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ORIGINAL SCIENTIFIC REPORT

Long-Term Voice Outcomes After Robotic Thyroidectomy

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Abstract

Background The purpose of this study was to evaluate the long-term voice function after robotic thyroidectomy in comparison with conventional transcervical thyroidectomy.

Methods We prospectively evaluated the voice functions of 54 patients with thyroid nodules who underwent robotic thyroidectomy by a gasless unilateral axillary or axillo-breast approach and of 70 patients who underwent conventional thyroidectomy. Subjective voice symptom score (VSS) was evaluated in questionnaires before thyroidectomy and then at 3, 6, 12, and 24 months after surgery. Objective acoustic parameters analyzed during the same period included fundamental frequency, jitter, shimmer, noise-to-harmonic ratio, highest frequency, frequency and intensity range, and maximal phonation time.

Results At 3 months after surgery, VSS was better in the robotic group than in the conventional group. At 2 years after surgery, VSS had recovered to the pre-operative level in the robotic group, whereas it remained significantly worse at 2 years in the conventional group. The phonatory frequency range and highest frequency were significantly wider and higher, respectively, in the robotic group than the conventional group at 6, 12, and 24 months post-operatively. Within the robotic group, the frequency range and highest frequency recovered to pre-operative levels by 6 months, whereas in the conventional group they remained below the pre-operative levels at 2 years post-operatively. There were no differences in other acoustic parameters between the two groups of patients at any period.

Conclusion Up to 2 years post-operatively, robotic thyroidectomy has advantages in terms of recovery of voice symptoms and acoustic parameters over conventional thyroidectomy.

Introduction

Robotic thyroidectomy has gained popularity worldwide [1–7], offering a scar-less neck and greater cosmetic satisfaction to the patients [8], while it offers a three-dimensional magnified view, hand-tremor filtration, and multi-articulated hand-like motions to surgeons [3]. During the initial period of adopting the robotic system in thyroid surgery, studies were focused on the technical feasibility, safety, and complications of robotic thyroidectomy [3, 9, 10]. Recently, surgical completeness and functional outcomes affecting patients' quality of life have been investigated [11–13].

Voice alteration is one of the main issues affecting the quality of life of patients after thyroidectomy, and prevention of voice impairment is considered a primary goal of thyroidectomy procedures. It is well known that damage to the laryngeal nerve causes vocal cord paralysis and hoarseness. However, in many cases, voice impairment after thyroidectomy is not related to impairment of the recurrent laryngeal nerve (RLN) or external branch of the superior laryngeal nerve (EBSLN) [14–16].

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Voice change following robotic thyroidectomy has not been thoroughly evaluated, although the short-term voice outcomes after transaxillary robotic thyroidectomy have been reported recently by us and others [17–19]. In the present study, we prospectively compared long-term voice functions after robotic thyroidectomy and conventional thyroidectomy. Voice outcomes were evaluated both subjectively and objectively, with evaluation of serial changes. To our knowledge, this is the first report on long-term functional voice outcomes after robotic thyroid surgery.

Patients and methods

Patients

We prospectively enrolled a consecutive cohort of patients undergoing conventional transcervical thyroidectomy or robotic thyroidectomy using a gasless unilateral axillary (GUA) or gasless unilateral axillo-breast (GUAB) approach between March 2011 and August 2012. The inclusion criteria were patients undergoing thyroidectomy with or without central neck dissection for treatment of thyroid nodule(s) and who provided informed consent for voice evaluation. The study was approved by the Institutional Review Board of Hanyang University Hospital.

Indications for robotic thyroidectomy included benign thyroid nodules less than 5 cm in diameter, differentiated thyroid carcinoma less than 3–4 cm with small nodal metastases [20]. The exclusion criteria were identical to those in our previous study evaluating short-term voice function after robotic thyroidectomy: age <18 or >70 years, vocal fold lesions and movement disorders, evidence of injury to the RLN or EBSLN on videolaryngostroboscopic or flexible laryngoscopic examination, history of surgery or irradiation to the neck, maximal extrathyroidal extension, or distant metastasis [18]. We also excluded male patients to eliminate the bias in acoustic parameters, due to the difference of acoustic parameters between male and female patients.

