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ORIGINAL ARTICLE

Relationship between quality of life instruments and phonatory function in tracheoesophageal speech with voice prosthesis

Masayuki Miyoshi[1,2] · Takahiro Fukuhara[3] · Hideyuki Kataoka[3,4] · Hiroshi Hagino[4,5]

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Abstract
Background The use of tracheoesophageal speech with voice prosthesis (T-E speech) after total laryngectomy has increased recently as a method of vocalization following laryngeal cancer. Previous research has not investigated the relationship between quality of life (QOL) and phonatory function in those using T-E speech. This study aimed to demonstrate the relationship between phonatory function and both comprehensive health-related QOL and QOL related to speech in people using T-E speech.
Methods The subjects of the study were 20 male patients using T-E speech after total laryngectomy. At a visit to our clinic, the subjects underwent a phonatory function test and completed three questionnaires: the MOS 8-Item Short-Form Health Survey (SF-8), the Voice Handicap Index-10 (VHI-10), and the Voice-Related Quality of Life (V-RQOL) Measure.
Results A significant correlation was observed between the physical component summary (PCS), a summary score of SF-8, and VHI-10. Additionally, a significant correlation was observed between the SF-8 mental component summary (MCS) and both VHI-10 and VRQOL. Significant correlations were also observed between voice intensity in the phonatory function test and both VHI-10 and V-RQOL. Finally, voice intensity was significantly correlated with the SF-8 PCS.
Conclusions QOL questionnaires and phonatory function tests showed that, in people using T-E speech after total laryngectomy, voice intensity was correlated with comprehensive QOL, including physical and mental health. This finding suggests that voice intensity can be used as a performance index for speech rehabilitation.

Keywords Total laryngectomy · Tracheoesophageal speech · Voice prosthesis · MOS 8-Item Short-Form Health Survey (SF-8) · Phonatory function · Speech rehabilitation

✉ Masayuki Miyoshi
japan.tottori1001mm@gmail.com

1 Division of Medical Education, Department of Social Medicine, School of Medicine, Faculty of Medicine, Tottori University, 86 Nishi-cho, Yonago, Tottori 683-8503, Japan

2 Graduate School of Medical Sciences, Tottori University, Yonago, Tottori, Japan

3 Division of Otolaryngology, Head and Neck Surgery, Department of Medicine of Sensory and Motor Organs, Tottori University Faculty of Medicine, 86 Nishi-cho, Yonago, Tottori 683-8503, Japan

4 School of Health Science, Faculty of Medicine, Tottori University, 86 Nishi-cho, Yonago, Tottori 683-8503, Japan

5 Rehabilitation Division, Tottori University Hospital, Yonago, Tottori, Japan

Introduction

As a major vehicle of communication, the voice has a key function in patient quality of life (QOL), and QOL should be considered as an indicator of health or disease [1]. Treatments for patients with laryngeal cancer can have a major impact on physical, social, and psychological function, thus altering their QOL [2]. Total laryngectomy is the removal of the entire larynx and separation of the airway from the mouth, nose, and esophagus. Patients who undergo this procedure cannot produce speech sounds in a conventional manner because their vocal folds have been removed. Three main options are currently possible for voice restoration after total laryngectomy: esophageal speech, electrolarynx speech, and tracheoesophageal speech with voice prosthesis (T-E speech). Although there are advantages and disadvantages to each method of speech, T-E speech has been increasingly used in recent years, because approximately 90 % of people using T-E speech regain speech, there are fewer issues after placement, the surgery is simple, and the number of words that can be spoken at once is more than with esophageal speech [3, 4].

T-E speech is becoming more common worldwide, and several QOL studies with T-E speech have been conducted [5, 6]. The two primary QOL instruments used are the Voice Handicap Index-10 (VHI-10) [7] and the Voice-Related Quality of Life (V-RQOL) Measure [8], although these are highly correlated [9]. However, these questionnaires assess only voice and not comprehensive health-related QOL. The World Health Organization (WHO) defines QOL as complete physical, social, and mental well-being, and not just the absence of disease [10]. To evaluate this broader concept, the MOS 8-Item Short-Form Health Survey (SF-8) has been frequently used [11, 12].

Voice characteristics are thought to influence QOL in people who regain speech via T-E. Voice pitch, intensity, and air flow rate are thought to be associated with voice characteristics in normal laryngeal speech. However, the impact of phonatory function on the QOL of persons using T-E speech has not been studied. Moreover, although persons using T-E speech undergo speech rehabilitation to improve their speech quality [13], the performance index of speech rehabilitation with the purpose of improving comprehensive QOL is yet to be determined.

