Critical Review:
How do the Provox and Blom-Singer voice prostheses compare in speech and voice measures after tracheoesophageal puncture?

Andrea Gold and Ashley Tinkham
M.Cl.Sc (SLP) Candidates
University of Western Ontario: School of Communication Sciences and Disorders

This critical review examined various variables which contribute to the rehabilitation of speech and voice of a laryngectomized patient. These variables included: speech and voice characteristics, patient variables (age, gender, etc.), primary versus secondary puncture, type of VP, radiotherapy/chemotherapy and complications due to surgery. Study designs included: within-groups design (3), between-groups design (2), and mixed (between and within group) design (3). Results suggested that favourable speech and voice outcomes are attainable after a total laryngectomy (TL) with the use of either Blom Singer (BS) or Provox (PX) voice prostheses (VP). Trends towards primary puncture and BS VPs were noted in the studies and these variables led to a more favourable prognosis. The findings of this review have implications that warrant future research in the field of speech-language pathology (SLP).

Introduction

TL after malignant disease of the larynx drastically alters a patient's ability to communicate verbally. There have been various efforts made in order to restore a patient's verbal communication through esophageal speech, electrolarynx and tracheoesophageal puncture (TEP) (Eksteen, Rieger, Nesbitt, & Seikaly, 2003). TEP is one of the most commonly used and preferred methods of rehabilitation for post-laryngectomy speech (Emerick, Tomycz, Bradford, Lyden, Chepeha, & Wolf et al., 2009). TEP can be performed as a primary procedure, which the puncture is created at the same time as the laryngectomy or a secondary procedure, which the puncture is created during a second surgery at least six weeks after the laryngectomy or completion of radiation treatment (Gress & Singer, 2004).

Since the advent of TEP speech, various VP have been made in effort to re-establish verbal communication. The most commonly used VPs are made BS (Inhealth, International Healthcare Technologies, CA) and PX (Atos Medical AB, Horby, Sweden) (Delsupehe, Zink, Lejaegere, & Delaere, 1998). The underlying concept behind the function of VP use is to occlude the stoma to redirect air from the lungs through the VP into the pharyngoesophageal (PE) segment (Cornu, Vlantis, Elliot, & Gregor, 2003). The PE segment functions as the new vibrating source in order to produce sound. The articulators still function to shape the airflow in production of sound in laryngeal speech.

Even though TEP speech is the most commonly used method of alaryngeal speech rehabilitation, there are various factors that contribute to its success in an individual. Success rates for TEP speech have been reported in the range of 50-90%, which is considerably higher than esophageal speech with a success rate reported at 33% (Van Weissenbruch & Albers, 1992). It has been hard to define 'success' with constant conditions as speech and voice characteristics, patient variables (age, gender, etc.), primary versus secondary puncture, type of VP, radiotherapy/chemotherapy and complications due to surgery all may contribute to the success of TEP speech. In this critical analysis review of the recent literature, the variables that contribute to success of TEP speech were investigated.

Objectives

The primary objective of this paper is to critically evaluate the literature available on how speech and voice measures compare after tracheoesophageal puncture (TEP) in patients using the BS and PX VPs. The secondary objective is to pose evidence-based practice recommendations for SLPs involved in head and neck cancer, specifically rehabilitation after TL.

Methods

Search Strategy

Computerized databases including PubMed, PsychINFO, and SCOPUS were searched using the following search terms: "voice rehabilitation" AND "laryngectomy"; "tracheoesophageal puncture"; "laryngectomy" AND "speech rehabilitation"; "tracheoesophageal voice restoration". Articles were limited to those in English published between 1995 and 2009. Articles were also found using reference lists of articles retrieved for this critical review.

Selection Criteria

Studies selected for this review examined factors contributing to successful voice and speech rehabilitation using either the BS or the PX VPs following laryngectomy. Studies included patients who underwent primary or secondary puncture for tracheoesophageal speech. No limits were set on the demographics of research participants and speech or voice outcome measures.

Data Collection

Results of the literature search provided the following types of articles that fit within the previously mentioned selection criteria: within-group design (3), between-groups design (2), and mixed (between and within group) design (3).

