78-80.

ISSHIKI, N. & SNIDECOR, J.C. (1964). Air intake and usage in esophageal speech. Acta Oto-Laryngologica, 59, 559-574.

ISSHIKI, N., OKAMURA, H. & MORIMOTO, M. (1967). Maximum phonation time and air flow rate during phonation: Simple clinical tests for vocal function. Annals of Otology, Rhinology, Laryngology, 76, 998-1007.

IWAI, H. & KOIKE, Y. (1973). Primary laryngoplasty. Archives of Oto-Rhino-Laryngology, 206, 1-10.

JACH, K., MOZOLEWSKI, E., ZIETEK, E., TARNOWSKA, C. & MIKOSZA, H. (1978). Evaluation of physical parameters of shunt phonation in the laryngectomees. Annales Academiae Medicae Stetinensis suppl. 15, 24, 43-55 PZWL Warszawa (Poland).

JACH, K., MOZOLEWSKI, E. & ZIETEK, E. (1979). Physikalische kennwerte der vokalfistelphonation bei laryngektomierten. HNO-Praxis, 4, 276-283.

KOMORN, R.M. (1974). Vocal rehabilitation in the laryngectomized patient with a tracheo-esophageal shunt. Annals of Otology Rhinology and Laryngology, 83, 445-451.

LECLUSE, F.L.E., TIWARI, R.M., SNOW, G.B. (1981). Electroglottographic studies of Staffieri neoglottis. Laryngoscope, 91, 971-975.

MAHIEU, H.F. & SHUTTE, H.K. (1984). Intelligibility, vocal intensity and L.T.A. spectral analysis of the Groningen button esophageal speech. In: Proceedings of the International Workshop Voice Prosthesis, Würzburg, W. Germany (in press).

MANNI, J.J., v.d. BROEK, P., de GROOT, M.A.H. & BERENDS, E. (1 98 4) Voice rehabilitation after laryngectomy with the Groningen prosthesis. Journal of Otolaryngology, 13, 333-336.

McCONNEL, F.M.S., SISSON, G.A. & LOGEMANN, J.A. (1977). Three years' experience with a hypopharyngeal pseudoglottis for vocal rehabilitation after total laryngectomy. Trans American Academy Opthalmology Otolaryngology, 84, 63-67.

McCONNEL, F.M.S. & WHITMIRE, R. (1980). Neoglottic Reconstructive Laryngectomy: A preliminary report. In: Shedd, D.P., Weinberg, B. (Eds). Surgical and prosthetic Approaches to Speech Rehabilitation. Boston G.K. Hall Medical Publishers.

McCONNEL, F.M.S. & TEICHGRAEBER, J. (1982). Neoglottis reconstruction following total laryngectomy: The Emory Experience. Otolaryngology Head and Neck Surgery, 90, 569-575.

McCURTAIN, F., NOSCOE, N., BERRY, R.J., SNOW, G.B., TIWARI, R.M., LECLUSE, F.L.E. & ROUMA, M. (1982). Xeroradiography - electro laryngography: An evaluative procedure for surgical speech rehabilitation. International Conference On Surgical Speech Rehabilitation, Charing Cross Hopsital London.

MOON, J., SULLIVAN, J. & WEINBERG, B. (1983). Evaluations of Blom-Singer tracheoesophageal puncture prostheses performance. Journal of Speech and Hearing Research, 26, 459-464.

MOON, J. & WEINBERG, B. (1984). Airway Resistance Characteristics of Voice Button Tracheoesophageal Prostheses. Journal of Speech and Hearing Disorders, 49, 326-336.

NIEBOER, G.L.J. & SCHUTTE, H.K. (1984). Aerodynamic properties of Buttons and of Button-assisted speech. In: Proceedings of the International Workshop on Voice Prosthesis Würzburg, W. Germany (in press).

NOVÁK, A., HLAVA, A., HYBÁSEK, I. & PRSÍKOVA, I. (1982). Phonation with the neoglottis phonatoria according to Staffieri. In: Novák, A., Sram, F. (Eds). Abstracta congressus decimus societatis phoniatricae Europaeae, Prague, Czechoslovak Medical Society, 81-83.

PANJE, W.R. (1981). Prosthetic vocal rehabilitation following laryngectomy - the voice button. Annals Otology Rhinology Laryngology, 90, 116-120.

PEARSON, B.W., WOODS, R.D. II, & HARTMAN, D.E. (1980). Extended hemilaryngectomy for T3 glottic carcinoma with preservation of speech and swallowing. Laryngoscope, 90, 1950-1961.

PEARSON, B.W. (1981). Subtotal laryngectomy. Laryngoscope, 91, 1904-1912.

PERKINS, W.H. & YANAGIHARA, N. (1968). Parameters of voice production. Some mechanisms for the regulation of pitch. Journal of Speech and Hearing Research, 11, 246-267.

PTACEK, P.H. & SANDER, E.K. (1963). Maximum duration of phonation. Journal of Speech and Hearing Disorders, 28, 171-182.

PTACEK, P.H., SANDER, E.K., MALONEY, W.H. & JACKSON, C.C.R. (1966). Phonatory and related changes with advanced age. Journal of Speech and Hearing Research, 9, 353-360.

ROBBINS, J., FISHER, H.B. & LOGEMANN, J.A. (1982). Acoustic characteristics of voice production after Staffieri's surgical reconstructive procedure. Journal of Speech and Hearing Disorders, 47, 77-84.

ROBBINS, J., FISHER, H.B., BLOM, E.D. & SINGER, M.I. (1984). A comparitive acoustic study of normal, esophageal, and tracheoesophageal speech production. Journal of Speech and Hearing Disorders, 49, 202-210.

ROLLIN, W.J. (1962). A comparitive study of vowel formants of esophageal and normal-speaking adults. Doctoral Dissertation Wayne State University.

SAITO, H., MATSUI, T., TACHIBANA, M., NISHIMURA, H. & MIZUKOSHI, O. (1977). Experiences with the tracheoesophageal shunt method for vocal rehabilitation after total laryngectomy. Archives of Oto-Rhino-Laryngology, 218, 135-142.

SCHULTZ-COULON, H.J., SYBRECHT, G.W. & PILAVAKIS, P. (1980). Die kardio-respiratorische Belastung beim tracheo-ösophagealen Shunt nach Staffieri. Archives of Oto-Rhino-Laryngology, 226, 467-469.

SCHUTTE, H.K. (1980). The efficiency of voice production. Thesis Groningen.

SEIDNER, W., WENDLER, J., WAGNER, H. & RAUHUT, A. (1981). Spectrales Stimmfeld. HNO-Praxis, 6, 187-191.

SHEDD, D.P., BAKAMJIAN, V., SAKO, K., MANN, A., BARBA, S. & SCHAAF, N. (1972). Reed-fistula method of speech rehabilitation after laryngectomy. American Journal of Surgery, 124, 510-514.

SHEDD, D.P. & WEINBERG, B. (1980). Surgical and prosthetic approaches to speech rehabilitation. Boston G.K. Hall Medical Publishers.

SHIPP, T. (1967). Frequency, duration, and perceptual measures in relation to judgements of alaryngeal speech acceptability. Journal of Speech and Hearing Disorders, 10, 417-421.

SINGER, M.I. & BLOM, E.D. (1980). An endoscopic technique for restoration of voice after laryngectomy. Annals Otology Rhinology Laryngology, 89, 529-533.

SINGER, M.I. & BLOM, E.D. (1981). Selective myotomy for voice restoration after total laryngectomy. Archives of Otolaryngology, 107, 670-673.

SMITHERAN, J.R. & HIXON, T.J. (1981). A clinical method for estimating laryngeal airway resistance during vowel production. Journal of Speech and Hearing Disorders, 46, 138-146.

SNIDECOR, J.C. & CURRY, E.T. (1959). Temporal ands pitch aspects of superior esophageal speech. Annals of Otology Rhinology Laryngology, 68, 623-636.