Videolaryngostroboscopic examination with an Endo-STROB DX (Xion, Berlin, Germany) or fiberoptic flexible laryngoscopy was routinely performed the day before surgery and again post-operatively to evaluate paralysis of the RLN or EBSLN. We estimated the motion of the vocal folds, vocal fold mucosal lesions and wave, symmetry of arytenoid excursion, bowing, and degree of glottic closure [18].

Surgical techniques

All robotic thyroid surgeries were performed by a single experienced surgeon (K.T.). The surgical procedures for robotic thyroidectomy using GUA and GUAB approaches have been described in previous reports [2, 3, 21]. Conventional thyroidectomy was performed by the usual method, with a 5–6 cm low-collar skin incision [13]. We routinely identified and preserved the RLN during thyroidectomy. However, we did not identify the EBSLN routinely to minimize the EBSLN injury in the both groups.

Evaluation of subjective voice symptoms

Voice symptoms were evaluated subjectively and objectively the day before surgery and again at 3, 6, 12, and 24 months after the operation. Subjective voice symptom score (VSS) was evaluated using a questionnaire to estimate discomforts associated with thyroid surgery [18]. The questionnaire comprised five questions on 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 in singing? All questions were scaled as 0 (no symptom), 1 (mild), 2 (moderate), 3 (severe), or 4 (very severe) [18]. The VSS was estimated as the sum of the scores for the five questions.

Objective acoustic parameters and aerodynamic study

Acoustic analysis and aerodynamic measurements were made using voice range profile (VRP) analysis and the multidimensional voice program (MDVP) with Computerized Speech Lab software (MDVP model 4150B, KayPENTAX, Lincoln Park, NJ, USA). The acoustic analysis was recorded by an experienced speech-language pathologist (B.R.Y).

For VRP analysis, patient was instructed to phonate the sustained vowel/a/as loudly and as softly as possible from the lowest frequency to the highest. The lowest frequency (F-low, Hz), highest frequency (F-high, Hz), frequency range (Hz), and intensity range (dB) were measured. For MDVP analysis, the patient produced a sustained vowel/a/at the most comfortable pitch/amplitude for at least 5 s. The parameters measured were noise-to-harmonic ratio (NHR), jitter (%), shimmer (%), and fundamental frequency (F0, Hz). For the aerodynamic study, maximal phonation time (MPT, seconds) was measured by asking the patient to produce the vowel/a/for as long as possible. This was repeated three times and the longest measurement was selected.

Statistical analysis

Student's *t* test, Chi squared test, and Fischer's exact test were used to compare factors between the robotic and conventional thyroidectomy groups of patients. Paired *t* tests were used to compare pre-operative and post-operative variables. SPSS version 18.0 software (SPSS

Chicago, IL, USA) was used for all statistical analyses. A value of $p < 0.05$ indicated statistical significance.

Results

Clinicopathological characteristics

During the study period, an overall total of 321 patients with thyroid nodules underwent robotic (97 cases) or conventional (224 cases) thyroidectomy. Of these, 165 patients were excluded from the present study due to exclusion criteria. Two further patients who underwent robotic thyroidectomy and four who underwent conventional thyroidectomy were observed to have transient RLN paralysis after operation and they were excluded from the study. Among the 150 female patients, 124 (82.6 %) successfully completed all of the acoustic analysis. Finally, the robotic group comprised 54 patients, and the conventional group comprised 70 patients. The clinical and pathological data of the both groups are summarized in Table 1. The mean age of the robotic group was lower, and operative time was longer than the conventional group.

