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HEAD & NECK

Long-term functional voice outcomes after thyroidectomy, and effect of endotracheal intubation on voice

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Abstract

Purpose The aim of this study was to evaluate long-term functional voice outcomes after thyroidectomy, and the effect of endotracheal intubation on post-operative voice impairment.

Methods We prospectively analyzed the voice outcomes of 155 serial thyroidectomy patients for up to 2 years. The control group consisted of 69 patients who underwent parotidectomy. Patients with post-operative recurrent laryngeal nerve palsy or palsy of the external branch of the superior laryngeal nerve were excluded. Self-assessment voice symptom scores (VSS) by questionnaire, and objective acoustic parameters and maximum phonation times, were evaluated pre-operatively and 1 day, 3 days, 1 week, 1 month, 3, 6, 12, 18, and 24 months after surgery.

Results VSS increased from day 1 after surgery in both groups, and returned to pre-operative levels by 24 months in the thyroidectomy group and after 1 week post-operatively in the parotidectomy (control) group. The post-operative VSS of the thyroidectomy group was significantly higher than that of the control group up to 12 months post-operatively. Highest frequency decreased immediately after surgery in the thyroidectomy group, and recovered to pre-operative levels by 12 and 18 months in females and males, respectively, whereas it recovered to pre-operative levels after the first week in the control group.

Conclusion Impairment of voice function may persist for more than 18 months after thyroidectomy even in patients without RLN palsy. Endotracheal intubation can affect voice outcomes adversely for 1 week post-operatively.

Keywords Long-term · Voice outcome · Thyroidectomy · Post-thyroidectomy syndrome · Acoustic analysis · Endotracheal intubation

Introduction

Voice and swallowing impairment, the so-called post-thyroidectomy syndrome, occurs frequently even without recurrent laryngeal nerve (RLN) palsy [1–11]. Voice symptoms after thyroidectomy include voice fatigue, roughness, difficulties with high frequencies and singing, and volume reduction [1, 3]. The possible causes of voice impairment after thyroidectomy without RLN palsy include injury to the external branch of the superior laryngeal nerve (EBSLN), cricothyroid muscle impairment, laryngotracheal fixation, endotracheal intubation, vocal cord edema or altered vascular supply and venous or lymphatic drainage, injury to the fine anastomotic branches connecting the RLN and EBSLN, laryngopharyngeal reflux, severe retractile cervical scar, local neck pain, and psychotic reaction and stress [6, 7, 12–17].

Voice quality is a matter of concern for most patients who undergo thyroidectomy. In general, subjective voice symptoms increase immediately after thyroidectomy and decrease gradually to pre-operative levels after about 3–6 months [10, 11, 18–21]. However, most previous evaluations of voice outcomes after thyroidectomy involved only short-term follow-up, usually of 3 or 6 months, and long-term voice outcomes after thyroidectomy have not yet been well evaluated,

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with only a few long-term follow-up studies. In addition, the effect of endotracheal intubation on voice outcome after thyroidectomy is not investigated well although endotracheal intubation is considered as one of the reasons of voice impairment after thyroidectomy, and the significant changes of jitter and shimmer values after endotracheal intubation due to vocal cord edema was reported [14].

The aim of this study was to examine long-term subjective and objective functional voice outcomes after thyroidectomy in patients without RLN palsy and in a control group of patients undergoing parotidectomy, and also to evaluate the effect of endotracheal intubation on post-thyroidectomy voice impairment.

Methods

Patients

We prospectively enrolled 159 patients with thyroid nodules who underwent the conventional trans-cervical thyroidectomy with or without central neck dissection between March 2013 and March 2015, and who agreed to undergo serial voice assessment before and after surgery (the case group) in a tertiary hospital. Sixty-nine patients with benign parotid tumors who underwent parotidectomy over the same period and who also agreed to undergo serial voice assessment before and after surgery served as the control group, because anterior neck structures such as the strap muscles and RLN are not affected by parotidectomy. Exclusion criteria were <18 and >70 years of age, vocal mucosal lesions such as vocal nodules, polyps, sulcus vocalis, and Reinke's edema, pre-operative RLN paralysis, vocal cord movement disorder, and severe post-operative hematoma or hypocalcemia. Also excluded were patients who underwent completion thyroidectomy or lateral neck dissection simultaneously with thyroidectomy, patients with a history of neck irradiation or previous neck surgery, and patients with apparent injury related to endotracheal intubation. Patients with post-operative RLN paralysis or apparent injury to the EBSLN after thyroidectomy were excluded. Patients who underwent selective neck dissection along with parotidectomy or had facial nerve paralysis after parotidectomy were also excluded from the control group. All patients provided informed consent for the voice assessments and serial follow-up. The Institutional Review Board of Hanyang University Hospital approved the study.