Results

Delsupehe, Zink, Lajaegere & Delaere (1998) used a prospective randomized mixed study design to determine which of the two main VPs used (BS and PX) were different in terms of voice quality, length of lifetime and greater patient satisfaction. This study examined 52 patients who underwent a TL or extended laryngectomy in combination with a partial pharyngectomy between January 1995 and July 1996. All patients received primary TEP and placement of VP. Changing of the VP was included as 113 VPs were used on 52 patients. Fifty of the VPs were BS (40 male, 10 female) and 63 were PX (60 male, three female). Patients were randomly assigned to the BS or PX indwelling VP. The groups were analyzed for background data using Fisher's Exact Test. Their voices were recorded one and four months after initiation of speech therapy in primary placements and one and four months after placements in secondary placements.

Subjective and objective evaluation methods were used in conjunction with patients' perception of the VP and lifetime (Delsupehe et al., 1998). Patients read a standard text to subjectively analyze their voice for six voice parameters (intonation, intelligibility, acceptability, extraneous noise, loudness and speech rate) using various rating scales by eight different judges (four speech pathologists and four naïve listeners). Interrater reliability was checked using Spearman's range correlation coefficient. Scores of the most consistent judge were used for further analysis (Mann-Whitney *U* test was used for statistical difference for subjective criteria; Wilcoxon's rank sum test was used for comparisons of VP groups over time). The objective analysis consisted of evaluating number of syllables per breath, maximum phonation time, fundamental frequency, and minimal and maximal loudness. The student's *t* test was used to determine if there were any statistically significant differences. Patient's perceptual assessments included parameters of overall assessment of the VP, perception of voice quality and ease of VP cleaning management all rated on three point-scales (1, bad; 2, okay; 3, good). The mean scores with standard deviations were calculated for each of these groups and compared. Subgroup analysis was performed for primary versus secondary placement, as well as comparison of TL and extended laryngectomy with partial pharyngectomy. The Mann-Whitney *U* and Wilcoxon's statistical tests were used for the subgroup analysis.

Subjective voice quality was good for both types of VP with no statistically significant difference between the two VP groups. However, there was a trend towards better voice quality for all the separate subjective criteria in the BS group compared to the PX group. There was a gradual improvement in voice quality over time for both VP groups which reached statistical significance for intelligibility (p=.001), acceptability (p=.0001) and speech rate (p=.047) using Wilcoxon's test. Voice quality showed improvement at four months compared to one month and significance was reached for acceptability (p=.0005) and speech rate (p= .004) in the BS group and for extraneous speaking noise (p= .029) in the PX group. A trend towards better subjective voice parameters for secondary placements was observed when the primary versus secondary placements was compared for both types of prostheses. There was a slightly better subjective voice quality for the BS in both primary and secondary groups. Voice quality was significantly better for intelligibility, acceptability, and speech rate at four months compared with one month in the primary and secondary BS and PX groups. Lastly, the TL group had better voice quality compared to the extended laryngectomy in combination with partial pharyngectomy group (p= .03).

There was a significant difference (p= .007) in the objective analysis for minimal loudness in the BS VP compared to the PX prostheses. The patients' assessments showed that patients using the BS VP rated it with higher scores for overall assessment and voice quality. However, the PX group gave better ratings for daily maintenance. Also, patients that used both types of prostheses had a small preference for the BS VP. Lastly, the lifespan of the two VP was not significantly different.

Akbas & Dursun (2003) conducted a non-randomized mixed clinical trial to examine voice quality of patients using the BS VP. There were 187 patients (184 males, three females) that had an average age of 63.7. The patients had been diagnosed with squamous cell

carcinoma of the larynx and underwent TL and primary voice restoration between November 1992 and July 2000. A low pressure BS VP was inserted in the fluent (ability to sustain phonation without interruption for 10 seconds and to count from one to 15) and disfluent patients at the postoperative 12-15th day. Speech therapy was implemented for all patients. Patients were followed up in the first postoperative month, every three months for the first year, and every six months thereafter.

In the 156 patients that Abkas & Dursun (2003) studied, fluent speech was attained. Twenty-four of the patients that achieved fluent speech were unable to look after their prosthesis and preferred to use an alternate mode of alaryngeal speech (esophageal or electrolaryngeal speech). Thirty-one out of the total number of patients were disfluent or aphonic due to hypertonicity or partial spasm of the PE segment (17) and preferred esophageal speech. The other 14 patients had a complete spasm of the PE segment and preferred electrolaryngeal speech. Mean stomal pressure was higher in fluent compared to disfluent patients. The average life span of the VP was 98 days. Complications of the TEP and VP included: postoperative fistula, infection, hematoma, granulation tissue, aspiration, and swallowing of the prosthesis. Additionally, fungal colonization on the prosthesis was found to be the main reason for valve deterioration.