Analysis of subjective voice symptoms

A comparison of VSS in the two groups of patients is shown in Table 2. At 3 months after surgery, the VSS was significantly lower (corresponding to less voice impairment) in the robotic group than in the conventional group ($p = 0.025$); however, no difference between the groups was observed at 6 months, 1 year, and 2 years post-operatively ($p = 0.203$, 0.536, and 0.785, respectively). Within the robotic group, the VSS at 3 months was significantly higher than the pre-operative VSS, but by 2 years there was no significant difference from the pre-operative level. In contrast, the VSS at 2 years in the conventional group remained significantly above the pre-operative VSS.

Measurement of objective acoustic and aerodynamic parameters

The results of measurement of aerodynamic and acoustic parameters in the two groups of patients are listed in Table 3. The F-high and the frequency range were higher and wider, respectively, in the robotic group than in the conventional group at 6 months, 1 year, and 2 years after surgery. Within the robotic group, the F-high and the frequency range recovered to pre-operative levels by 6 months after surgery. In contrast, in the conventional group, these parameters had not recovered to pre-operative levels at 2 years. No differences were found between the two groups regarding intensity range, F0, jitter, shimmer, NHR, and MPT.

Discussion

Thyroidectomy causes post-thyroidectomy syndrome, including voice impairment and discomfort during swallowing. Injury to the RLN is the main cause of functional

Table 1 Clinical and pathological characteristics of the robotic and conventional thyroidectomy groups

Characteristics	Robotic surgery ($n = 54$)	Conventional surgery ($n = 70$)	p value
Age	41.93 ± 8.71	54.04 ± 11.53	<0.001
BMI (Kg/m^2)	23.36 ± 3.70	24.03 ± 2.79	0.257
Vocal risk factors			
Smoking	2/54 (3.7 %)	3/70 (4.3 %)	0.622
Drinking	12/54 (22.2 %)	12/70 (17.1 %)	0.500
LPR	29/54 (53.7 %)	34/70 (48.6 %)	0.592
Tumor			
Nodule size (mm)	11.20 ± 8.37	12.50 ± 13.72	0.540
Pathology type			0.146
Benign	3/54 (5.6 %)	10/70 (14.3 %)	
Malignancy	51/54 (94.4 %)	60/70 (85.7 %)	
Type of thyroidectomy			0.455
Total thyroidectomy	44/54 (81.5 %)	61/70 (87.1 %)	
Lobectomy	10/54 (18.5 %)	9/70 (12.9 %)	
CND n (%)	50/54 (92.6 %)	62/70 (88.6 %)	0.549
Operative time (min)	167.4 ± 40.8	149.3 ± 39.1	0.016

LPR laryngopharyngeal reflux, *BMI* body mass index, *CND* central neck dissection

Table 2 Comparison of pre- and post-operative voice symptom scores in the robotic and conventional thyroidectomy groups

VSS	Robotic surgery ($n = 54$, A)	p value versus pre-op	Conventional surgery ($n = 70$, B)	p value versus pre-op	p value A versus B
Pre-operative	2.07 ± 3.18		1.91 ± 3.09		0.782
3 months, post-op	3.79 ± 3.66	0.047*	5.77 ± 5.19	<0.001*	0.025*
6 months, post-op	3.76 ± 3.72	0.012*	4.78 ± 4.59	<0.001*	0.203
1 year, post-op	3.84 ± 3.71	0.007*	3.39 ± 3.45	0.012*	0.536
2 years, post-op	3.25 ± 4.01	0.070	3.46 ± 3.56	0.007*	0.785

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

* p value <0.05

voice impairment after thyroidectomy. The prevalence of RLN paralysis after conventional thyroidectomy is 0.77–7.2 % [22–24]. In earlier studies, no difference was reported in the incidence of RLN injury between patients who underwent robotic and conventional thyroidectomy [3, 21, 25]. Nonetheless, impairment of vocal or throat functions occur in 15–84 % of patients who undergo thyroidectomy, even without definite injury of the laryngeal nerves [26]. These impairments may remain for a long period of time after thyroidectomy.