The conventional trans-cervical thyroidectomy was performed using a transverse incision two finger breadths above the suprasternal notch. The sternothyroid muscles were not cut routinely. The RLN was identified and preserved routinely using a loupe. Intraoperative RLN and EBSLN neuromonitoring was not performed routinely. Parotidectomy was performed via a modified facelift approach preserving the facial nerve.

Functional voice outcomes were evaluated serially using a self-assessment voice questionnaire and simultaneous objective acoustic voice analysis and aerodynamic study on the day before surgery, and 1 day, 3 days, 1 week, 1 month, 3, 6, 12, 18, and 24 months after surgery, where possible. However, in the control (parotidectomy) group, subjective and objective voice analysis was evaluated pre-operatively and post-operatively only up to 12 months, because further follow-up was very difficult. All voice questionnaire and acoustic voice analysis was performed by an expert speech-language pathologist. Videolaryngostroboscopy with an EndSTROB DX (Sion, Berlin, Germany) and fiberoptic flexible laryngoscopy were also routinely performed the day before surgery and the day after surgery in all patients to assess movement of the vocal folds, vocal mucosal lesions, arytenoid asymmetry, vocal cord bowing, degree of glottis closure, and mucosal wave characteristics.

Voice symptom scores (VSS)

Subjective voice outcomes were assessed using a self-assessment voice questionnaire developed specifically by this group [22, 23]. The questionnaire consists of five questions concerning changes in voice pitch, range, intensity, fatigability, and singing quality: (1) Do you have vocal fatigue? (2) Do you have a hoarse voice? (3) Is it difficult to produce a high pitch? (4) Is your voice weak or breathy? (5) Do you have difficulty singing? Each question was scored on a 0–4 symptom grading scale: 0 (no symptoms), 1 (mild), 2 (moderate), 3 (severe), and 4 (very severe), and the voice symptom score (VSS) is defined as the sum of the scores on the five questions. It, therefore, ranges from a minimum of 0 to a maximum of 20.

Acoustic analysis and aerodynamic study

The acoustic voice analysis was performed using a Multidimensional Voice Program (MDVP) and Voice Range Profile (VRP) in the Computerized Speech Lab software (model 4150B, Kay PENTAX, Lincoln Park, NJ, USA). For the MDVP analysis, after three training emissions, a consistent vowel /a/ produced at a comfortable pitch and loudness level for at least 5 s was recorded. We chose an interval of 3 s from the mid-portion of each vowel. The following parameters were analyzed in the MDVP: fundamental frequency (F0, Hz), jitter (%), shimmer (%), and noise-to-harmonic ratio (NHR, dB). In the VRP analysis, patients were asked to phonate a consistent vowel /a/ as loudly and as softly as possible from the lowest to highest frequencies. Lowest (F-low)

and highest (F-high) frequencies (Hz), frequency range (Hz), and intensity range (dB) were measured in the VRP analysis.

Maximum phonation time (MPT) was measured aerodynamically. It was obtained by having patients sustain the vowel /a/ for as long as possible on a single breath. The longest of three attempts was recorded as the MPT.

Statistical analysis

Statistical analysis was performed with SPSS 20 (SPSS Inc., Chicago, IL, USA). Categorical variables were evaluated by the Chi-square test or Fisher's exact test in cases with small cell sizes. Continuous variables were analyzed by *t* tests or the Mann–Whitney *U* test in cases with small cell sizes. Paired *t* tests were used to compare post-operative VSS, acoustic parameters, and MPT with pre-operative variables. A *p* value less than 0.05 was considered significant.

Results

Clinicopathological characteristics

Of 159 thyroidectomy patients enrolled as the case group, three (1.9%) had temporary RLN palsies after the operation and were excluded from the study, and one patient who underwent reoperation under general anesthesia to remove a post-operative hematoma was also excluded. Finally, 155 thyroidectomy cases were included in the study. Table 1 presents the clinicopathologic characteristics of the case and control groups. In the thyroidectomy (case) group, there were 109 women and 46 men, and the mean age was 48.8 ± 17.1 years. There were 30 (19%) benign thyroid nodules and 125 (81%) malignancies including papillary and follicular carcinomas. Lobectomy was performed in 34 (22%) patients and total thyroidectomy in 121 (78%). The control group consisted of 54 women and 15 men. There were no significant differences in sex, age, and operative time between the case and control groups. Among the risk factors that can affect voice quality, smoking and alcohol consumption did not differ between the groups. However, laryngopharyngeal reflux disease (LPRD) was significantly more common in the thyroidectomy group than the control group.