SNIDECOR, J.C. (1968). Speech rehabilitation of the laryngectomized. Second edition, Charles C. Thomas, Springfield, Illinois.

STAFFIERI, M. (1976). La chirurgia riabilitativa della voce dopo laringectomia totale. In: Staffieri, M., Serafini, I. (Eds). La riabilitazione chirurgica della voce e della respirazione dopo laringectomia totale: Relazione ufficiale del 29° congresso nationale AOOI Bologna.

STAFFIERI, M. (1979). Neue chirurgische Möglichkeiten zur Rehabilitation der Stimme nach totaler Laryngektomie. HNO-Praxis, 4, 243-253.

STEINER, W. (1980). Chirurgische Rehabilitation der Stimme nach Laryngektomie (derzeitiger stand). Therapeutische Umschau, 37, 1117-1127.

TARNOWSKA, C., MOZOLEWSKI, E., LOBACZ, P., JASSEM, W. & WYSOCKI, R. (1979). Die Fistelsprache nach Laryngektomie aus phoniatrischer Sicht. HNO-Praxis, 4, 284-292.

TARNOWSKA, C., JACH, K. & MOZOLEWSKI, E. (1982). Zur Frage der phonations-mechanismus bei Sprachfisteln nach der Laryngektomie. In: Novák, A., Sram, F. (Eds). Abstracta congressus decimus societatis phoniatricae Europaeae, Prague, Czechoslovak Medical Society, 84-86.

TAUB, S. & SPIRO, R.H. (1972). Vocal rehabilitation of laryngectomees: Preliminary report of a new technique. American Journal of Surgery, 124, 87-90.

TAUB, S. & BERGNER, L.H. (1973). Air bypass voice prosthesis for vocal rehabilitation of laryngectomees. American Journal of Surgery, 125, 748-756.

TAUB, S. (1980). Air bypass voice prosthesis: An 8-year experience. In Shedd, D.P. & Weinberg, B. (Eds), Surgical and prosthetic approaches to speech rehabilitation. Boston G.K. Hall Medical Publishers.

UNGER, E., JENTZSCH, H. & WILKE, J. (1982). Die chirurgische Stimmrehabilitation nach Laryngektomie mittels der Neoglottis Phonatoria nach Staffieri. In: Novák, A., Sram, F. (Eds). Abstracta congressus decimus societatis phoniatricae Europaeae, Prague, Czechoslovak Medical Society, 87-90.

VUYK, H.D., TIWARI, R.M. & SNOW, G.B. (1985a). Staffieri's procedure, revisited. Head and Neck Surgery (in press).

VUYK, H.D., KLINKENBERG-KNOL, E. & TIWARI, R.M. (1985b). The role of the upper esophageal sphincter in voice rehabilitation after laryngectomy and Staffieri's procedure. Journal of Laryngology and Otology (in press).

WEINBERG, B. & BENNETT, S. (1972). Selected acoustic characteristics of esophageal speech produced by female laryngectomees. Journal of Speech and Hearing Reserach, 15, 211-216.

WEINBERG, B., SHEDD, D.P. & HORII, Y. (1978). Reed-fistula speech following pharyngolaryngectomy. Journal of Speech and Hearing Disorders, 43, 401-413.
WEINBERG, B., HORII, Y. & SMITH, B.E. (1980). Long-time spectral and intensity characteristics of esophageal speech. Journal of the Acoustical Society of America, 67, 1781-1784.
WEINBERG, B. (1982a). Airway Resistance of the Voice Button. Archives of Otolaryngology, 108, 498-500.
WEINBERG, B., HORII, Y., BLOM, E. & SINGER, M. (1982b). Airway resistance during esophageal phonation. Journal of Speech and Hearing Disorders, 47, 194-199.
WEINBERG, B. & MOON, J. (1982c). Airway resistance characteristics of Blom-Singer tracheoesophageal puncture prostheses. Journal of Speech and Hearing Disorders, 47, 441-442.
WEINBERG, B. & MOON, J. (1984). Aerodynamic Properties of Four Tracheoesophageal Puncture Prostheses. Archives of Otolaryngology, 110, 673-675.
WETMORE, S.J., KRUEGER, K. & WESSON, K. (1981). The Singer-Blom speech rehabilitation procedure. Laryngoscope, 91, 1109-1117.
ZINNER, E.M. & FLESCHLER, B. (1972). Intraesophageal pressures during phonation in laryngectomized patients. Journal of Laryngology and Otology, 86, 129-140.
ZWITMAN, D.H. & CALCATERRA, T.C. (1973). Phonation using the tracheoesophageal shunt after total laryngectomy. Journal of Speech and Hearing Disorders, 38, 369-373.

Chapter V

THE ROLE OF THE UPPER ESOPHAGEAL SPHINCTER IN VOICE REHABILITATION AFTER LARYNGECTOMY AND STAFFIERI'S PROCEDURE

H.D. Vuyk, MD*, E. Klinkenberg-Knol MD°,
R.M. Tiwari, MS, FRCS, DLO, PhD*

From the Department of Otolaryngology* and Gastro-enterology°, Free University Hospital, Amsterdam, The Netherlands

(accepted for publication in Journal of Laryngology and Otology)

ABSTRACT

The Staffieri method was used for voice rehabilitation after total laryngectomy in our patients. Leakage of saliva has sometimes been a problem. It has been suggested that aspiration could be due to specific pressure relations in the pharynx, upper esophageal sphincter and cervical esophagus during deglutition (Mann, 1980). With respect to voice production, the upper esophageal sphincter appears to be the main sound source, functioning in essentially the same way as in esophageal speech.

Intraluminal pressure recordings at rest and during swallowing were used in 16 Staffieri speakers and 9 esophageal speakers. Upper esophageal sphincter dysfunction was seen more often in Staffieri speakers with aspiration problems than in Staffieri speakers without aspiration problems, but the relation is not clearly understood. A definite relation could be established between upper esophageal sphincter function in terms of relaxation and coordination and aerodynamic pressure measured in the tracheostoma, necessary to sustain phonation. After distention of the esophagus, produced by the inflow of air, a reflex rise in the upper esophageal sphincter pressure is thought to occur. The pressure necessary to sustain phonation probably depends on the extent to which this reflex mechanism occurs and on the ability of the patient to induce a relaxation of the upper esophageal sphincter before air expulsion.

Selective myotomy will possibly lower the necessary pressure and enhance vocal rehabilitation. Whether this will solve a part of the aspiration problems in Staffieri speakers is unpredictable as the relation of the motor function of the upper esophageal sphincter and the aspiration problems is not well understood.

INTRODUCTION

During the past two decades several methods of surgical voice rehabilitation after total laryngectomy have been described. Among these Staffieri's technique has been widely used (Staffieri, 1979). His technique essentially consists of the creation, in a single stage procedure, of a mucosa-lined connection between the trachea and hypopharynx (Fig. 1). This so-called "neoglottis phonatoria" is established following laryngectomy on top of the trachealstump and serves two purposes. It permits shunting of air from the trachea to the hypopharynx and it is meant to prevent aspiration during deglutition. Phonation is achieved on exhalation while occluding the stoma. Endoscopic examination in our patients with a neoglottis phonatoria and results of xeroradiography lead one to think that the neoglottis functions as an inlet of air and that the pharyngeal mucosa above this level develops a form and a moving pattern which may be reminiscent of the original vocal fold.

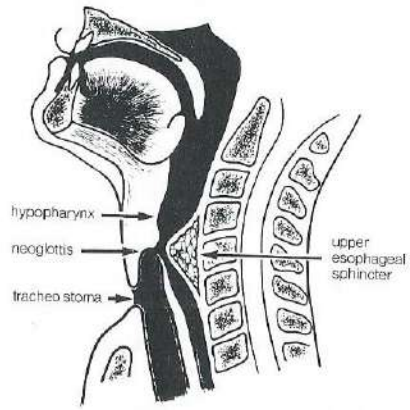


Figure 1. Tracheo-hypopharyngeal shunt (Staffieri's neoglottis) in sagital section — diagrammatic.