Therefore, the objective of this study was to determine how comprehensive health-related QOL and speech-related QOL were associated with phonatory function to improve QOL in people using T-E speech.

Materials and methods

The subjects of this study were men using tracheoesophageal speech with voice prostheses after total laryngectomy. All patients had visited the outpatient clinic of the Department of Head and Neck Surgery of the Tottori University Hospital. Females and subjects who could not use phonation were excluded. Data collection was performed from March 2013 to June 2014. This study was conducted with approval from the Tottori University Faculty of Medicine Ethics Committee (Approval Number 2125). At a visit to our clinic, the subjects completed three questionnaires, that is, the SF-8, VHI-10, and V-RQOL, and underwent a phonatory function test. As summarized in Table 1, the participants were 20 men with an average age of 70.8 years (SD, 9.2; range, 57–88). Two participants already had voice prostheses placed in a one-phase manner after total laryngectomy; however, 18 participants had voice prostheses placed by the two-phase Fukuhara method [14].

Table 1 Summary of participants

	Participants ($n = 20$)
Age (years)	
Mean (SD)	70.8 (9.23)
Range	57–88
50–59	2 (10 %)
60–69	7 (35 %)
70–79	8 (40 %)
80–89	3 (15 %)
Primary disease	
Laryngeal cancer	16 (80 %)
Hypopharyngeal cancer	3 (15 %)
Cervical esophageal cancer	1 (5 %)
Stage	
I	8 (40 %)
II	4 (20 %)
III	8 (40 %)
Surgical method	
Total laryngectomy	16 (80 %)
Pharyngo-laryngo-esophagectomy	4 (20 %)
Reconstructive method	
No reconstruction	11 (55 %)
Jejunum	4 (20 %)
Pectoralis major musculocutaneous flap	3 (15 %)
Rear musculocutaneous flap	1 (5 %)
Large intestine	1 (5 %)
Placement method for voice prosthesis	
One-phase	2 (10 %)
Two-phase (Fukuhara method)	18 (90 %)
Postoperative follow-up duration (months)	
Mean (SD)	32.55 (19.82)
Range	7–88
Shunt follow-up duration (months)	
Mean (SD)	28.25 (10.82)
Range	13–48

The three questionnaires

SF-8

The SF-8, which uses a 4-week recall format, is an eight-item instrument that measures general aspects of health-related QOL [15]. Using the SF-8 to assess QOL has become popular in part because of its ease of administration [16–18]. The original instrument was developed in English and was subsequently translated into Japanese [15, 19]. Each administration of the SF-8 generates a health profile of eight dimensions, including General Health (GH), Physical Function (PF), Role Physical (RP), Bodily Pain (BP), Vitality (VT), Social Functioning (SF), Mental Health (MH), and Role Emotional (RE). In addition, the SF-8 provides two higher-order summary scores, the Physical Component Summary (PCS) and the Mental Component Summary (MCS). Scores for each item and summary range from 0 to 100, with higher scores indicating better health.

The reliability and validity of the Japanese version of the SF-8 were confirmed in a general Japanese population [19], and many Japanese researchers have since used it as an outcome measure for health-related QOL [20–22]. The QOL scores are assessed using the norm-based scoring (NBS) method outlined in the manual of the original version of the SF-8 [15]. The NBS method can be used to compare the results of the SF-8 and SF-36 instruments (the two most widely used instruments for health-related QOL). The means, variances, and regression weights used to score the Japanese version of the SF-8 were derived from the general Japanese population [19].

VHI-10

The VHI, developed by Jacobson et al. in 1997, is a 30-question instrument [23]. In 2004, Rosen et al. distilled the VHI down to the 10 most clinically valuable items concerned with the functional, physical, and emotional domains. The abridged version, the VHI-10, was then compared with the parent questionnaire and found to be highly correlated [7]. Response options range from 0 to 4, with higher numbers indicating greater impairment [23]. The VHI and VHI-10 have been translated and validated for Japanese [24].

V-RQOL

Voice-related quality of life was assessed by the Japanese version of the V-RQOL Measure [26]. The V-RQOL, which has been translated and validated for Japanese [24], is a ten-item outcome instrument with two domains: Social-Emotional and Physical Functioning. Every item can be rated from 1 to 5, wherein 1 represents “not a problem” and 5 “a very large problem.” The calculation of the final score is based on the rules employed in several QOL questionnaires. A standard score is calculated from the raw score, with higher values indicating that quality of life is less impaired by voice functionality. For both the individual domain and for the overall instrument, the maximum score is 100 (best quality of life) and the minimum score is 0 (worst quality of life).