A non-randomized between groups clinical prospective study by Chone, Spina, Crespo, & Gripp (2005) examined 71 TL patients with neck dissection or post-operative radiotherapy following diagnosis of laryngeal squamous cell carcinoma to determine if certain variables contributed to success of speech rehabilitation. All patients were rehabilitated for voice using the indwelling BS VP between January 1995 and September 2001. The patients that had TL as of 1995 were rehabilitated with primary TEP (62 total; 32 aged less or equal to 60; 30 aged over 60) and those that had a TL before 1995 were submitted to secondary TEP (nine; two aged less or equal to 60; seven aged over 60). Successful use of the VP was defined using maximum phonation time (successful phonation was equal or greater than 8 seconds) and was assessed by an otorhinolaryngologist and speech and hearing therapist. Follow up was done at one month post-operation, every three months up to one year, and every six months after the first year. Data collected included insertion time, duration of VP use, use of radiation post-operatively, follow up and duration of each VP.

Chone, Spina, Crespo, & Gripp, 2005 found no difference in the primary TEP group regarding success rate between patients submitted to radiotherapy (38) or not (24) and those followed up for two years or more (53) or less than two years (9). All patients in this group, regardless of age, achieved a 97% success rate. In the group with secondary TEP, there were no statistically significant differences in success rate of VP use in patients with (4) and without post-operative radiation (5) and with two years or more of follow up (8) or less (1). The overall success rate of secondary TEP was 78%; 50% of patients aged 60 or younger and 86% of patients aged greater than 60 achieved successful use of the VP. Between primary and secondary TEP groups, there was no statistically significant difference for number of patients in follow up for longer than two years and number of patients submitted to radiotherapy ($p>0.05$). Greater success in voice rehabilitation was found in the group that had the primary TEP. Post-operative radiation and age was not shown to influence the success rate ($p>0.05$) (Chone et al., 2005).

Cornu et al. (2003) used a non-randomized within groups clinical trial to examine 128 (113 male, 15 female) patients that were rehabilitated after TL between January 1995 and September 2009 with a PX VP. They measured subjective and objective voice quality, life of the VP, and adverse events relating to the VP and fistula. Subjective voice quality was evaluated using a three-point scale (good, poor or no speech) by a speech therapist or surgeon after initial placement of the prosthesis and upon follow-up. Objective voice quality was evaluated using a computerized speech laboratory that assessed the following parameters: maximum phonation time, dynamic and frequency ranges, mean pitch and intensity, jitter and shimmer. In addition, spontaneous speech, counting forward on one breath, and sustaining the vowel /a/ for as long as possible were examined to determine length of utterance, speech rate, maximum phonation time, availability, tonicity, fluency, and intelligibility. Average age was 57 (age ranged from 41 to 88 years old). Primary puncture was performed in 104 of the patients and the remaining 24 underwent secondary puncture.

Quality of voice assessments were performed on 104 patients (24 were lost to follow-up) (Cornu et al., 2003). This revealed that 77 had good voice, seven had poor voice, 18 had no voice and two did not use the VP. Of the 77 with good voice, 26 (21 men and five women) were selected for objective analysis using the criteria adopted during The Third International Congress on the VP in Groningen (Van Weissenbruch & Albers, 1993). Eighty-three percent of the patients had good length of utterance (>19 syllables), 58% had good speech rate (>140 syllables/min) and 31% had good maximum phonation time (>10 seconds). Subjective analysis was also performed in this group: availability was good

(delay <3 seconds) in 100%, voice quality was good in 69%, fluency was good in 100% and intelligibility was good in 86%. Mean device life was 303 days. Devices needed to be replaced due to leakage or loss of VP. Some patients (16) experienced adverse events during follow up such as posterior or anterior displacement of prosthesis, granuloma formation, enlarged fistula and leakage adjacent to fistula.

A non-randomized between groups clinical trial was performed by Globlek, Simunjak, Ivkic, and Hedjever (2004) that compared voice quality between five male patients with near TL (mean age 54) and five male patients with TL (mean age 61) and TEP with insertion of the PX-2 VP. All patients read a standard text into a microphone attached to their head, 20 cm from the mouth, in a soundproof booth. Each patient's voice was analyzed acoustically using the EZ Voice Plus program for the parameters of fundamental frequency, range of fundamental frequency, maximal phonation time, jitter, shimmer, and noise to harmonic ratio (Globlek, Simunjak, Ivkic, & Hedjever, 2004). Voice intensity was measured with the Spectra LAB Ver. 4.32.13 program (Globlek, Simunjak, Ivkic, & Hedjever, 2004).