Table 1 Clinicopathologic characteristics of the thyroidectomy (case) and parotidectomy (control) groups

	Thyroidectomy group ($n=155$)	Parotidectomy group ($n=69$)	*p* value
Sex (women:men)	109:46	54:15	0.531
Age (years)	48.79 ± 17.10	52.71 ± 11.44	0.213
Operative time (min)	151.41 ± 39.427	147.50 ± 42.952	0.182
Type of thyroidectomy			
Lobectomy	34 (22%)		
Total thyroidectomy	121 (78%)		
Central neck dissection	128/155 (83%)		
Pathology			
Benign	30 (19%)	69 (100%)	
Malignant	125 (81%)	0	
Vocal risk factors			
Smoking	20 (13%)	14 (20%)	0.189
Alcohol drinking	29 (19%)	18 (27%)	0.247
Laryngopharyngeal reflux	45 (29%)	1 (1.4%)	< 0.001

Changes of voice symptom scores (VSS)

The questionnaire about subjective voice impairment was completed by all 224 patients in the case and control groups 1 day before surgery and 1 day, 3 days, and 1 week post-operatively, and by 209 patients after 1 month, 196 patients after 3 months, 165 patients after 6 months, and 129 patients after 12 months. In the case group, 103 patients completed the voice questionnaire at 18 months post-operatively and 86 at 24 months.

The changes of VSS are shown in Table 2. In the thyroidectomy group, VSS increased immediately after the surgery and did not return to the pre-operative value until 24 months after surgery. In the control group, VSS also increased significantly on days 1 and 3 after surgery, but it returned to the pre-operative level within a week. The post-operative VSS of the case group was significantly higher than that of the control group from day 1 to 12 months post-operatively, the last time VSS was evaluated in the control group. The pre-operative VSS of the thyroidectomy group was also significantly higher than that of the control group.

In a stratification analysis according to the extent of thyroidectomy, the VSS of the total thyroidectomy patients was higher than that of the lobectomy group from 1 day to 1 week after surgery (data not shown). However, the difference disappeared after 1 month.

Changes of acoustic parameters and MPT

The acoustic analysis and MPT were completed in all 224 patients on pre-operative day 1 and 1 day, 3 days, and 1 week post-operatively, and by 209 patients after 1 month, 189 patients after 3 months, 158 patients after 6 months, and 120 patients after 12 months. In the case group, 99 patients completed the acoustic analysis and MPT 18 months post-operatively and 80 patients 24 months post-operatively.

We compared the acoustic parameters and MPT according to gender, because the fundamental frequency is different in females and males. The changes of acoustic parameters and MPT in females are shown in Table 3. Fundamental

Table 2 Pre- and post-operative voice symptom scores (VSS) in the thyroidectomy (case) and parotidectomy (control) groups

VSS	Thyroidectomy group ($n=155$) (A)	p value vs. pre-op	Parotidectomy group ($n=69$) (B)	p value vs. pre-op	p value, A vs. B
Pre-op	0.835 ± 1.424		0.072 ± 0.494		< 0.001*
1 day	5.724 ± 4.633	< 0.001*	0.812 ± 1.904	0.002*	< 0.001*
3 days	4.087 ± 4.184	< 0.001*	0.797 ± 1.787	0.001*	< 0.001*
1 week	3.328 ± 3.744	< 0.001*	0.203 ± 0.932	0.267	< 0.001*
1 month	3.725 ± 5.282	< 0.001*	0.032 ± 0.254	0.182	< 0.001*
3 months	4.837 ± 4.847	< 0.001*	0.075 ± 0.384	0.844	< 0.001*
6 months	3.406 ± 3.766	< 0.001*	0.104 ± 0.424	0.209	< 0.001*
12 months	2.241 ± 2.087	< 0.001*	0.146 ± 0.572	0.710	< 0.001*
18 months	2.091 ± 2.605	0.003*			
24 months	0.975 ± 0.973	0.926			

VSS voice symptom score, *pre-op* pre-operative

*p value < 0.05

frequency (F0), jitter and NHR did not change significantly after surgery in either the case or control groups, except at occasional time points. Shimmer was significantly worse for 12 months after thyroidectomy, except in the 1st week post-operatively. F0, jitter, shimmer, and NHR did not differ significantly between the case and control groups at most time points.

Highest frequency (F-high) decreased significantly for 6 months after surgery in the thyroidectomy group, and returned to the pre-operative level by 12 months after surgery. It decreased significantly on days 1 and 3 after surgery in the control group. F-high was significantly lower in the case group than the control group for the first post-operative month. Low frequency (F-low) decreased significantly for the first 3 months after surgery in the thyroidectomy group, but did not change in the control group. F-low did not differ significantly between the case and control groups.