Roentgenographic studies of our patients showed a remarkable similarity to those of esophageal speakers during phonation. A constriction of the lumen at the transition of the esophagus into the pharynx above the neoglottis is noted with an adequate air column below. Damsté (1958) and Van den Berg and Moolenaar-Bijl (1959) suggested that in esophageal speech the narrowing of the lumen at the transition of the esophagus into the pharynx is determined by the cricopharyngeal muscle. However, this muscle cannot by itself account for the entire constriction of the hypopharynx. Diedrich and Youngstrom (1966) showed that the constriction was actually 18 mm or more in length rather than the expected length of 10-12 mm, corresponding anatomically to the cricopharyngeal muscle alone (Batson, 1955). Moreover, Shipp (1970) found simultaneous electromyographic activity of the cricopharyngeal muscle and the inferior pharyngeal constrictor muscle in esophageal speakers during phonation.

It is known that the cricopharyngeal muscle and the inferior pharyngeal constrictor muscle constitute the upper esophageal sphincter and have a distinct behaviour in normal subjects (Goyal, 1984). The term upper esophageal sphincter is an operational definition given to an intraluminal zone of high pressure that exists between the pharynx and the esophageal body. Some authors are of the opinion that a zone of circular esophageal fibers below the cricopharyngeal muscle attributes to the high pressure zone as well (Ingelfinger, 1958; Ellis, 1971). The upper esophageal sphincter is known to relax during deglutition in order to allow the passage of a bolus. Relaxation occurs early in the deglutitive sequence simultaneously with or just after the contraction of the tongue and upper part of the pharynx (Code and Schlegel, 1968).

The exact nature of the physiological function of the upper esophageal sphincter in alaryngeal sound production is not clear. By means of inhalation and suction or injection, as well as through relaxation of the upper esophageal sphincter (Kelly et al, 1981), the esophageal speaker introduces air into the esophagus. Air is trapped in the esophagus by means of a reflectory increase in the tone of the upper esophageal sphincter, which is a result of the distension of the esophagus. In normal individuals, with the placement of a balloon catheter at the middle esophageal region, distension of the walls has been shown to produce elevated intraluminal pressures manometrically measured at the pharynx and esophageal inlet (Creamer and Schlegel, 1957). This mechanism plays a role in esophageal speech as well. Pruszewicz et al (1982) performed electromyographic studies on the activity of the cricopharyngeal muscle during esophageal speech. The pressure measured under the sphincter necessary for air expulsion was found to be correlated with the amplitudes of the electromyographic records. In esophageal speakers as well as in our patients a tight upper esophageal sphincter will prevent the passage of air superiorly, while a relaxation will clearly facilitate air expulsion and subsequent phonation.

This brings us to the clinical observation that patients, who have undergone a total laryngectomy and a Staffieri procedure vary in the ease with which they produce useful neoglottis speech. This can be due to differences in the neoglottis itself. However, it has already been suggested that although the slit itself has the potentiality to act as a sound source, the upper esophageal sphincter performs this function as well and in essentially the same way as in esophageal voice (McCurtain et al 1982; Novak et al, 1982). The mentioned data clearly suggest a relation between the function of the upper esophageal sphincter and the Staffieri sound production.

As with several other methods of surgical rehabilitation of voice leakage of saliva and food into the trachea is sometimes a distressing problem. Recent studies (Steiner, 1980; McConnel and Teichgraeber, 1982) have shown that in the long run the neoglottis phonatoria is not able to prevent aspiration in all cases. Revision and sometimes even closure of the neoglottis phonatoria is necessary to control the aspiration. In all of our reoperated cases we found a mucosa shunt that had not changed in dimensions. No change in the anteroposterior stretch or any other abnormality was noted. It is not easy to understand why with an apparently normal neoglottis some patients had aspiration problems and some had not. Mann et al (1980) suggested that aspiration in laryngectomy patients after Staffieri's procedure could be due to specific pressure relations in the hypopharynx and cervical esophagus during deglutition. They regarded a relatively high pressure generated by the hypopharyngeal muscles in combination with a high pressure zone in the esophagus below the neoglottis as unfavourable. The bolus would be pushed along the route of least resistance through the neoglottis into the trachea. Whether from a manometrical point of view Mann et al (1980) actually found any differences between patients with and patients without aspiration problems is not clear.

In the last decade considerable thought has been given to the importance of anatomic and physiologic features of the post-laryngectomy esophagus which might determine its ability to function as an air reservoir and sound source in esophageal speech. The aim of the present study was to evaluate the function of the pharynx, hypoharynx and cervical esophagus in patients after laryngectomy and Staffieri's procedure. Intraluminal pressure recordings at rest and during swallowing were used. Concerning the aspiration problems special attention was paid to possible differences between patients with and patients without aspiration. In order to clarify the role of the upper esophageal sphincter in voice production after laryngectomy and Staffieri's procedure we studied the possible relationship between manometrically assessed parameters of the motor function of the pharynx, hypopharynx and cervical esophagus and aerodynamic parameters of phonation.

MATERIALS AND METHODS

Manometric studies were performed in 16 patients (15 male, 1 female), who underwent a total laryngectomy and a Staffieri procedure because of laryngeal cancer. In none of these cases the hypopharynx or cervical esophagus was involved. The mean age was 55.3 years (41-68). They all used their neoglottis as the primary method of communication. Apart from these 16 patients, 9 patients (8 male, 1 female), who acquired esophageal speech after conventional total laryngectomy, were investigated. No additional esophageal or pharyngeal surgery was done in these patients. The mean age was 65.9 (50-72 years).

The patients with a neoglottis phonatoria were rated as to complaints of leakage or aspiration. A subjective opinion was gathered from a questionnaire completed by these patients. The patients could be classified in two distinctive groups. Six patients had no or seldom any problems with the aspiration. The other 10 patients experienced aspiration with swallowing more frequently than the previous group, including 6 patients who needed to be treated for the aspiration problems.

Manometric evaluations were performed with a triple-lumen catheter assembly (internal diameter 1.1 mm) with lateral recording orifices 5 cm apart, each side hole radially oriented 120° from each other. As the axial and radial asymmetry of the upper esophageal sphincter disappears after laryngectomy (Welch et al., 1979), we did not think it necessary to use a spatially oriented manometric system in our patients. All three lumens were perfused continuously with water at a rate of

0.5 ml/min with a low-compliance pneumohydraulic infusion pump (Arndorfer Medical Specialities). Pressures from the column of water within the catheters were transmitted to physiological pressure transducers (Beckman type 4-527-C) and registered by a six-channel recorder (Beckman-Instruments). Pressures were recorded in mm Hg with the zero reference point being one atmosphere. At the time of the study the patients had fasted for at least 4 hours. The catheter was passed nasally and positioned with all three pressure recording openings in the distal tubular esophagus. During the recording patients were in the supine position. The tube was then withdrawn at 1 cm intervals, and both resting and post-deglutitive pressures were recorded at each station. All dry swallow recordings in the pharynx, upper esophageal sphincter and cervical esophagus were analysed for resting pressure, post-deglutitive ("peak") pressure, degree of relaxation and coordination. The length of the upper esophageal sphincter was determined. The upper esophageal sphincter was said to be coordinated with the proceeding pharyngeal wave when relaxation completely corresponded to the contraction of that wave. Relaxation was complete when intrasphincteric pressures fell to the pharyngeal resting pressure level, which virtually equals the atmospheric pressure.

In another, yet unpublished study, we reported on the subneoglottic pressure measured in the tracheostoma and the air flow values necessary to sustain phonation at 65 dBA for these patients (Vuyk et al, 1985).