The TL PX-2 group was found to produce voice that had closer to normal voice fundamental frequency (136 Hz compared to 232 Hz; normal male is 130 Hz) and jitter value (1.9% compared to 4.8%; normal is 1%). The group with the near TL was found to have more natural shimmer value (2.26 dB compared to 3.78 dB; normal value is 0.35 dB) and noise to harmonic ratio (1.1 compared to TL PX-2 0.5; normal ratio is 10-11). The range of fundamental frequency for both groups was high (28 semitones for TL PX-2 and 21 for near TL; normal is 3-4 semitones) which indicated that they were unable to control fundamental frequency. Maximal phonation time was shown to be better in the TL PX-2 group (10 seconds compared to 4.8 for near TL) and both groups had low levels of intensity (21.57 dB SPL for near TL and 28.71 for TL PX-2; normal voice in conversation is 55 dB SPL). No statistically significant results were found.

Hotz, Bauman, Schaller, and Zbaren (2002) conducted a prospective non-randomized within groups clinical trial that examined success rate and clinical factors related to VP rehabilitation. Eighty-seven patients (82 men and five women) with an average age of 61 years (age range was 44 to 81) with squamous cell carcinoma of the larynx and/or hypopharynx who underwent TL and primary puncture and were implanted with the PX or PX-2 VP between 1992 and 1998. Of the 87 patients, 66 received radiotherapy in addition to surgery.

Before TL, patients were evaluated psychologically and spoke with voice-rehabilitated patients. Patients received VP rehabilitation training by an SLP 14 days after TL and were observed for a period of 18 months by the SLP and an otolaryngologist. The otolaryngologists assessed patients with VP that required change (e.g. leakage), and rated the patient's condition before change. The Harrison-Robillard-Shultz (HRS) TEP Rating Scale was used to evaluate success at two, six, 12 and 18 months. The HRS defined success using three parameters: use (primary means of communication), quality (ease of voice production and effect on intelligibility), and care (independence from professional aid for maintenance of prosthesis). Rehabilitation was divided into three phases: phase I (months zero to nine after implantation), phase II (months 10 to 30), and phase III (months 31 to 72). SLPs saw patients most often during phase I and otolaryngologists saw patients most often during phase II and III. Patients were evaluated independently by SLPs and otolaryngologists and data collected was analyzed for statistic significance using the Mantel-Hanzel chi-squared test.

The variables of age, sex, tumor localization and stage, and radiotherapy did not influence the success of VP rehabilitation. The SLP reported an overall VP rehabilitation success rate of 42% (34% in phase I, 64% in phase II) and an overall patient rehabilitation success rate of 40% (29% in phase I, 65% in phase II). Results of overall VP rehabilitation success for otolaryngologist were 62% (39% in phase I, 77% in phase II, 81% in phase III) and overall patient rehabilitation success rate of 43% (17% in phase I, 15% in phase II, 11% in phase III). Phase II results were significantly better than phase I for both VP and patient rehabilitation success for SLP, and phase III was significantly better than phase II for otolaryngologists. There was no significant difference between SLPs and otolaryngologists in their HRS ratings. Patients with more successful vocal rehabilitation were seen more often by otolaryngologists due to higher VP replacements. For the HRS scale, it was found that the parameters of quality and use correlate highly.

Vlantis, Gregor, Elliot, and Oudes (2003) used a non-randomized within groups clinical trial to determine the differences in voice quality and patient preference between non-indwelling to indwelling VPs. Their study had 17 patients (15 men, two women) that underwent TL and were currently using non-indwelling VP to produce tracheoesophageal speech. The average age of the patients was 62.6 (age ranged from 50 to 78). Voice characteristics of each patient were measured twice: first with the non-indwelling VP and second with the indwelling VP (when the patient was comfortable with

the change). A computerized speech laboratory was used by a SLP to objectively evaluate each patient's voice. The following variables were examined: length of utterance, maximum phonation time, dynamic range, frequency range, average pitch and intensity, jitter, and shimmer. At the time of each measurement, the patient read a paragraph for future perceptual analysis by two independent SLPs who would rate the availability of voice, fluency and intelligibility of speech as either poor, moderate or good. A structured questionnaire was completed by the patients two weeks after receiving their new, indwelling prosthesis concerning whether the parameters of intensity, fluency, intonation, availability, swallowing, voice use, mucus production, effort, maintenance, benefit of non-indwelling to indwelling, family reaction and patient preference either improved, stayed the same, or became worse.