Phonatory function test

The phonatory function test used the Model PS-77E device (Nagashima Medical Instruments, Japan). Subjects were asked to produce the /a/ vowel sound for several seconds at whatever voice pitch and intensity were most comfortable. Pitch, intensity, and exhalation flow rate were measured during sound production.

Statistical analysis

Correlation coefficients were calculated to examine the relationships between the SF-8 and the VHI-10 and V-RQOL, and between the phonatory function test results and the SF-8, VHI-10, and V-RQOL. Additionally, we used the Student’s t test to investigate the differences in the SF-8, VHI, and V-RQOL between participants with and without esophageal reconstruction. The correlation coefficients were calculated to determine the degree of association between the postoperative follow-up duration and the SF-8, VHI, and V-RQOL. The Shapiro–Wilk test was used before all statistical tests to determine whether variables were normally distributed. A significance level of $p = 0.05$ was used for all tests. SPSS Statistics Ver. 19 (IBM Japan, Tokyo, Japan) was used for all statistical analyses.

Results

Results of the SF-8, VHI-10, and V-RQOL

Table 2 shows the results of the SF-8, VHI-10, and V-RQOL. In the SF-8, the average PCS and MCS scores were 49.84 (SD, 5.82) and 47.67 (SD, 8.38), respectively. In the VHI-10, the average Total, Functional, Physical, and Emotional scores were 14.65 (SD, 8.43), 5.40 (SD, 3.58), 6.55 (SD, 3.33), and 2.70 (SD, 2.23), respectively. In the V-RQOL, the average total, physical functioning, and social-emotional scores were 62.25 (SD, 26.59), 61.06 (SD, 25.69), and 62.84 (SD, 28.44), respectively.

Results of the phonatory function test

The results of the phonatory function test are shown in Table 3. The average voice pitch, voice intensity, and air flow rate were 171.07 Hz (SD, 58.35), 68.83 dB SPL (SD, 3.55), and 250.85 ml/s (SD, 170.83), respectively.

Correlation between the SF-8 and the VHI-10 and V-RQOL

Correlation coefficients between the SF-8 and both the VHI-10 and V-RQOL are shown in Table 4. A

Table 2 Results of the MOS 8-Item Short-Form Health Survey (SF-8), the Voice Handicap Index-10 (VHI-10), and the Voice-Related Quality of Life (V-RQOL) Measure

	Mean (SD)	Median (25–75 %)	Range
SF-8			
PCS[a]	49.84 (5.82)	52.06 (43.25–54.86)	39.30–56.08
MCS[b]	47.67 (8.38)	49.30 (43.06–55.21)	28.35–57.09
GH[c]	51.34 (7.50)	50.71 (50.71–58.70)	33.37–61.52
PF[d]	49.10 (5.80)	53.64 (41.93–53.64)	36.68–53.64
RP[e]	49.42 (5.05)	51.18 (42.58–53.90)	42.58–53.90
BP[f]	55.32 (7.69)	60.22 (51.75–60.22)	37.91–60.22
VT[g]	52.33 (6.90)	54.48 (45.27–59.64)	39.78–59.64
SF[h]	45.39 (11.58)	49.98 (38.44–54.74)	20.50–54.74
MH[i]	51.17 (6.32)	50.28 (46.31–57.45)	38.46–57.45
RE[j]	49.02 (6.61)	49.07 (49.07–54.30)	32.20–54.30
VHI-10			
Total	14.65 (8.43)	14.50 (5.75–21.75)	3–30
Functional	5.40 (3.58)	5.00 (2.25–8.50)	1–12
Physical	6.55 (3.33)	6.50 (3.25–10.00)	1–12
Emotional	2.70 (2.23)	2.00 (0.25–4.75)	0–6
V-RQOL			
Total	62.25 (26.59)	65.00 (35.62–88.12)	25–100
Physical functioning	61.06 (25.69)	64.60 (37.50–85.42)	16.7–100
Social-emotional	62.84 (28.44)	62.90 (37.50–92.15)	25–100

PCS physical component summary, *MCS* mental component summary, *GH* general health perception, *PF* physical functioning, *RP* role physical, *BP* bodily pain, *VT* vitality, *SF* social functioning, *MH* mental health, *RE* role emotional