Studies that have evaluated the long-term voice outcomes after thyroidectomy were all confined to conventional thyroidectomy [15, 26, 27]. One prospective observational study evaluating long-term voice functions after conventional thyroidectomy showed that vocal frequency range was narrower, perceptual voice remained rougher, and subjective parameters of vocal symptoms remained worse than during the pre-operative period, even up to 12 months after thyroidectomy [26]. In another study with a mean follow-up period of 4 years, voice change persisted in 28 % of the patients in the absence of definite laryngeal nerve injury [15]. At present, there is no consensus on the definition of a long-term post-operative period in evaluating post-thyroidectomy syndrome. In one study on assessment of post-thyroidectomy voice function, 1–2 weeks after thyroidectomy was considered the early post-operative and 3 months the late post-operative period [28]. However, in the present study, we considered 1 year or more after the surgery as long-term, in accordance with other reports [13, 27].

Previously, we have reported short-term results for voice and swallowing function following robotic thyroidectomy [18]. In our previous study, subjective voice impairment following robotic thyroidectomy was less than with conventional thyroidectomy at 1 day, 1 month, and 3 months post-operatively. In addition, measurements of acoustic parameters gave better results for vocal frequency range and F-high in the robotic group than in the conventional group at 3 months after surgery. These results were reproduced in the present study, even though the patient groups differed and surgery took place later than in the earlier study [18]. In the present study, we analyzed the extended long-term serial voice outcomes up to 2 years post-operatively. Long-term subjective and objective outcomes were significantly better in the robotic group than in the conventional group. At 3 months post-operatively, subjective voice functions were better in the robotic group and voice symptoms had recovered to the pre-operative level by 2 years, whereas voice symptoms had not recovered by 2 years in the conventional group. However, the difference in recovery of VSS to pre-operative levels in the two groups must be interpreted with caution, since the VSS at 2 years was not significantly different between the two groups.

In the robotic group, the F-high was higher and the frequency range was wider at 6 months, 1 year, and 2 years after surgery than in the conventional group. The F-high and the frequency range recovered to pre-operative levels by 6 months in the robotic group, whereas those parameters had not recovered by 2 years post-operatively in the conventional group. We additionally compared the risk factors between patients with VSS or F-high (Hz) that were >10 % increase than pre-operative baseline at 2 years (56 patients) and patients with VSS and F-high ≤10 % increase (68 patients). The analyzed risk factors were robotic versus conventional surgery, total thyroidectomy versus lobectomy, central neck dissection, age ≤30 versus 30 <age ≤50 versus age >50, laryngopharyngeal reflux, smoking, alcohol, and body mass index. In univariate analysis, age ($p = 0.039$) and conventional thyroidectomy ($p = 0.011$) were risk factors for worsening VSS/acoustic parameter. In multivariate logistic regression analysis, only conventional thyroidectomy was an independent risk factor (OR = 2.298, 95 % confidence interval 1.029–5.132, $p = 0.042$).

The proposed factors that affect voice symptoms following thyroidectomy in cases without apparent laryngeal nerve injury are delayed healing, surgical trauma of the strap muscles or cricothyroid muscle, laryngotracheal fixation, subclinical hematoma, laryngeal edema caused by

Table 3 Comparison of pre- and post-operative aerodynamic and acoustic parameters in the robotic and conventional thyroidectomy groups