Frequency range decreased significantly for a month after surgery in the thyroidectomy group and for 3 days after surgery in the control group. The frequency range of the thyroidectomy group was significantly lower than that of the control group for a month after surgery. Intensity range decreased for a month after surgery in the thyroidectomy group, and for 3 days in the control group. It did not differ significantly between the case and control groups before or after surgery. MPT decreased significantly for 18 months after surgery in the thyroidectomy group, and for only 1 day in the control group. It did not differ significantly between the case and control groups.

The results for the acoustic parameters and MPT in males are presented in Table 4. F0, jitter, shimmer, NHR, F-low, and MPT were not significantly affected at most times after surgery in either the case or control groups, and they did not differ between the groups.

F-high decreased significantly for the first 12 months (except at 1 week) after surgery and frequency range decreased significantly for 3 months (except for week 1) after surgery in the thyroidectomy group. F-high and frequency range did not differ significantly between case and control groups. Intensity range decreased for 3 months in the thyroidectomy group. It also decreased for the first week post-operatively in the control group. There was no significant difference in intensity range between the case and control groups.

In a stratification analysis according to the extent of thyroidectomy, the acoustic parameters and MPT did not differ between the total thyroidectomy and lobectomy cases in either females or males (data not shown).

Discussion

In this study, we evaluated long-term functional voice outcomes after thyroidectomy without RLN palsy serially for up to 2 years. A few previous studies have evaluated outcomes for more than a year. In the study, self-assessment VSS decreased immediately after thyroidectomy and the decrease was maintained for 18 months post-operatively. Highest frequency also worsened immediately after thyroidectomy, and recovered by 12 months and 18 months post-operatively in females and males, respectively, whereas they recovered to pre-operative levels by 1 week after surgery in the control group. It is noteworthy that impairment of subjective voice capacities and F-high continued for more than 18 months and 6–12 months, respectively, after thyroidectomy, quite long compared to the previous studies. In many such studies, subjective voice outcomes and acoustic parameters recovered within 3 months after surgery, or at most 6 months [11, 19–21]. In the few articles that analyzed voice outcomes after thyroidectomy for up to 1 year, subjective voice impairment resolved within 6 months or 12 months, and only a few patients complained of voice impairment 1 year after surgery [6, 24, 25]. We need to recognize the possibility of

Table 3 Comparison of pre- and post-operative acoustic parameters and MPT in females in the thyroidectomy and parotidectomy groups

	Thyroidectomy group ($n=109$, A)	p value vs. pre-op	Parotidectomy group ($n=54$, B)	p value vs. pre-op	p value, A vs. B
F0 (Hz)					
Pre-op	194.07 ± 25.13		195.48 ± 24.18		0.519
1 day	178.73 ± 38.58	0.005*	194.24 ± 24.18	0.503	0.021*
3 days	187.58 ± 32.21	0.206	195.62 ± 22.53	0.914	0.156
1 week	187.56 ± 30.96	0.200	198.95 ± 23.66	0.008	0.043*
1 month	188.01 ± 24.19	0.335	193.18 ± 32.25	0.576	0.368
3 months	185.41 ± 25.33	0.151	188.80 ± 29.03	0.784	0.764
6 months	183.05 ± 22.70	0.139	194.45 ± 26.79	0.390	0.266
12 months	185.02 ± 32.09	0.820	182.78 ± 30.89	0.428	0.456
18 months	192.63 ± 25.20	0.296			
24 months	177.58 ± 11.68	0.346			
Jitter (%)					
Pre-op	4.44 ± 27.32		1.01 ± 0.65		0.422
1 day	1.79 ± 1.46	0.440	1.57 ± 1.16	0.001*	0.408
3 days	1.49 ± 1.59	0.392	1.01 ± 0.65	0.126	0.360
1 week	1.23 ± 1.07	0.347	0.97 ± 0.53	0.647	0.062
1 month	1.26 ± 0.89	0.350	0.81 ± 0.52	0.115	0.002*
3 months	1.15 ± 0.80	0.336	1.24 ± 0.56	1.000	0.793
6 months	1.29 ± 0.97	0.347	1.06 ± 0.61	0.022	0.580
12 months	1.28 ± 1.02	0.348	1.35 ± 1.24	0.501	0.915
18 months	1.25 ± 0.99	0.106			
24 months	1.57 ± 0.70	0.306			
Shimmer (%)					
Pre-op	3.44 ± 1.60		3.43 ± 1.18		0.944
1 day	5.60 ± 4.07	< 0.001*	4.11 ± 2.37	0.067	0.017*
3 days	4.32 ± 3.07	0.010*	3.37 ± 1.60	0.757	0.064
1 week	3.85 ± 2.05	0.121	3.14 ± 1.18	0.059	0.024
1 month	4.50 ± 2.34	0.003*	2.88 ± 0.93	0.017	< 0.001*
3 months	4.11 ± 1.85	0.036*	3.34 ± 0.82	0.248	0.321
6 months	4.29 ± 2.51	0.023*	3.31 ± 0.98	0.177	0.353
12 months	4.28 ± 1.65	0.004*	4.92 ± 0.64	0.007	0.511
18 months	3.50 ± 1.32	0.699			
24 months	3.23 ± 0.07	0.051			
NHR (dB)					
Pre-op	0.17 ± 0.36		0.13 ± 0.02		0.415
1 day	0.15 ± 0.05	0.610	0.14 ± 0.04	0.068	0.395
3 days	0.19 ± 0.40	0.772	0.13 ± 0.04	0.686	0.278
1 week	0.16 ± 0.24	0.232	0.12 ± 0.03	0.748	0.298
1 month	0.14 ± 0.03	0.453	0.12 ± 0.02	0.479	0.603
3 months	0.13 ± 0.02	0.414	0.14 ± 0.02	0.730	0.310
6 months	0.14 ± 0.04	0.415	0.13 ± 0.02	0.312	0.396
12 months	0.13 ± 0.02	0.405	0.13 ± 0.01	0.983	0.720
18 months	0.13 ± 0.03	0.372			
24 months	0.12 ± 0.03	0.705			
F-high (Hz)					
Pre-op	412.83 ± 111.79		440.33 ± 133.36		0.245
1 day	295.05 ± 79.54	< 0.001*	394.58 ± 129.63	< 0.001*	< 0.001*
3 days	332.74 ± 93.42	< 0.001*	415.75 ± 130.88	0.026*	0.001*
1 week	347.38 ± 101.38	< 0.001*	429.12 ± 136.59	0.251	0.001*
1 month	367.12 ± 125.41	< 0.001*	425.81 ± 139.96	0.170	0.031*
3 months	374.41 ± 110.92	< 0.001*	406.62 ± 135.48	0.339	0.519
6 months	371.81 ± 115.05	0.014*	376.85 ± 77.31	0.673	0.918