When the voice was analyzed, a significant difference was found between the old and new prosthesis for the length of utterance ($p = .027$). Voice availability, fluency and intelligibility were rated on a three-point scale (poor, moderate or good) for the old and new VPs by two SLPs. There were no significant differences between the old and new prostheses for voice availability, fluency and intelligibility. The questionnaire was completed by 13 patients to compare the indwelling VP to the non-indwelling VP. Majority of respondents reported better vocal intensity (77%), fluency (62%), intonation (62), availability of voice (85%), less effort required to produce voice (62%), less maintenance (92%) and greater benefit of indwelling versus non-indwelling (re-insertion) (69%). Overall, 62% of family members and 92% of patients preferred the indwelling VP.

Emerick et al. (2009) used a non-randomized mixed clinical trial to evaluate 30 patients who underwent induction chemotherapy followed by concurrent chemo-radiation and salvage TL for recurrent laryngeal carcinoma between 1998 and 2005. Patients in the study had either total pharyngolaryngectomy, TL with partial pharyngectomy or TL with partial glossectomy with primary or secondary puncture for TEP speech. In the primary TEP group, the TEP prosthesis was placed at three to four weeks post-operatively (procedure was delayed if patient had fistula or other complication). For the secondary TEP group, the puncture was attempted two to three months postoperatively and the prosthesis was placed one to two weeks following the puncture procedure. Prosthesis placement and voice assessment was performed by an SLP. Time to fluent speech acquisition was recorded for each patient (calculated from the time of documented fluency by the SLP).

Of the 30 patients, 20 received primary TEP (17 men, three women) and 10 received secondary TEP (all men). All patients implanted with VP achieved fluent speech. There were no statistical significant differences between the group ($p>0.05$) and no correlation between the patient variables (e.g. age, diabetes, etc.) and postoperative complications. Postlaryngectomy-related complications for each TEP group were analyzed. The only statistically significant complication related to primary versus secondary TEP was pharyngocutaneous fistula (PCF), with 50% of patients who had the primary TEP developed a PCF compared to 0% in the secondary TEP group ($p=0.006$; $p<0.05$). The median time to acquisition of fluency was much greater for the secondary TEP group (125 days) compared with the primary TEP group (63 days). In addition, a larger time difference was noted between primary TEP patients who did not develop fistulas and secondary TEP patients (48 versus 125 days). Lastly, primary TEP patients who developed PCF still acquired fluency more quickly than secondary patients as a group (75 versus 125 days).

Discussion

When considering the results, one must be cognizant of the various factors that contribute to 'successful' speech and voice rehabilitation of patients who have undergone TL. These factors include: speech and voice characteristics of the individual, patient variables (age, gender, etc.), primary versus secondary puncture, type of VP, radiotherapy/chemotherapy, and complications due to surgery. One limitation of the articles examined in this review was speech and voice characteristics were not measured consistently across studies. Some studies assessed voice by subjective and objective measures (Cornu et al., 2003; Delsupehe et al., 1998; Vlantis et al., 2003) while others only used either method of evaluation (Abkas & Dursun, 2003; Chone et al., 2005; Emerick et al., 2009; Globlek et al., 2004; Hotz et al., 2002). Further complicating this issue, subjective and objective measures were not always the same as some studies measured voice quality using MPT, certain scales or guidelines (e.g. HRS scale), level of fluency and intelligibility while other studies used different measurements. The methods employed to obtain results were also different across studies, ranging from SLPs to otolaryngologists or a combination of both, to naïve listeners and graduate SLP students. The majority of studies did not use naïve listeners, who may provide very different ratings of voice quality compared to SLPs, otolaryngologists and graduate SLP students whom all have knowledge and/or experience working with laryngectomized patients using TEP speech. These professionals could be biased toward successful voice rehabilitation due to expectations or opinions

formed from interacting with patients using VPs, having knowledge about the literature and hands-on experience with VPs. The limitations of descriptions and definitions, measures and methods all contribute to a complicated comparison of results on achievement of success using a VP in terms of speech and voice quality rehabilitation.