Parameters	Robotic surgery ($n = 54$, A)	p value versus pre-op	Conventional surgery ($n = 70$, B)	p value versus pre-op	p value A versus B
F-high (Hz)					
Pre-op	499.85 ± 167.51		505.82 ± 213.82		0.870
3 months	447.15 ± 94.51	0.016*	425.84 ± 129.74	0.004*	0.317
6 months	490.05 ± 138.07	0.736	434.53 ± 140.67	0.003*	0.034*
1 year	491.79 ± 120.57	0.673	425.66 ± 126.77	0.003*	0.009*
2 years	472.23 ± 120.75	0.231	428.64 ± 108.74	0.009*	0.039*
F-low (Hz)					
Pre-op	140.28 ± 31.96		137.72 ± 28.00		0.645
3 months	138.19 ± 27.59	0.744	137.16 ± 25.86	0.570	0.838
6 months	143.93 ± 27.00	0.275	141.48 ± 23.39	0.329	0.606
1 year	144.47 ± 22.60	0.204	140.59 ± 19.18	0.500	0.351
2 years	144.48 ± 21.58	0.341	144.61 ± 20.35	0.094	0.973
Frequency range (Hz)					
Pre-op	359.57 ± 181.01		368.11 ± 220.02		0.823
3 months	308.95 ± 99.75	0.025*	288.68 ± 129.04	0.006*	0.363
6 months	346.12 ± 140.29	0.603	293.05 ± 141.62	0.002*	0.045*
1 year	347.33 ± 128.34	0.524	286.04 ± 125.01	0.003*	0.017*
2 years	327.76 ± 128.86	0.176	284.03 ± 107.17	0.005*	0.043*
Intensity range (dB)					
Pre-op	24.10 ± 6.27		23.53 ± 7.87		0.680
3 months	23.61 ± 9.56	0.161	23.19 ± 8.30	0.941	0.806
6 months	23.73 ± 9.76	0.413	22.09 ± 6.01	0.326	0.264
1 year	23.24 ± 4.93	0.214	21.75 ± 5.48	0.267	0.158
2 years	21.77 ± 6.31	0.124	21.59 ± 7.10	0.142	0.882
F0 (Hz)					
Pre-op	200.4 ± 25.3		193.5 ± 15.3		0.263
3 months	192.8 ± 27.1	0.220	188.5 ± 22.9	0.223	0.206
6 months	198.6 ± 27.3	0.771	188.5 ± 22.8	0.192	0.168
1 year	197.8 ± 21.1	0.295	184.3 ± 22.1	0.319	0.119
2 years	197.1 ± 17.6	0.291	188.0 ± 20.6	0.242	0.131
Jitter (%)					
Pre-op	1.39 ± 1.09		1.23 ± 0.92		0.378
3 months	1.15 ± 1.02	0.149	1.31 ± 1.14	0.807	0.457
6 months	1.45 ± 1.62	0.860	1.31 ± 1.02	0.795	0.567
1 year	1.12 ± 0.71	0.061	1.27 ± 0.98	0.747	0.418
2 years	1.18 ± 0.84	0.232	1.27 ± 0.83	0.832	0.541
Shimmer (%)					
Pre-op	4.23 ± 3.12		3.97 ± 2.41		0.602
3 months	3.69 ± 2.24	0.198	4.15 ± 3.37	0.760	0.405
6 months	4.84 ± 5.40	0.531	4.39 ± 3.69	0.502	0.594
1 year	3.66 ± 1.40	0.187	3.84 ± 2.03	0.402	0.605
2 years	3.57 ± 1.29	0.157	4.02 ± 2.15	0.967	0.177
NHR (dB)					
Pre-op	0.15 ± 0.06		0.15 ± 0.04		0.985
3 months	0.13 ± 0.03	0.634	0.16 ± 0.12	0.913	0.171
6 months	0.14 ± 0.05	0.375	0.14 ± 0.04	0.246	0.599
1 year	0.13 ± 0.02	0.727	0.14 ± 0.03	0.376	0.226
2 years	0.13 ± 0.02	0.460	0.14 ± 0.04	0.805	0.165