Table 3 (continued)

	Thyroidectomy group ($n=109$, A)	p value vs. pre-op	Parotidectomy group ($n=54$, B)	p value vs. pre-op	p value, A vs. B
12 months	410.45 ± 116.60	0.087	359.01 ± 102.61	0.380	0.467
18 months	411.74 ± 126.73	0.125			
24 months	411.23 ± 113.58	0.105			
F-low (Hz)					
Pre-op	150.15 ± 19.47		145.21 ± 26.67		0.253
1 day	142.80 ± 21.74	0.001*	145.57 ± 23.59	0.798	0.531
3 days	142.18 ± 27.61	0.005*	145.34 ± 24.50	0.847	0.542
1 week	138.43 ± 29.83	< 0.001*	146.66 ± 24.35	0.194	0.134
1 month	141.53 ± 22.30	0.001*	138.53 ± 25.73	0.036	0.536
3 months	144.40 ± 23.90	0.005*	142.19 ± 17.39	0.262	0.830
6 months	142.51 ± 16.90	0.178	117.36 ± 34.12	0.336	0.058
12 months	150.51 ± 22.57	0.513	139.20 ± 16.05	0.185	0.113
18 months	144.03 ± 16.82	0.282			
24 months	139.51 ± 22.69	0.918			
Frequency range (Hz)					
Pre-op	263.27 ± 115.55		295.33 ± 137.53		0.185
1 day	148.74 ± 80.74	< 0.001*	249.01 ± 131.09	< 0.001*	< 0.001*
3 days	189.93 ± 90.79	0.001*	270.40 ± 136.12	0.027*	< 0.001*
1 week	205.99 ± 103.51	0.031*	282.45 ± 141.45	0.197	0.003*
1 month	221.35 ± 141.49	0.041*	287.27 ± 136.87	0.397	0.042*
3 months	230.01 ± 138.92	0.152	264.43 ± 129.82	0.707	0.375
6 months	228.53 ± 143.47	0.139	259.48 ± 81.21	0.575	0.224
12 months	251.26 ± 103.15	0.369	219.80 ± 86.58	0.633	0.262
18 months	258.67 ± 113.01	0.531			
24 months	262.09 ± 115.20	0.910			
Intensity range (dB)					
Pre-op	20.69 ± 5.57		21.04 ± 6.10		0.720
1 day	15.33 ± 5.63	< 0.001*	16.93 ± 4.98	< 0.001*	0.134
3 days	17.58 ± 6.66	< 0.001*	19.34 ± 5.48	0.014*	0.150
1 week	19.31 ± 5.49	0.087*	20.02 ± 6.26	0.079	0.537
1 month	18.60 ± 5.29	0.007*	25.27 ± 29.36	0.345	0.099
3 months	20.55 ± 6.53	0.441	19.83 ± 7.46	0.943	0.803
6 months	18.97 ± 5.85	0.015	24.01 ± 8.34	0.625	0.069
12 months	20.87 ± 6.18	0.061	19.33 ± 6.11	0.808	0.682
18 months	20.08 ± 5.08	0.685			
24 months	21.50 ± 7.77	0.570			
MPT (s)					
Pre-op	16.07 ± 5.12		12.83 ± 5.11		0.002*
1 day	12.15 ± 5.08	< 0.001*	12.84 ± 5.09	0.001*	0.349
3 days	13.34 ± 4.86	< 0.001*	12.68 ± 4.93	0.729	0.491
1 week	13.56 ± 4.29	0.001*	13.06 ± 5.03	0.591	0.579
1 month	14.08 ± 5.12	0.006*	14.09 ± 4.85	0.037	0.991
3 months	14.23 ± 5.70	0.010*	9.67 ± 3.19	0.344	0.063
6 months	13.19 ± 5.62	< 0.001*	12.41 ± 4.50	0.775	0.745
12 months	13.20 ± 5.46	< 0.001*	13.41 ± 7.67	0.679	0.759
18 months	13.23 ± 5.61	< 0.001*			
24 months	15.28 ± 6.68	0.121			