Another limiting factor of these studies involved patient variables which included age and gender of the patients. Despite the random selection of participants across the studies, the majority of the subjects included were male (Akbas & Dursun, 2003; Chone et al., 2005; Cornu et al., 2003; Delsupehe et al., 1998; Emerick et al, 2009; Globek et al., 2004; Hotz et al., 2002; Vlantis, 2003). TEP speech has been measured as having a low fundamental frequency, relative to laryngeal speech. This low frequency voice more closely approximates the natural laryngeal fundamental frequency of males as opposed to females. Thus, the high level of voice and speech success demonstrated in the results may be biased to due to the masculine sound of TEP speech. Age was not found to be a factor in successful voice and speech rehabilitation (Chone et al., 2005).

Although patients in these studies underwent a TL, the extent of the surgery, time of TEP, pre- and post-operative treatments (e.g. chemotherapy and radiation therapy), complications due to surgery, and type of VP used (i.e. BS, PX, both or a non-indwelling PX VP) varied. These factors add an additional layer of complication when evaluating success in TEP voice restoration because the population is heterogeneous.

Regarding the extent of surgery, some studies explored voice qualities within groups of patients who had all undergone TL and TEP relative to normal laryngeal speech parameters (Akbas & Dursun, 2003; Cornu et al., 2003; Hotz et al., 2002; Vlantis, 2003), while others compared voice quality of patients who had undergone a TL to patients who had undergone extended laryngectomy with partial pharyngectomy (Delsupehe et al., 1998), or compared patients who had TL to patients with near TL (Globek et al., 2004). The remaining studies explored patients who had TL with a neck dissection (Chone et al., 2005), and patients who had total pharyngectomy, TL with a partial glossectomy or TL with a pharyngectomy (Emerick et al, 2009). The type of surgery did not seem to influence success of voice rehabilitation as each study reported high levels of success, despite the different extents of surgery included in the category of TL. For instance, Delsupehe et al. (1998) found better results for voice quality in TL group in comparison to extended laryngectomy and Globek et al. (2004) found mixed rates of success for different voice quality measures between the TL and near TL groups. The range of types of surgeries has made it difficult to compare the results across studies. Thus, future research should be directed as directly comparing different extents of surgeries to gain a better understanding of which type procedure in combination with TEP and indwelling VP produces the closest to normal laryngeal measures of voice quality.

The results of the literature reviewed provided support that primary TEP produces better speech and voice outcomes compared to secondary TEP (Chone et al., 2005; Emerick et al., 2009). However, one study found that secondary TEP resulted in a better subjective voice quality for both BS and PX VPs (Delsupehe et al., 1998). Another issue concerning time of TEP is that none of the studies examined reported statistically significant results (Akbas & Dursun, 2003; Chone et al., 2005; Cornu et al., 2003; Delsupehe et al., 1998; Emerick et al., 2009; Globek et al., 2004; Hotz et al., 2002; Vlantis et al., 2003), but instead found trends toward better voice outcome with primary TEP. These trends towards better speech and voice outcomes with a primary puncture versus a secondary puncture have important implications for SLPs and their patients' prognosis.

In addition to TL, other treatments examined in the literature include pre- or post- operative radiation (Chone et al., 2005; Hotz et al., 2002), induction chemotherapy and concurrent chemo-radiation (Emerick et al., 2009). These additional treatments were not found to have an effect on voice quality compared with patients who did not receive radiation/chemotherapy. This information is important and clinically relevant as patients who are in need of additional treatments will not feel as though they are compromising their voice quality by means of a TEP and VP for future communication.

Another limitation addressed in the literature is complications due to surgery and issues related to maintenance of the VP. The patients across studies who were unable to achieve successful speech and voice rehabilitation experienced surgical complications of the TEP and VP such as hypertonicity of the pharyngeal-esophageal (PE) segment, partial or full spasm of the PE segment, post-operative fistula, infection, hematoma, granulation tissue, aspiration, swallowing of the VP and fungal colonization of the VP (Akbas & Dursun, 2003; Chone et al., 2005; Cornu et al., 2003; Emerick et al., 2009; Hotz et al., 2002). Some patients were able to attain successful voice and speech rehabilitation over a greater period of time despite having a post-operative fistula (Emerick et al., 2009). Due to the extent of surgery that constituted the TL and the different times of TEP, it is difficult to

compare the occurrence or likelihood of post-operative complications that may affect successful speech and voice rehabilitation and voice quality measures. Furthermore, based on the pre-surgical cognitive, psychological and physiological abilities of the patient, differences in ability to care for the VP also vary. Thus, it is difficult to draw conclusions regarding the effects post-surgical complications can have on successful voice rehabilitation. This information can be applied to clinical practice in that clinicians should be aware of the different types of complications that may arise and if the complication prevents the use of TEP speech, to have a secondary mode of speech or communication available to the patient (e.g. electrolarynx, alternative or augmentative communication devices, etc).