RESULTS

Tables 1, 2 and 3 summarize the variables measured in each individual patient. The tables show clearly the low resting pressure values in the upper esophageal sphincter after laryngectomy compared to normals (N = 40-80 mm Hg). In a few patients very low resting pressures were registered. It is remarkable that the values of the post deglutitive peak pressure fell within the normal range ($N > 100$ mm Hg) in various patients. The upper esophageal sphincter had a normal length in all patients. In 6 Staffieri speakers and 7 esophageal speakers the registrations showed a complete relaxation of the upper esophageal sphincter (Fig. 2). Only in these 13 patients a coordinated deglutition was seen. Figure 3 shows the manometric tracing of hypopharynx, upper esophageal sphincter area and proximal esophagus as was found in the rest of the patients. Note the incomplete relaxations of the upper esophageal sphincter and the incoordinated deglutition. Most of the subjects had a normal motor function of the pharynx ($N > 100$ mm Hg). The pharyngeal peak pressure was only 25 mm Hg in one patient, possibly due to surgical closure of a pharyngo-cutaneous fistula with a sternocleidomastoid muscle flap. In these subjects pressures in the proximal esophagus just below the upper esophageal sphincter were low as compared to normals (N = 60-80 mm Hg).

In comparing the 9 esophageal speakers with the 16 Staffieri speakers no significant differences could be found ($p > 0.05$; Wilcoxon's two sample test). A higher percentage of subjects showed a normal relaxation in the group of esophageal speakers but the differences were not of statistical significance ($p > 0.05$; Fisher test).

Table I. Variables measured in 6 Staffieri speakers without aspiration problems.

Patient	Age/Sex	length (cm)	UPPER ESOPHAGEAL SPHINCTER resting pressure (mmHg)	peak pressure (mmHg)	complete relaxation	normal coordination	HYPOPHARYNX peak pressure (mmHg)	duration contraction (sec)	CERVICAL ESOPHAGUS peak pressure (mmHg)	duration contraction (sec)
1	46 M	4	10	30	+	+	100	0.6	50	2
2	41 M	7	10	80	+	+	120	0.4	40	2
3	59 M	6	40	170	+	+	200	0.8	80	1.8
4	63 M	5	<5	50	+	+	70	0.4	80	2
5	68 M	3	<5	20	+	+	60	0.6	40	2
6	56 M	5	8	100	+	+	120	0.6	10	2.5
Mean values	55.5	5	11.3	75			111.7	0.56	50	2.1

Table II. Variables measured in 10 Staffieri speakers with aspiration problems.

Patient	Age/Sex	length (cm)	UPPER ESOPHAGEAL SPHINCTER resting pressure (mmHg)	peak pressure (mmHg)	complete relaxation	normal coordination	HYPOPHARYNX peak pressure (mmHg)	duration contraction (sec)	CERVICAL ESOPHAGUS peak pressure (mmHg)	duration contraction (sec)
1	56 M	5	10	90	−	−	70	0.6	40	2
2	51 M	4	20	120	−	−	100	0.4	80	2
3	58 F	6	20	100	−	−	100	1.2	50	1.2
4	67 M	5	<5	10	−	−	100	0.6	40	2
5	62 M	3	10	35	−	−	100	0.6	30	1.2
6	41 M	2	<5	30	−	−	90	0.4	10	2
7	50 M	5	8	30	−	−	25	0.4	30	2
8	64 M	6	10	50	−	−	100	0.4	20	1.2
9	52 M	2	12	150	−	−	90	0.4	10	2
10	50 M	3	6	40	−	−	120	0.6	20	3
Mean values	55.1	4.1	9.6	65.5			89.5	0.56	34	1.9

Table III. Variables measured in 9 esophageal speakers.

Patient	Age/ Sex	length (cm)	UPPER ESOPHAGEAL SPHINCTER resting pressure (mmHg)	peak pressure (mmHg)	complete relaxation	normal coordination	HYPOPHARYNX peak pressure (mmHg)	duration contraction (sec)	CERVICAL ESOPHAGUS peak pressure (mmHg)	duration contraction (sec)
1	63 M	4	<5	30	+	+	40	0.4	30	2
2	62 F	4	<5	150	+	+	120	0.4	5	0.6
3	50 M	6	8	50	+	+	100	0.4	4	2
4	70 M	6	<5	20	+	+	100	0.6	30	2
5	72 M	6	<5	10	−	−	100	0.8	40	1.2
6	70 M	5	10	80	−	−	100	0.6	50	1.2
7	69 M	6	15	20	+	+	90	0.6	30	1.6
8	72 M	4	15	90	+	+	70	0.4	20	2.5
9	65 M	4	5	25	+	+	90	0.5	20	2
Mean values	65.9	5	5.9	52.8			90	0.52	25.4	1.8

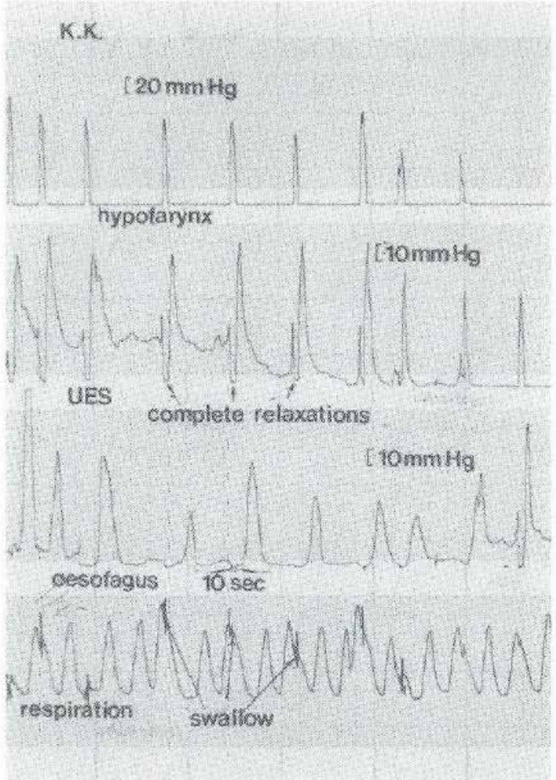


Figure 2. Staffieri's procedure manometric tracing of hypopharynx, upper esophageal sphincter and proximal esophagus (Pat. K.K.). The 3 recording orifices are 5 cm apart. The bottom tracing is showing the respiration and swallowing act. Note the complete relaxations of the upper esophageal sphincter after swallowing.

Slightly higher resting pressures and peak pressures were registered in neoglottis speakers with aspiration problems compared to the neoglottis speakers without aspiration problems. The differences were small and did not reach statistical significance ($p > 0.05$; Wilcoxon's two sample test). A striking difference between these two groups of patients was the relaxation and coordination of the upper esophageal sphincter. In all Staffieri speakers with aspiration the relaxation of the upper esophageal sphincter was incomplete and the deglutation incoordinated, while Staffieri speakers without aspiration showed a normal relaxation. Figure 4 shows the relaxation of the upper esophageal sphincter and coordination in these 16 Staffieri speakers related to subneoglottic pressure and air flow necessary to sustain phonation at 65 dBA. These aerodynamic parameters of speech were subject of another study (Vuyk et al, 1985). The mean subneoglottic pressure necessary to

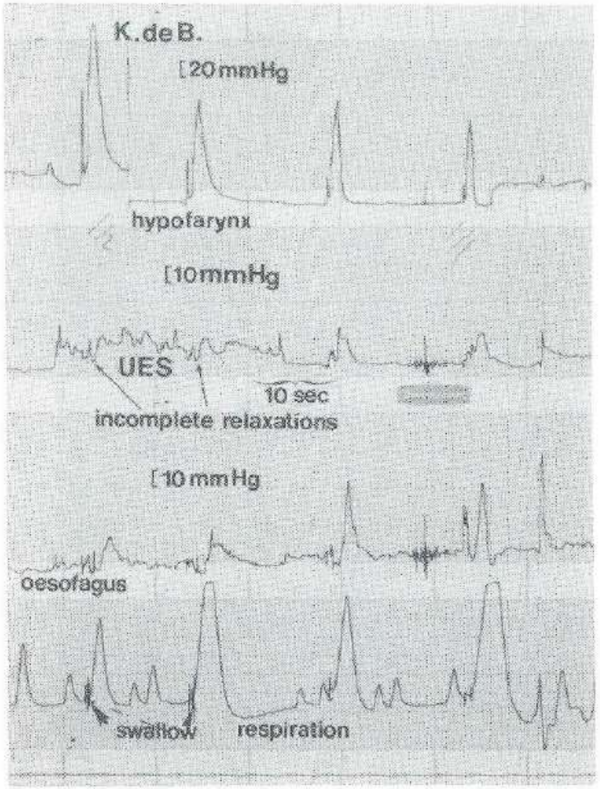


Figure 3. Staffieri's procedure manometric tracing of hypopharynx, upper esophageal sphincter and proximal esophagus (Pat. K. de B.). Now note the incomplete relaxations (see arrows) after swallowing.