F0 fundamental frequency, *NHR* noise-to-harmonic ratio, *F-high* highest frequency, *F-low* lowest frequency, *MPT* maximum phonation time

Table 4 Comparison of pre- and post-operative acoustic parameters and MPT in males in the thyroidectomy and parotidectomy groups

	Thyroidectomy group ($n=46$, A)	p value vs. pre-op	Parotidectomy group ($n=15$, B)	p value vs. pre-op	p value, A vs. B
F0 (Hz)					
Pre-op	114.41 ± 19.64		120.01 ± 30.87		0.446
1 day	110.91 ± 23.57	0.412	115.68 ± 24.51	0.086	0.503
3 days	114.03 ± 16.94	0.870	122.20 ± 29.53	0.443	0.229
1 week	114.95 ± 17.75	0.838	120.38 ± 29.72	0.914	0.362
1 month	111.04 ± 16.83	0.499	129.21 ± 36.67	0.133	0.049
3 months	110.25 ± 13.22	0.168	111.62 ± 8.30	0.683	0.688
6 months	110.97 ± 16.11	0.849	106.48 ± 0.91	0.056	0.793
12 months	111.76 ± 14.02	0.935	109.32 ± 5.81	0.067	0.976
18 months	112.80 ± 8.76	0.985			
24 months	112.55 ± 10.11	0.964			
Jitter (%)					
Pre-op	0.85 ± 0.68		0.91 ± 0.87		0.818
1 day	1.41 ± 1.23	0.025*	0.83 ± 0.62	0.620	0.063
3 days	0.98 ± 0.65	0.252	0.94 ± 0.79	0.702	0.845
1 week	0.99 ± 0.74	0.346	0.84 ± 0.77	0.640	0.546
1 month	0.69 ± 0.47	0.582	0.71 ± 0.63	0.185	0.914
3 months	0.84 ± 0.82	0.347	0.59 ± 0.27	0.122	0.457
6 months	1.32 ± 3.25	0.016*	0.85 ± 0.53	0.650	0.761
12 months	0.56 ± 0.21	0.042	0.86 ± 0.79	0.672	0.500
18 months	0.76 ± 0.28	0.624			
24 months	0.70 ± 0.35	0.593			
Shimmer (%)					
Pre-op	3.77 ± 2.24		3.13 ± 0.92		0.246
1 day	4.47 ± 2.94	0.312	3.22 ± 1.17	0.761	0.086
3 days	3.86 ± 1.58	0.852	3.10 ± 0.85	0.913	0.062
1 week	3.96 ± 2.01	0.751	2.89 ± 0.64	0.322	0.038
1 month	3.39 ± 1.41	0.831	3.16 ± 0.98	0.913	0.586
3 months	4.30 ± 5.25	0.408	3.34 ± 0.70	0.120	0.672
6 months	4.02 ± 4.71	0.557	3.35 ± 3.24	0.105	0.775
12 months	3.75 ± 1.51	0.564	3.30 ± 3.39	0.135	0.637
18 months	3.74 ± 1.51	0.549			
24 months	3.70 ± 0.24	0.512			
NHR (dB)					
Pre-op	0.13 ± 0.04		0.12 ± 0.02		0.518
1 day	0.14 ± 0.05	0.319	0.13 ± 0.02	0.246	0.428
3 days	0.13 ± 0.02	0.646	0.13 ± 0.01	0.318	0.524
1 week	0.13 ± 0.03	0.507	0.12 ± 0.01	0.901	0.078
1 month	0.12 ± 0.02	0.836	0.11 ± 0.02	0.231	0.105
3 months	0.15 ± 0.05	0.086	0.13 ± 0.01	0.361	0.657
6 months	0.17 ± 0.16	0.350	0.15 ± 0.01	0.075	0.821
12 months	0.14 ± 0.01	0.268	0.12 ± 0.01	0.902	0.515
18 months	0.15 ± 0.01	0.091			
24 months	0.13 ± 0.02	0.509			
F-high (Hz)					
Pre-op	303.92 ± 107.70		276.49 ± 96.43		0.374
1 day	229.68 ± 72.17	0.001*	263.62 ± 101.22	0.079	0.181
3 days	249.06 ± 75.19	0.010*	279.26 ± 100.97	0.745	0.253
1 week	265.20 ± 86.66	0.115	283.50 ± 98.09	0.379	0.445
1 month	237.71 ± 79.71	0.005*	287.05 ± 86.66	0.449	0.051
3 months	245.05 ± 76.95	0.028*	263.93 ± 37.82	0.367	0.536
6 months	264.54 ± 75.12	0.018*	275.55 ± 65.81	0.425	0.222