Table 3 continued

Parameters	Robotic surgery ($n = 54$, A)	p value versus pre-op	Conventional surgery ($n = 70$, B)	p value versus pre-op	p value A versus B
MPT (Sec)					
Pre-op	12.43 ± 5.23		11.85 ± 4.92		0.534
3 months	12.35 ± 5.07	0.220	11.97 ± 5.62	0.903	0.718
6 months	12.27 ± 5.24	0.740	12.10 ± 4.89	0.711	0.857
1 year	12.54 ± 4.11	0.976	13.06 ± 5.56	0.105	0.598
2 years	11.73 ± 4.27	0.279	12.06 ± 5.03	0.665	0.707

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

* p value <0.05

disturbance of venous or lymphatic drainages, local neck pain, vocal fold changes, and injury of the arytenoid caused by orotracheal intubation [14, 18, 28–32]. Acoustic and aerodynamic parameters that are influenced by thyroid surgery are decreases in the MPT, fundamental frequency, F-high, and frequency range, and increases in jitter, shimmer, and the NHR [29, 31]. After thyroidectomy, subjective voice symptoms without laryngeal nerve injury are more common than objective acoustic abnormalities [13, 33]. The discordance between objective parameter abnormalities and subjective vocal symptoms is found in approximately one-third of patients who undergo thyroidectomy [28, 34].

Laryngotracheal fixation and altered strap muscle or cricothyroid muscle movement can be the major causes of voice change after thyroidectomy [35]. Adhesion of the strap muscle to the larynx and trachea is caused by scar formation after thyroidectomy, and results in defective pitch control during phonation [14, 18]. Strap muscle movement effects laryngotracheal movement, and damage to the muscles by retraction and adhesion is associated with a reduction in fundamental frequency and range [36, 37]. The impairment of cricothyroid muscle movement is usually related to paralysis of the EBSLN or surgical trauma of the muscle, and it results in lowered pitch, loss of upper range and projection, vocal fatigue, and breathiness [14]. Typical cricothyroid dysfunction can be observed by a shift of the posterior commissure toward the affected side, weak tension, and shortened vocal fold on videostroboscopic examination [14].

We assume that the better long-term results for voice symptoms and vocal pitch after robotic thyroidectomy compared with conventional thyroidectomy might be mainly due to reduced adhesion of the skin flap, the strap muscles and the laryngotracheal structure, and fewer traumas to the strap muscles [18]. Robotic transaxillary approach avoids the need to make an incision in the skin of the neck, and permits limited dissection of strap muscles and fine dissection of the thyroid gland; therefore, laryngotracheal fixation is reduced. The better results for phonatory pitch after robotic surgery may be the result of reduced injury to the EBSLN in comparison with conventional thyroidectomy. Robotic procedures allow fine dissection in a ×10 magnified view, and provide a better view of the small branches of neurovascular structures compared with direct vision, or viewing with a surgical loupe.

The present study has several limitations. First, the different distribution of age between the two groups might have affected the results. Second, electromyography to confirm EBSLN injury was not used in this study, because of the reluctance of patients to undergo an invasive procedure, although we excluded cases with definite EBSLN injury on videostroboscopy examination [33, 38]. Third, the study lacks randomization of the robotic or conventional thyroidectomy techniques. Randomized clinical trial of robotic thyroidectomy is difficult because robotic thyroidectomy is not covered by the national health insurance system in our country and costs 4–5 times more than conventional thyroidectomy. A further study with randomization and a larger patient pool may minimize these limitations. Fourth, VSS questionnaire is not validated. However, VSS questionnaire has been used in the previous study, and was effective in evaluating specific voice symptoms related with thyroidectomy, and showed high compliance due its conciseness [18].

Conclusion

In the long-term post-operative period of up to 2 years after surgery, robotic thyroidectomy via a GUA/GUAB approach has advantages in recovery of subjective voice symptoms and better acoustic parameters of frequency range and highest frequency than with conventional thyroidectomy.

Compliance with ethical standards

Conflict of interest Chang Myeon Song, Bo Ram Yun, Yong Bae Ji, Eui Suk Sung, Kyung Rae Kim, and Kyung Tae have no conflicts of interest or financial ties to disclose.

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