sustain phonation at 65 dBA for the 6 neoglottis speakers who showed a normal relaxation and coordination of the upper esophageal sphincter in deglutition was 19.2 mm Hg (12.6-23.3 mm Hg). The mean subneoglottic pressure during phonation at 65 dBA for the remaining 10 neoglottis speakers was 33.8 mm Hg (17.9-50.4 mm Hg). These differences are of statistical significance ($p < 0.05$; Wilcoxon's two sample test). Concerning the air flow values no statistical significant differences could be found between Staffieri speakers with a normal relaxation and coordination of the upper esophageal sphincter and those speakers who showed an incomplete relaxation and abnormal coordination of the upper esophageal sphincter ($p > 0.05$; Wilcoxon's two sample test). No relation could be established between the resting and post deglutitive peak pressure of the upper esophageal sphincter and the aerodynamic parameters of speech. The peak pressure and duration of contraction of the hypopharynx and cervical esophagus on the one hand and the aerodynamic parameters of speech on the other showed no relation either.

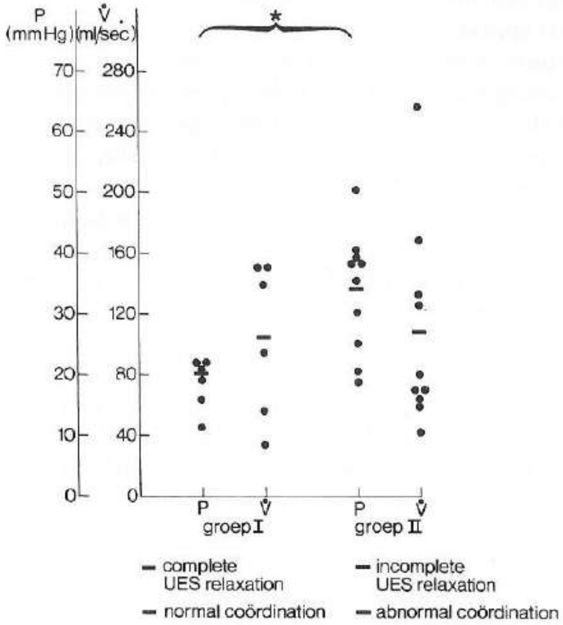


Figure 4. Aerodynamic values (p and V) in Staffieri speakers with and without upper esophageal sphincter dynsfunction. *A statistical significant difference exists between these two groups of patients ($p < 0.05$; Wilcoxon's two sample test). — = mean.

DISCUSSION

Sixteen Staffieri speakers and 9 esophageal speakers underwent esophageal motility studies. The measurements were used to evaluate the motor function of the pharynx, upper esophageal sphincter and cervical esophagus in these patients. The manometrically established inter-individual differences reflect the variation in post-laryngectomy, anatomy and physiology.

Due to the detachment of the inferior pharyngeal contrictor muscle, the cricopharyngeal muscle and the muscle fibers of the cervical esophagus from the larynx a significant decrease in the resting pressure of the upper esophageal sphincter in these patients was registered. These values agree with most other manometric studies in post-laryngectomy patients (Reichbach and Winans, 1970, 1970; Winans et al, 1974; Duranceau et al, 1976; Collo et al, 1977; Hanks et al, 1981).

The upper esophageal sphincter had a normal length in our patients. This corresponds to the results of Reichbach and Winans (1970) as well as to the results of Welch et al (1979).

The post-deglutitive peak pressures showed large inter-individual differences.

These values did not discriminate between Staffieri and esophageal speakers or between Staffieri speakers with or without aspiration problems.

The present study showed a marked derangement in upper esophageal sphincter relaxation and coordination in 50% of these patients. Duranceau et al (1976) and Hanks et al (1981) mentioned a slightly higher percentage (70%). Removal of the larynx, partial sensory denervation due to section of the superior laryngeal nerve, damage to the pharyngeal plexus in combination with scar tissue formation form the clinical basis for upper esophageal sphincter dysfunction in post-laryngectomy patients. Upper esophageal sphincter dysfunction was seen more often in Staffieri speakers than in esophageal speakers and mostly in those Staffieri speakers who had aspiration problems.

Does the upper esophageal sphincter play a role in the occurrence of aspiration problems? Staffieri speakers with and without aspiration problems could be differentiated by studying the relaxation of the upper esophageal sphincter and the coordination of the deglutition. Although the upper esophageal sphincter is located above the neoglottis phonatoria an explanation can still be given for the differences between the two groups of patients. A non-relaxing upper esophageal sphincter and an incoordinated deglutition can possibly lead to longer contact of a bolus and in particular fluids with the upper surface of the neoglottis. However, one patient (Table I, 2) had no aspiration problems at the time of this study. He developed aspiration problems 7 months later. Two other patients (Table II, 6 and 9) had aspiration problems at the time of this study, which they only developed approximately 9 months after the operation. Changes in the anatomical and physiological character of the neoglottis may also play some role in the occurrence of aspiration problems in these patients, however, this is not born out by our experience with revision surgery.

The upper esophageal sphincter plays an important role in the regulation of the pressure necessary for subsequent sound production in patients after laryngectomy and the Staffieri procedure. In this study the degree of relaxation of the upper esophageal sphincter, registered manometrically during deglutition, was related to the pressure necessary to sustain phonation. No relation was found between the manometrically assessed peak and resting pressures and the aerodynamic parameters. In the introduction we mentioned the reflex mechanism leading to elevated intraluminal pressures in the esophagus after distension of the esophagus below the sphincter, as described by Creamer and Schlegel (1957). In Staffieri speakers the dilatation is produced by the inflow of air through the neoglottis phonatoria during phonation. The distention raises the resting tone of the upper esophageal sphincter to a certain degree. The pressure measured in the tracheostoma during phonation will depend on this reflex mechanism and as to what extent the patient is able to control the upper esophageal sphincter, particularly regarding its relaxation. We identified patients with poor upper esophageal sphincter control by manometrical measurements. Incomplete relaxation and incoordination were found to be determinants of inefficient phonation characterised by high pressures, necessary to sustain phonation.

In the past Damsté (1958) had already stressed the negative effect of upper esophageal sphincter dysfunction particularly regarding its relaxation on esophageal speech. However, he laid more emphasis on air inflow than outflow in this respect. Singer and Blom (1981) proposed the concept of pharyngeal constrictor spasm or dyscoordination regarding voice failures after tracheo-esophageal puncture. Voice failures in the patients described were associated with cessation of air flow during voluntary speech. Roentgenograms demonstrated pharyngeal constrictor spasm. Effortless speech resulted upon parapharyngeal nerve block. Videofluoroscopy confirmed the relaxation of the upper esophageal sphincter after blocking of the pharynx. He then performed an extensive myotomy with successful results. Recently Chodosh et al (1984) and Holden (1984) had similar results with pharyngeal myotomy for vocal rehabilitation failures after laryngectomy.

In conclusion this study gives support to earlier publications in respect of the importance of a well coordinated functioning upper esophageal sphincter in alaryngeal speech, especially by proving the relationship between manometrically registered upper esophageal sphincter relaxation and aerodynamic measured pressure, necessary to produce phonation. Selective myotomy will possibly lower the necessary pressure and enhance vocal rehabilitation. Whether this will solve a part of the aspiration problems is unpredictable as the relation of the motor function of the upper esophageal sphincter and the aspiration problems are at present not well understood.