Table 4 (continued)

	Thyroidectomy group ($n=46$, A)	p value vs. pre-op	Parotidectomy group ($n=15$, B)	p value vs. pre-op	p value, A vs. B
12 months	251.23 ± 57.65	< 0.001*	268.64 ± 70.42	0.398	0.623
18 months	303.68 ± 34.32	0.903			
24 months	303.31 ± 46.52	0.853			
F-low (Hz)					
Pre-op	90.80 ± 14.32		91.06 ± 20.20		0.959
1 day	91.60 ± 22.11	0.855	92.07 ± 21.35	0.782	0.943
3 days	92.75 ± 12.55	0.348	91.40 ± 18.52	0.906	0.764
1 week	91.89 ± 12.45	0.841	92.56 ± 17.85	0.837	0.724
1 month	88.02 ± 13.42	0.517	96.78 ± 26.66	0.090	0.141
3 months	90.68 ± 12.74	0.898	90.41 ± 24.48	0.425	0.934
6 months	86.19 ± 7.65	0.810	92.41 ± 7.35	0.825	0.711
12 months	84.85 ± 8.336	0.362	98.16 ± 6.54	0.079	0.195
18 months	90.35 ± 10.85	0.824			
24 months	91.73 ± 11.54	0.835			
Frequency range (Hz)					
Pre-op	206.01 ± 110.89		185.43 ± 87.54		0.497
1 day	133.47 ± 69.79	< 0.001*	171.55 ± 92.69	0.082	0.151
3 days	151.79 ± 110.89	0.006*	187.86 ± 92.36	0.766	0.351
1 week	166.11 ± 89.66	0.085	190.93 ± 90.02	0.489	0.394
1 month	145.47 ± 92.48	0.002*	190.26 ± 79.20	0.702	0.295
3 months	153.51 ± 95.01	0.008*	173.52 ± 42.45	0.152	0.491
6 months	175.07 ± 142.44	0.069	183.11 ± 39.29	0.347	0.782
12 months	165.54 ± 110.85	0.052	170.78 ± 96.99	0.129	0.867
18 months	199.73 ± 119.21	0.750			
24 months	201.36 ± 107.81	0.895			
Intensity range (dB)					
Pre-op	25.10 ± 7.15		24.10 ± 5.85		0.615
1 day	18.34 ± 5.03	< 0.001*	20.10 ± 6.23	0.009*	0.287
3 days	19.96 ± 6.06	< 0.001*	21.26 ± 5.46	0.040*	0.455
1 week	22.35 ± 5.27	0.029*	20.73 ± 5.05	0.019*	0.265
1 month	22.34 ± 5.85	0.037*	22.47 ± 5.34	0.057	0.897
3 months	20.05 ± 5.34	0.014*	23.33 ± 3.38	0.268	0.147
6 months	24.78 ± 4.06	0.543	22.00 ± 1.15	0.051	0.960
12 months	24.42 ± 7.68	0.415	22.50 ± 1.73	0.064	0.987
18 months	23.50 ± 6.75	0.324			
24 months	25.25 ± 4.27	0.923			
MPT (s)					
Pre-op	16.94 ± 6.33		16.95 ± 5.17		0.995
1 day	15.60 ± 7.34	0.106	13.96 ± 4.88	0.028*	0.397
3 days	15.04 ± 7.25	0.053	16.00 ± 5.14	0.528	0.622
1 week	15.47 ± 6.62	0.188	17.14 ± 5.50	0.895	0.377
1 month	17.55 ± 6.47	0.172	17.08 ± 5.50	0.910	0.916
3 months	16.72 ± 6.53	0.804	16.97 ± 6.98	0.924	0.862
6 months	16.71 ± 6.80	0.921	16.68 ± 0.30	0.859	0.615
12 months	17.67 ± 7.05	0.811	16.88 ± 0.12	0.874	0.213
18 months	17.14 ± 3.60	0.956			
24 months	17.55 ± 4.58	0.896			