As previously stated, it is difficult to compare the voice quality results across studies as each study used various subjective and objective criteria and measures to collect their data. This issue is further complicated as Delsupehe et al. were the only authors that directly compared the BS VP to the PX VP using the same subjective and objective measures in 1998. They noted the development of a new VP, the PX 2, to help resolve complications related to TEP surgery, which demonstrates that the article may be out of date. More recent studies examined either the BS (Akbas & Dursun, 2003; Chone et al., 2005) or the PX (Cornu et al., 2003; Globek et al., 2004; Hotz et al., 2002). Vlantis et al. (2003) examined converting from a non-indwelling PX VP to the indwelling PX, and found better voice quality results and patient satisfaction with the indwelling PX VP. Overall, each study found successful voice rehabilitation results using either the BS or PX indwelling VP, but due to the differences in how voice quality was measured across articles, it is difficult to compare the BS and PX directly in terms of voice quality. A more comprehensive, current review of the literature is needed to compare the BS to the PX using the same measures to better inform clinical practice as to which VP should be recommended to patients that promotes optimal voice quality post-TL.

Conclusions

The literature reviewed presents strong evidence concerning successful speech and voice rehabilitation after TL with TEP using either the BS or PX VP. As previously discussed, more insight regarding TEP speech rehabilitation and voice quality parameters is required. One of these issues is related specifically to voice quality satisfaction of female participants. Based on the aging population, increased rates of laryngeal cancer among females and the described low frequency pitch produced by VPs, continuing research is essential to assess how satisfied females are with this current more masculine sounding voice (Eadie, Doyle, Hansem, & Beaudin, 2008; Ernst, Covey, Mabuchi, & Mushinski, 2006). Research should also be directed at developing a surgical modifications or a VP that enables women to achieve a higher, more feminine sounding pitch.

Another issue, possibly the central limitation to this review was the variability in defining 'good' voice quality and how to measure voice quality. A standardized definition or protocol is required to be able to compare results across different types of VPs with the goal of learning if one VP consistently provides a variety of patients with better voice quality than other VPs. Furthermore, 'success' was defined in different ways across studies and the level of success a patient is able to attain inherently varies from patient to patient based on personal factors such as age, gender, pre-operational cognitive, psychological and physiological functioning, extent of cancer/recurrence of cancer (e.g. first or second surgery), ability to cope and quality of life variables. Thus, the terms 'success' and 'good voice quality' should be examined in the context of a highly controlled set of patient variables. A variety of listeners should be used to promote social acceptance, education and coping skills to ensure a positive reintegration into society and healthy quality of life.

Lastly, as technology advances and treatments change, an up-to-date study of how the BS and PX VPs and any new VPs since developed should be conducted. This study should use a controlled patient population in which data is collected and measured using the same parameters to learn if one VP offers more advantages in terms of voice quality in TL, TEP patients.

Clinical Implications

This clinical review has examined various factors that will influence an SLP's clinical decision making pertaining to patients that use TEP voice restoration as their primary method of communication. Although limitations in the research exist regarding VPs, there are some important findings an SLP should keep in mind when deciding which VP would be best for individual patients. SLPs should engage in continuous learning regarding recent advances and innovations in voice restoration technology in order to make the best fit between the patient and the VP. Depending on the patients' individual treatment regimes and personal variables, the clinician should be able to work with other professionals regarding surgical and other pre- or post-operative treatments to help optimize speech and voice outcomes. The SLP should be informed of potential complications that may arise regarding VP use

and maintenance of the VP and be able to educate the patient regarding these issues. As these patients have undergone a major surgery and life change, the patient and their support network need to be counselled to promote an optimal quality of life. The SLP is an integral part of the laryngectomized patients' rehabilitation process and therefore must possess expert knowledge to enhance their communication.

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