REFERENCES

BATSON, O.V. (1955) The cricopharyngeus muscle. Annals of Otology, Rhinology and Laryngology 64: 47-54.

VAN DEN BERG, J. & MOOLENAAR-BIJL, A.J. (1959) Crico-pharyngeal sphincter, pitch, intensity and fluency in oesophageal speech. Practica Oto-Rhino-Laryngologica 21: 298-315.

CHODOSH, P.L., GIANCARLO, H.R., GOLDSTEIN, J. (1984) Pharyngeal myotomy for vocal rehabilitation postlaryngectomy. The Laryngoscope 94: 52-57.

CODE, C.F. & SCHLEGEL, J.F. (1968) In: Handbook of Physiology, Heidel W. (Ed.) section 6, chapter 90, pp. 1821-1839. American Physiological Society, Washington DC.

COLLO, D., WEIHRAUCH, T.R. & FÖRSTER, C.F. (1977) Vergleichende intraluminale Ösophagusdruckmessungen nach Laryngektomie. Laryngologie, Rhinologie, Otologie, 56: 1003-1007.

CREAMER, B. & SCHLEGEL, J.F. (1957) Motor responses of the esophagus to distension. Journal of Applied Physiology 10: 498-504.

DAMSTÉ, P.H. (1958) Oesophageal speech after laryngectomy. Thesis Groningen.

DIEDRICH, W.M. & YOUNGSTROM, K.A. (1966) Alaryngeal speech, Charles C. Thomas, Springfield Illinois.

DURANCEAU, A., JAMIESON, G., HURWITZ, A.L., SCOTT JONES, R. & POSTLETHWAIT, R.W. (1976) Alteration in esophageal motility after laryngectomy. American Journal of Surgery 131: 30-35.

ELLIS, F.H. jr. (1971) Symposium on gastrointestinal surgery: upper esophageal sphincter in health and disease. Surgical Clinics of North America 51: 553-565.

GOYAL, R.K. (1984) Symposium on the larynx: disorders of the cricopharyngeus muscle. Otolaryngologic Clinics of North America 17: 115-130.

HANKS, J.B., FISHER, S.R., MEYERS, W.C., CHRISTIAN, K.C., POSTLETHWAIT, R.W. & SCOTT JONES, R. (1981) Effect of total laryngectomy on esophageal motility. Annals of Otology, Rhinology and Laryngology 90: 331-334.

HOLDEN, H.B. (1984) Surgical implications of tracheo-esophageal punctures. Proceedings of the International Workshop on Voice Prosthesis, Würzburg (in press).

INGELFINGER, F.J. (1958) Esophageal motility. Physiological reviews 38: 533-584.

KELLY, D.R., ADAMOWICH, B.L.B. & ROBERTS, T.A. jr. (1981) Detailed investigation of alaryngeal speech to elucidate etiology of variation in quality. Otolaryngology Head and Neck Surgery 89: 613-623.

MANN, W., LANIADO, K. & SCHUMANN, K. (1980) Pitfalls after laryngectomy and neoglottis formation. Archives of Otorhinolaryngology 226: 207-211.

McCONNEL, F.M.S. & TEICHGRAEBER, J. (1982) Neoglottis reconstruction following total laryngectomy: the Emory experience. Otolaryngology Head and Neck Surgery 90: 569-575.

McCURTAIN, F., NOSCOE, N., BERRY, R.J., SNOW, G.B., TIWARI, R.M., LECLUSE, F.L.E. & ROUMA, M. (1982) Xeroradiography – electro laryngography: an evaluative procedure for surgical speech rehabilitation. International Conference on Surgical Speech Rehabilitation, Charing Cross Hospital, London.

NOVÁK, A., HLAVA, A., HYBÁSEK, I. & PRSÍKOVA, I. (1982) Phonation with the neoglottis phonatoria according to Staffieri. In: Novák, A., Sram, F. (Eds). Abstracta Congressus Decimus Societatus Phoniatricae Europaeae, Prague, 81-83.

PRUSZEWICZ, A., OBREBOWSKI, A. & WOZNICA, B. (1982) EMG examination of musculus cricopharyngeus in patients with oesophageal speech. In: Novák, A., Sram, F. (Eds). Abstracta Congressus Decimus Societatus Phoniatricae Europaeae, Prague, 70-72.

REICHBACH, E.J. & WINANS, C.S. (1970) Esophageal manometrics in the post-laryngectomy patient. Gastroenterology 58: 987.

SHIPP, T. (1970) EMG of pharyngoesophageal musculature during alaryngeal voice production. Journal of Speech and Hearing Research 13: 184-192.

SINGER, M.I. & BLOM, E.D. (1981) Selective myotomy for voice restoration after total laryngectomy. Archives of Otolaryngology 107: 670-673.

STAFFIERI, A. (1979) Katamnestische Erhebungen über funktionelle Resultate der Rehabilitation von Stimme under natürlicher Atmung nach Laryngektomie bei über 1000 von verschiedenen Chirurgen operierten Patienten. HNO-Praxis 4: 301-309.

STEINER, W. (1980) Chirurgische rehabilitation der Stimme nach Laryngektomie (derzeitiger Stand). Therapeutische Umschau, Band 37: 1117-1127.

VUYK, H.D., FESTEN, J.M., SPOELSTRA, A.J.G. & TIWARI, R.M. (1985) Acoustic and aerodynamic data of speech after total laryngectomy and Staffieri's procedure (submitted for publication in Journal of Speech and Hearing Disorders).

WELCH, R.W., GATES, G.A., LUCKMANN, K.F., RICKS, P.M. & DRAKE, S.T. (1979) Changes in the force-summed pressure measurements of the upper esophageal sphincter prelaryngectomy and postlaryngectomy. Annals of Otology, Rhinology and Laryngology, 88: 804-806.

WINANS, C.S., REICHBACH, E.J. & WALDORP, W.F. (1974) Esophageal Determinants of alaryngeal speech. Archives of Otolaryngology 99: 10-14.

SUMMARY AND CONCLUSIONS

Restoration of voice is of utmost importance to the individual who has undergone a total laryngectomy. The most commonly employed method for voice restoration is that of esophageal speech. However, at least one out of three patients fail to master this technique. This has led to the development of various surgical procedures for voice restoration. The object of all surgical methods for the restoration of voice after total laryngectomy is to create a communication between the airway and food passages, with the intention of producing vibrations of an air column in the pharynx through the expired air. The resultant sound, or voice, is articulated as it continues through the resonating oral and nasal cavities. The surgical method for the restoration of voice described by Staffieri – involving the creation of a so-called neoglottis phonatoria at the time of laryngectomy – has been applied worldwide. This procedure is relatively simple and does not involve the use of a prosthesis. Between 1979 and 1983 42 patients have undergone this procedure at the department of Otolaryngology of the Free University of Amsterdam. The aim of this thesis is the evaluation of the results of this surgical method for the restoration of voice in this series of patients.

In Chapter I the literature concerning surgical methods for the restoration of voice after total laryngectomy is reviewed. Techniques are briefly described; and various advantages and disadvantages are discussed.

In Chapter II some technical aspects of the method of voice restoration described by Staffieri are discussed. The technique which has been applied in our patients is in essence similar to the technique described by Staffieri. Some of the variations mentioned in the literature are discussed. Emphasis is laid on strict criteria for patient selectiôn for this procedure to be oncologically safe (see also addendum Chapter III).

In Chapter III the results of Staffieri's surgical method are presented and are discussed regarding voice production, aspiration problems and postoperative pharyngo-cutaneous fistula formation. Approximately 50% of the patients are successfully rehabilitated. Half of the patients who are not succesfully rehabilitated do not use the neoglottis for voice production, mostly because of a stenosis of the neoglottis. The other half has had serious aspiration problems which needed treatment. Revision surgery which has been suggested to treat these problems was not successful in our patients. We therefore either closed the neoglottis or used a "Groningen" type prosthesis. It is striking that half of the patients with aspiration problems initially benefited from the Staffieri procedure and had no aspiration at all.