F0 fundamental frequency, *NHR* noise-to-harmonic ratio, *F-high* highest frequency, *F-low* lowest frequency, *MPT* maximum phonation time

long-term voice impairment after thyroidectomy and should inform patients of it pre-operatively.

The most commonly affected acoustic parameters after thyroidectomy are highest frequency and frequency range. In the previous studies, acoustic parameters including highest frequency and frequency range usually declined after thyroidectomy and recovered within 3 months [1, 4, 9]. However, as shown in this study, impairment of F-high can continue for 6 or 12 months after thyroidectomy. This provides objective evidence for long-term post-thyroidectomy voice impairment. F-high in the thyroidectomy groups was significantly worse than in the control group in females. In males, F-high in the thyroidectomy cases was also worse than in the control group, but the effect did not reach statistical significance, perhaps, due to the relatively small sample size.

In a meta-analysis, F0, shimmer and MPT significantly worsened in the early period after thyroidectomy, whereas jitter and NHR remained unchanged throughout [26]. In the present study, F0 decreased only on day 1 and shimmer increased for 12 months after thyroidectomy in females, whereas neither parameter changed after surgery in males. MPT also decreased after thyroidectomy for 18 months in females.

Laryngotracheal fixation is considered an important cause of post-thyroidectomy voice impairment [1] as is endotracheal intubation [7, 13, 27]. In this study, we investigated the effect of endotracheal intubation on post-thyroidectomy voice outcomes by analyzing self-reported voice symptoms and acoustic parameters. Impairment of VSS, F-high and frequency range continued for 1–18 months after thyroidectomy, compared with only 3 days after parotidectomy. These findings suggest that the early post-operative voice impairment in the parotidectomy group is associated with endotracheal intubation, while the long-term voice impairment after thyroidectomy is caused by the thyroidectomy itself.

Interestingly, pre-operative VSS in the thyroidectomy group was significantly worse than in the control group. The standard deviation of pre-operative VSS was significantly larger than the mean value. We do not know the exact cause of this effect. However, the worse pre-operative VSS in the thyroidectomy group might be related to compressive symptoms of thyroid nodule, LPRD or psychological attitude. Actually, thyroid pathologies could cause compressions on the larynx, the respiratory and/or digestive system, and voice and swallowing complaints are common in pre-operative thyroidectomy patients [28, 29]. The incidence of LPRD was significantly higher in the thyroidectomy group and LPRD can cause hoarseness, globus symptoms, throat discomfort, and throat clearing like post-thyroidectomy syndrome. In addition, patients with thyroid nodules may generally be more concerned or anxious about their throat and voice than patients with benign parotid tumors.

This study has several limitations. First, we did not perform laryngeal electromyography (EMG) to exclude EBSLN paralysis definitively. However, videolaryngostroboscopic examination was performed in all patients before and after thyroidectomy and there was no evidence of EBSLN paralysis in any of them. Second, the voice questionnaire for VSS developed by us was not validated officially, although it was used in our previous studies [16, 17]. However, it includes questions about all five typical symptoms, and it is easy and quick to use. Third, the incidence of LPRD was significantly higher in the thyroidectomy group than the control group and LPRD could affect voice outcomes. Fourth, we did not compare voice outcomes in the case and control groups at 18 and 24 months after surgery. However, the results at post-operative 18 and 24 months in the control group would probably not have differed from pre-operative levels because VSS and all acoustic parameters returned to pre-operative levels within 1 week of surgery.

Conclusion

Self-assessed voice symptoms and effects on objective acoustic parameters can persist for up to 18 months after thyroidectomy. This possibility should be explained to patients and discussed in pre-operative counseling. Endotracheal intubation can affect voice function adversely for 1 week post-operatively.

Compliance with ethical standards

Conflict of interest The authors have no funding, financial relationships, or conflicts of interest to disclose.

Ethical approval All procedures performed in studies involving human participants were done so in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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