Table 3 Investigation of phonatory function

	Mean (SD)	Median (25–75 %)	Range
Voice pitch (Hz)	171.07 (58.35)	148.50 (126.60–239.68)	81.6–275.4
Voice intensity (dB SPL)	68.83 (3.55)	68.45 (65.50–72.35)	62.5–74.6
Air flow rate (ml/s)	250.85 (170.83)	207.85 (103.72–401.72)	63.7–617.9

significant difference was observed between the SF-8 PCS and the Physical domain of VHI-10. A significant correlation was also observed between the SF-8 MCS and the Total, Functional, Physical, and Emotional domains of VHI-10. Moreover, significant correlations were observed between the SF-8 MCS and the Total, Physical Functioning, and Social-Emotional domains of V-RQOL. Finally, significant correlations were observed between the SF-8 MCS and all domains of the VHI-10 and V-RQOL, with correlation coefficients of 0.50 or higher for all domains.

Correlations between phonatory function and the SF-8, VHI-10, and V-RQOL

Correlation coefficients between the phonatory function test and the SF-8, VHI-10, and V-RQOL are shown in Table 5. A significant correlation was confirmed between voice intensity and all the following: the SF-8 PCS, the Total, Functional, and Physical domains of the VHI-10, and the Physical Functioning domain of the V-RQOL.

Table 4 Correlation between the SF-8 and the VHI-10 and V-RQOL

	SF-8 PCS	SF-8 MCS
VHI-10		
Total	−0.41	−0.62**
Functional	−0.27	−0.56*
Physical	−0.49*	−0.50*
Emotional	**−0.35**	**−0.70****
V-RQOL		
Total	0.33	0.62**
Physical functioning	0.35	0.56**
Social-emotional	**0.28**	**0.65****

Bold represents Pearson * $p < 0.05$, ** $p < 0.01$

Spearman * $p < 0.05$, ** $p < 0.01$

Table 5 Correlation between phonatory function and the SF-8, VHI-10, and V-RQOL

	Voice pitch	Voice intensity	Air flow rate
SF-8			
PCS[a]	0.33	0.51*	**0.20**
MCS[b]	0.04	0.08	**0.24**
GH[c]	0.01	0.55*	**0.23**
PF[d]	0.37	0.29	**0.26**
RP[e]	0.25	0.51*	**0.39**
BP[f]	0.19	0.41	**0.28**
VT[g]	0.42	0.24	**0.24**
SF[h]	−0.11	0.41	**0.41**
MH[i]	0.03	0.26	**0.27**
RE[j]	0.08	0.21	**0.35**
VHI-10			
Total	0.24	−0.53*	−0.22
Functional	0.17	−0.49*	−0.22
Physical	0.28	−0.62**	−0.27
Emotional	0.21	−0.39	**−0.31**
V-RQOL			
Total	−0.14	0.43	0.23
Physical functioning	−0.15	0.47*	0.23
Social-emotional	−0.18	0.23	**0.20**

PCS physical component summary, *MCS* mental component summary, *GH* general health perception, *PF* physical functioning, *RP* role physical, *BP* bodily pain, *VT* vitality, *SF* social functioning, *MH* mental health, *RE* role emotional

Bold represents Pearson * $p < 0.05$, ** $p < 0.01$

Spearman * $p < 0.05$, ** $p < 0.01$

Differences in QOL between patients with and without esophageal reconstruction

The average total VHI-10 scores in participants with ($n = 9$) and without ($n = 11$) esophageal reconstruction were 14.22 (SD, 5.52) and 15.00 (SD, 10.51), respectively. The Student's *t* test revealed no significant difference between the two values ($p = 0.835$). Similarly, the average total V-RQOL scores in participants with and without reconstruction were 60.83 (SD, 22.91) and 63.41 (SD, 30.34), respectively. The Student's *t* test revealed no significant difference between the two values ($p = 0.836$). Finally, for the SF-8, the average MCS scores in participants with and without reconstruction were 47.41 (SD, 6.66) and 51.82 (SD, 4.40), respectively; the average PCS scores were 49.89 (SD, 7.04) and 45.85 (SD, 9.26), respectively. The Student's *t* test revealed no significant difference in either case ($p = 0.111$ for MCS; $p = 0.296$ for PCS).

Correlation between duration of postoperative follow-up and QOL

We calculated the correlation coefficients between postoperative follow-up duration and the VHI-10 total score, V-RQOL total score, MCS score for SF-8, and PCS score for SF-8. The correlation coefficients and *p* values between postoperative follow-up duration and the four scores were as follows: for VHI-10, $r = 0.08$ and $p = 0.73$; for V-RQOL, $r = 0.15$ and $p = 0.53$; for MCS, $r = -0.09$ and $p = 0.70$; and for PCS, $r = 0.23$ and $p = 0.33$. In each case, the *p* value as determined by the Student's *t* test revealed no significant difference.