A comparative study has been carried out with regard to pharyngo-cutaneous fistula formation using a group of 43 patients who underwent a conventional total

laryngectomy in about the same period of time. Patients after Staffieri procedure, especially those who were previously treated with radiotherapy showed a higher frequency of pharyngo-cutaneous fistulas and also more serious pharyngo-cutaneous fistulas compared to the group of patients who underwent a conventional total laryngectomy. In general our approach to the therapy of patients with an advanced laryngeal cancer is conservative. As a result only patients with large tumours are subjected to a primary total laryngectomy while approximately half of the total laryngectomies in our department are carried out for a recurrence after previous radiotherapy.

In Chapter IV results are given of a comparative study on objective parameters regarding phonation for various methods of voice restoration after total laryngectomy. For our own patients who had undergone a Staffieri procedure we measured aerodynamic parameters such as subneoglottic pressure and airflow as well as acoustical parameters such as sound intensity and fundamental frequency simultaneously. The maximum phonation time and speaking rate were measured and the resistance and efficiency of the phonatory mechanism were calculated. The results are compared with those of other methods of voice restoration after total laryngectomy and with normal speech. This comparison as well as comparisons of individual patients within our own group are made on the basis of the results at 65 dBA intensity level, obtained from a regression analysis. This intensity level is approximately the middle of the intensity range. In the acoustic data no significant differences were found between Staffieri patients and patients using various forms of alaryngeal speech.

Airflow during Staffieri speech and also for other surgical methods of voice restoration falls within the normal range. The lower airflow found for esophageal speech mainly reflects the difference in the source of air. Staffieri speakers as well as patients who underwent other surgical methods of voice restoration may draw upon the considerably larger respiratory volume and are subsequently able to sustain voicing for substantially longer periods of time than esophageal speakers.

The pressure necessary to sustain phonation after Staffieri's procedure is 10 times higher than in normal phonation. The pressure data do not vary much among the different forms of alaryngeal speech. Regarding the acoustical parameters and the pressure necessary to sustain phonation, the surgical methods for restoration of voice are similar to esophageal speech. Our findings support the notion that the upper esophageal sphincter is the main sound source in all forms of surgical voice restoration and performs this function in essentially the same way as in esophageal voice.

In Chapter V a study of the function of the upper esophageal sphincter after total laryngectomy and Staffieri's procedure is described using intraluminal pressure recordings. It is thought that apart from the neoglottis itself pressure variations induced by the upper esophageal sphincter may play a role in the causation of aspiration problems. Moreover, as mentioned above, the upper esophageal sphincter possibly plays an important role in voice production. The pressure recordings were carried out in 16 Staffieri speakers and 9 esophageal speakers at

rest and during swallowing. Upper esophageal sphincter dysfunction – in terms of relaxation and coordination – was seen more often in Staffieri speakers with aspiration problems than in those who did not have aspiration problems. Apart from a dysfunction of the upper esophageal spincter, the neoglottis itself may play some role in the occurrence of aspiration in these patients. A definite relation could be established between the upper esophageal sphincter function and aerodynamic pressure measured in the tracheostoma during phonation. It is known that a distention of the esophagus leads to a reflex rise in pressure within the upper esophageal sphincter in normal individuals. In patients with a "neoglottis phonatoria" a distention of the esophagus is produced during phonation by the inflow of air. The pressure necessary to sustain phonation in our patients probably depends on the extent to which the afore mentioned reflex rise in upper esophageal sphincter pressure occurs. Moreover it is possible that some patients are able to influence this reflex and can induce a relaxation of the upper esophageal sphincter before expulsion of air. This results in a decrease of the pressure necessary to sustain phonation. Myotomy of the upper esophageal sphincter will probably lower the necessary pressure and enhance vocal rehabilitation.

In conclusion it is fair to state that the results of surgical restoration of voice by Staffieri's method as seen in the group of patients studied in Chapter III, in the long term, do not outweigh the disadvantages such as aspiration problems and a high incidence of serious postoperative pharyngo-cutaneous fistulas, particularly in previously irradiated patients. Concerning the acoustic and aerodynamic qualities of the obtained voice, as tested by the various parameters studied in Chapter IV, the quality of the Staffieri voice does not seem appreciably better than the quality of voice obtained by other surgical methods of alaryngeal speech. The upper esophageal sphincter, studied in Chapter V, seems to play an important role, both in sound production and in the problem of aspiration. The question remains, whether a combination of voice rehabilitation and myotomy of the upper esophageal sphincter will change the results and help to solve the problem of aspiration.

SAMENVATTING EN CONCLUSIES

Het verlies van de eigen stem na totale laryngectomie betekent voor de patient een ernstige handicap. Voor herstel van spraak na totale laryngectomie staan verschillende mogelijkheden ter beschikking. De meest toegepaste methode is de zgn. slokdarmspraak. Het gelukt echter een relatief groot percentage van de gelaryngectomeerden niet de slokdarmspraak te beheersen. Dit heeft geleid tot de ontwikkeling van verschillende chirurgische methoden voor spraakrevalidatie. Al deze technieken zijn er op gericht weer een verbinding tussen de luchtweg en voedselweg tot stand te brengen met de bedoeling door de uitademingslucht de luchtkolom in de pharynx in trilling te brengen. Het geluid dat hierdoor ontstaat, wordt door middel van de natuurlijke modulerende mechanismen voor resonantie (mond-, keel- en neus(bij)holten) en articularie (tong, gehemelte, lippen en gebit) omgevormd tot spraak. De chirurgische methode voor spraakrevalidatie volgens Staffieri – waarbij direct in aansluiting op de laryngectomie een zgn. neoglottis phonatoria wordt aangelegd – heeft veel navolging gekregen aangezien deze betrekkelijk eenvoudig is en daarbij geen gebruik gemaakt wordt van een prothese. In de periode 1979-1983 is deze methode op de afdeling Keel-, Neus-, Oorheelkunde van het Academisch Ziekenhis van de Vrije Universiteit van Amsterdam bij 42 patienten toegepast. Dit proefschrift betreft de evaluatie van de resultaten van deze chirurgische spraakrevalidatie methode bij deze groep patienten.

In hoofdstuk I wordt een overzicht gegeven van in de literatuur beschreven chirurgische methoden voor spraakrevalidatie na totale laryngectomie. De technieken worden beknopt weergegeven en de verschillende voor- en nadelen worden toegelicht.

In hoofdstuk II worden enkele technische aspecten van de methode voor spraakrevalidatie volgens Staffieri besproken. De door ons toegepaste techniek is vrijwel identiek aan die van Staffieri. Enkele in de literatuur vermelde variaties worden genoemd. Een bespreking is gewijd aan de selectiecriteria waaraan patienten moeten voldoen. Indien men zich hieraan strikt houdt, is de methode oncologisch verantwoord (zie ook addendum hoofdstuk III).

In hoofdstuk III worden de resultaten besproken van de methode voor spraakrevalidatie volgens Staffieri wat betreft stemvorming, aspiratieproblemen en het voorkomen van postoperatieve speekselfistels. Vijftig procent van de patienten werd met succes gerevalideerd. De helft van de niet met succes gerevalideerde patienten maakte geen gebruik van de aangelegde neoglottis om te phoneren; stenosering van de neoglottis was hiervan de meest voorkomende reden. De andere helft had dusdanige aspiratieproblemen dat een heringreep noodzakelijk was. Een zgn. revisie operatie zou de functie van de neoglottis kunnen herstellen. De door ons uitgevoerde revisies waren echter niet succesvol. Om de aspiratieproblemen op te lossen werd derhalve of de neoglottis gesloten of gebruik gemaakt van een zgn. "Groningen" spreekprothese. Opvallend is dat van de groep patienten met aspiratieproblemen de helft aanvankelijk niet of nauwelijks aspiratieproblemen vertoonde.

Uit een vergelijkend onderzoek met een groep van 43 patiënten die in vrijwel dezelfde periode een conventionele totale laryngectomie ondergingen blijkt dat zich bij patienten die volgens de methode van Staffieri geopereerd werden, met name na eerdere radiotherapie, meer en vooral ernstiger speekselfistels voordeden. In dit kader zij opgemerkt dat in onze kliniek ook ten aanzien van patienten met een gevorderd larynxcarcinoom een relatief conservatief beleid wordt gevoerd. Dit betekent dat voor primaire totale laryngectomie alleen patienten met zeer uitgebreide tumoren in aanmerking komen, terwijl ongeveer de helft van de totale laryngectomieën in onze kliniek wordt uitgevoerd wegens recidief tumor na voorafgaande bestraling.

In hoofdstuk IV worden de resultaten vermeld van een objectief vergelijkend onderzoek van verschillende spraakrevalidatiemethoden na totale laryngectomie, voor wat betreft de phonatie. Daarbij werden bij 20 volgens de methode van Staffieri geopereerde patienten tijdens phonatie enkele aerodynamische parameters zoals subneoglottische druk en volumestroom tezamen met enkele akoestische parameters zoals geluidintensiteit en grondfrequentie van het verkregen stemgeluid simultaan geregistreerd. Daarnaast werd de maximale phonatietijd en de spreeksnelheid gemeten en tevens de weerstand en efficientie van het fonatiemechanisme berekend. De verkregen gegevens werden vergeleken met die welke in de literatuur voor de betreffende parameters in relatie tot andere methoden van spraakrevalidatie na totale laryngectomie en tot normale spraak worden opgegeven. Bij deze vergelijking en bij de vergelijking van de patienten onderling werd gebruik gemaakt van geinterpoleerde meetgegevens bij een geluidsniveau van 65 dBA, wat ongeveer overeenkomt met de gemiddelde spraaksterkte. Wat betreft de akoestische parameters kon geen verschil worden gevonden tussen onze patienten en patienten die verschillende andere vormen van spraak na totale laryngectomie gebruikten. Tijdens de fonatie werd bij de Staffieri patienten een volumestroom gemeten die evenals bij andere chirurgische methoden voor spraakrevalidatie in de normale orde van grootte valt. Dat bij oesophagusspraak een kleinere volumestroom wordt gemeten dan bij spraak na chirurgische stemrevalidatie hangt samen met de andere wijze waarop de voor spraak benodigde volumestroom geleverd wordt. Dit is tevens de reden dat met behulp van de Staffieri methode en andere chirurgische methoden voor spraakrevalidatie over het algemeen een langere maximale phonatietijd bereikt kan worden dan met behulp van oesophagusspraak. De voor phonatie benodigde druk bij Staffieri spraak is ongeveer 10× hoger dan normaal. Deze ligt bij vrijwel alle vormen van spraak na totale laryngectomie in dezelfde orde. Voor wat betreft de akoestische parameters en de voor de phonatie benodigde druk bestaat een overeenkomst tussen de chirurgische methoden voor spraakrevalidatie en oesophagusspraak. Het is derhalve waarschijnlijk dat de bovenste slokdarmsphincter de trillingsgenerator is bij vrijwel alle vormen van chirurgische spraakrevalidatie en dat deze op dezelfde wijze functioneert als bij oesophagusspraak.

In hoofdstuk V wordt beschreven hoe met behulp van intraluminale drukregistraties in het overgangsgebied hypopharynx-oesophagus gepoogd is meer inzicht te verkrijgen over het functioneren van de bovenste slokdarmsphincter na een totale laryngectomie volgens de methode van Staffieri. De aanleiding tot dit deel van het onderzoek is de veronderstelling dat met name de door de bovenste slokdarmsphincter gegenereerde drukverhoudingen een rol spelen bij de aspiratie problemen. Bovendien speelt zoals hierboven aangegeven de bovenste slokdarmsphincter waarschijnlijk een centrale rol bij de stemproductie. Bij 16 Staffieri patienten en 9 oesophagussprekers werden zowel in rust als tijdens het slikken drukregistraties verricht. Bij Staffieri patienten met aspiratieproblemen werd vaker een dysfunctie van de bovenste slokdarmsphincter gevonden – in termen van relaxatie en coordinatie – dan bij Staffieri patienten zonder aspiratieproblemen. Naast een dysfunctie van de bovenste slokdarmsphincter zal bij een aantal patienten toch ook de neoglottis zelf een rol spelen bij de aspiratie problemen. In dit deel van het onderzoek kon een relatie worden gelegd tussen het functioneren van de bovenste slokdarmsphincter en de aerodynamische druk gemeten in het tracheostoma die nodig is voor de phonatie. Door tijdens phonatie instromende lucht treedt een dilatatie van de oesophagus op die, evenals bij normale proefpersonen een reflexmatige stijging van de druk in de bovenste slokdarmsphincter induceert. De voor de fonatie benodigde druk kan derhalve afhankelijk zijn van de mate waarin deze reflex optreedt. Het is bovendien mogelijk dat sommige patienten in staat zijn deze reflexmatige stijging van de druk in de bovenste slokdarmsphincter te beïnvloeden en een relaxatie van de bovenste slokdarmsphincter kunnen bewerkstelligen. Dit zou resulteren in een afname van de voor fonatie benodigde druk. Myotomie van de bovenste slokdarmsphincter zal derhalve waarschijnlijk de voor de fonatie benodigde druk verlagen en het resultaat van de stemrevalidatie verbeteren.

Samenvattend moet geconcludeerd worden dat met name op de lange duur de resultaten van de spraakrevalidatiemethode volgens Staffieri, althans bij deze bestudeerde patientengroep, niet opwegen tegen de met de methode samenhangende problemen zoals aspiratie en een hoge frequentie van ernstige postoperatieve speekselfistels, in het bijzonder bij eerder bestraalde patienten. Vanuit akoestisch en aerodynamisch oogpunt gezien lijkt de methode van Staffieri, voor wat betreft de bestudeerde parameters, niet duidelijk gunstiger dan andere chirurgische methoden van spraakrevalidatie na totale laryngectomie. Bij de spraakrevalidatiemethode van Staffieri speelt zowel bij de fonatie als bij de aspiratieproblemen die zich daarbij kunnen voordoen de bovenste slokdarmsphincter een belangrijke rol. Het is de vraag of een in combinatie met deze methode van spraakrevalidatie uitgevoerde myotomie de functie van de bovenste slokdarmsphincter zodanig zal veranderen dat dit zal bijdragen tot de oplossing van de aspiratieproblemen.

CURRICULUM VITAE

De schrijver van dit proefschrift werd geboren op 29 oktober 1955 te Madrid, Spanje.
Het middelbaar onderwijs werd gevolgd aan het Kennemer Lyceum te Haarlem en aan de Alliance Française te Santiago, Chili.
Na het eindexamen HBS-B in 1972 studeerde hij 1 jaar Theoretische Natuurkunde aan de Rijksuniversiteit te Leiden.
Vanaf 1973 studeerde hij aan dezelfde universiteit Geneeskunde; in 1979 legde hij het doctoraal examen af en in 1981 werd de studie afgesloten met het arts examen (predicaat cum laude).
Op 15 maart 1981 werd de specialisatie tot Keel-, Neus- en Oorarts aangevangen in het Academisch Ziekenhuis van de Vrije Universiteit te Amsterdam (Prof. Dr. G.B. Snow).
Als onderdeel van de opleiding tot KNO-arts was hij van 1 januari 1983 tot en met 30 juni 1983 werkzaam in het Westeinde Ziekenhuis te Den Haag (Dr. T. Bottema).
Op 15 maart 1985 werd hij ingeschreven in het specialisten register. Sindsdien maakt hij deel uit van de staf van de afdeling Keel-, Neus- en Oorheelkunde van het Academisch Ziekenhuis van de Vrije Universiteit te Amsterdam.