Discussion

These reference values for SF-8 were derived from 1000 Japanese citizens 18–75 years of age in 2002 and were calculated from national survey results using the 4-week recall format. The average PCS and MCS reference values were 49.84 (SD, 5.99) and 50.09 (SD, 6.04), respectively [19]. In our study, the average PCS score was identical to the reference value. Moreover, the average SF-8 score was only slightly lower than the reference value. Speech loss is inevitable in people undergoing total laryngectomy, which can result in a large degree of anxiety and stress. This disability can cause socioeconomic problems such as loss of employment, which has been reported to influence QOL to a large degree after loss of speech [25]. However, our participants demonstrated that regaining speech via a T-E voice prosthesis, even after total laryngectomy, led to physical and mental improvements in comprehensive QOL. No significant differences in QOL scores were observed between participants who required esophageal reconstruction before total laryngectomy and those for whom surgery was not necessary. This result suggests that enabling T-E speech improves QOL, even for patients whose cancer has progressed enough to require esophageal reconstruction. Moreover, the lack of correlation between QOL and duration after total laryngectomy suggests that enabling T-E speech improves QOL even in cases having a long postoperative period without speech. To further investigate factors that will improve overall QOL, we think it is important to conduct a detailed study that evaluates QOL not only in patients who use T-E speech but also in those who use esophageal speech or electrolarynx speech.

With respect to the phonatory function test results shown in Table 3, Kawamura et al. performed a study on 38 adult males (aged 23–33 years) without a previous history of laryngeal or pulmonary conditions. The authors reported that the average voice pitch and intensity when continuously vocalizing the vowel /a/ were 136 Hz (95 %

confidence interval, 129–143 Hz) and 74.8 dB SPL (95 % confidence interval, 74–76 dB), respectively [26]. Compared to these results, the participants in the current study who were using T-E speech had a higher pitch but weaker voice intensity. The voice intensity of laryngeal speech is thought to be associated with subglottic pressure and the rate of expiratory flow. Additionally, voice pitch and intensity change depending on whether there has been reconstruction. In prior studies, the minimal vibration pressure for comfortable speech by tracheoesophageal fistula was approximately 30 mmHg [27, 28], almost twice the value for speech by tracheojejunal fistula, which was approximately 16.2 mmHg [29]. Additionally, the average rates of expiratory flow in speech by tracheoesophageal and tracheojejunal fistula were 105.5 ml/s [27, 28] and 129.6 ml/s [28], respectively. In speech by tracheoesophageal fistula, appropriate closing of the new glottis is maintained through contraction of the thyropharyngeal part of the inferior constrictor under pressure from the new glottis. However, this active closing mechanism does not exist for vibrations created through speech by tracheojejunal fistula [27]. Therefore, in previous research on speech by tracheoesophageal fistula in people with or without jejunal reconstruction, voice intensity was weaker because of decreased vibration pressure and average rate of respiration. Our study included participants without reconstruction and with reconstruction, which suggests that differences in reconstructive methods could influence voice intensity.

The report suggests a strong correlation between the SF-36 and VHI [30], and our study showed a correlation between the SF-8 MCS and all the VHI domains. Additionally, the significant correlation between the SF-8 MCS and V-RQOL suggests that the VHI and V-RQOL reflect the psychological characteristics of people using T-E speech, and the results of these instruments are associated with psychological health as measured by the SF-8. Voice intensity was not directly associated with the SF-8 MCS; however, improvements to voice intensity improve VHI and V-RQOL scores, which subsequently improve the SF-8 MCS. Voice intensity showed a significant positive correlation with the SF-8 PCS, suggesting that voice intensity affects comprehensive QOL, including physical and mental health, in people using T-E speech after total laryngectomy.

Although persons using T-E speech undergo speech rehabilitation to improve their speech quality [14], the performance index of speech rehabilitation for improving comprehensive QOL is yet to be determined. Given that our study revealed a correlation between comprehensive QOL and voice intensity, the latter can be a performance index for future speech rehabilitation studies. Moreover, in speech rehabilitation aimed at increasing voice intensity, it will be important to continuously evaluate and improve each of the items in the VHI-10 and V-RQOL to improve comprehensive QOL in people using T-E speech. We recommend future investigations of speech rehabilitation or intervention methods to improve voice intensity. Finally, it will be necessary to thoroughly investigate the relationship between QOL and phonatory function based on age or method of reconstruction and to use these findings to establish new methods of rehabilitation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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