Perceptual and Acoustic Analysis of Voice in Individuals with Total Thyroidectomy: Pre-Post Surgery Comparison

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Abstract Total thyroidectomy (TT) is a surgical procedure which involves complete removal of the thyroid gland, usually done in massive goitre compressing the trachea and esophagus, hyperthyroidism and carcinoma of thyroid gland. Laryngeal nerve damage is one of the most feared complications after TT which can lead to permanent changes in voice. Recent research suggests the occurrence of voice changes without any visible laryngeal nerve damage. Present study attempts to compare the pre and post-operative voice characteristics in individuals with total thyroidectomy without any laryngeal nerve damage. A total of 27 subjects (21 females and 6 males) who underwent total thyroidectomy participated in the study. Their recorded phonation of vowel/a/was subjected to two types of analyses viz. Perceptual analysis (using CAPE-V rating scale) and Acoustic analysis (using Multi Dimensional Voice Profile). Results of perceptual analysis indicated slight decrease in overall severity, roughness and breathiness and a slight increase in straininess, in only males. Acoustic analysis findings supported perceptual results with minimal changes in most of the parameters. The results suggest that after total thyroidectomy, in the absence of visible laryngeal nerve damage, functional changes in voice are minimal and temporary in nature. This study provides an insight to Otolaryngologists and Speech Language Pathologists about the voice characteristics in individuals with thyroidectomy, enabling them to formulate appropriate therapy protocol for this population. It further attempts to sensitize surgeons and physicians on the

need for referral of this population to Speech Language Pathologist in the event of dysphonia.

Keywords Total thyroidectomy · Perceptual analysis · Acoustical analysis · Laryngeal nerve damage

Total thyroidectomy (TT) is one of the surgical options for individuals with thyroid problems. This procedure involves complete removal of the thyroid gland and is usually done in cases of massive goitre compressing the trachea and esophagus, in cases of hyperthyroidism or carcinoma of thyroid gland. The intricate and delicate anatomic structures for voice production lie in close proximity to thyroid gland and are vulnerable during operations on the thyroid.

Complications subsequent to TT may range from minor (post operative seroma) to major ones (injury to laryngeal nerve). Injury to laryngeal nerve can be either due to injury to external branch of superior laryngeal nerve (SLN) or recurrent laryngeal nerve (RLN). Reported risk of SLN injury varies from 0.3 to 13% [1]. The estimated frequency of RLN injury fluctuates between 5 and 10%, of which 5% are temporary and between 0.8 and 1.7% are permanent [2].

Voice changes due to SLN and RLN injury may also be associated with laryngotracheal fixation with impairment of vertical movement or by temporary malfunction of the strap muscles after surgery. Typical voice symptoms after surgery are vocal fatigue during phonation and with high pitch and singing voice [3]. People with injury to SLN mostly do not notice any vocal change. On occasions, the subject may present with a complaint of mild hoarseness or decreased vocal stamina. However, for a singer or person who professionally relies on his or her voice, paralysis of the SLN may be threatening his or her career. Most

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damaging consequence in a singer is the loss of upper register, vital for his profession.

Injury to RLN can lead to unilateral vocal cord paralysis, where individuals may complain of hoarseness, vocal fatigue, decreased pitch and loudness range [4]. Laryngeal nerve preservation during TT is hence imperative for sustaining voice function. However, recent research suggests that not all postoperative voice disturbances are related to nerve injury. The voice changes can also occur without RLN or SLN damage.

Observations made by recent researchers have demonstrated that, after TT surgery in the absence of visible laryngeal nerve damage (RLN or SLN); voice parameters may still be minimally affected and could be temporary in nature. Several causes such as orotracheal intubation [5]; modification of the vascular supply and venous drainage of the larynx [6]; cricothyroid dysfunction [5–7]; laryngotracheal fixation with impairment of vertical movement [3, 5, 6, 8]; strap muscle malfunction due to denervation or direct injury (section); local pain in neck; and/or a psychological reaction to the postoperative situation have been postulated. However, there is inconsistency in the cited results. For example, results of Stojadinovic et al. [9] showed no significant changes between pre- and post operative voice parameters.

Another important issue is the type of outcome measures used. Most of the previous studies have used subjective voice assessment with only a few reports by multidimensional acoustic analysis. Through straightforward and reliable, multidimensional acoustic analysis is more robust and helps in identification of patients with significant postoperative voice dysfunction. Such clinical tools with high predictive value, would contribute to improved resource utilization and identification of the small percentage of post thyroidectomy patients who could benefit from early speech pathology referral and testing. Hence, the purpose of the present study is to document the voice changes in individuals who undergo thyroidectomy through perceptual and acoustical measures as complementing each other.

Method

Participants

A total of 27 individuals who underwent total thyroidectomy participated in the present study. The mean age of males was 50 years (SD 13.68) and of females, 48.57 years (SD 9.67). Participants' consent was obtained prior to the start of the study. The inclusion criteria for the participants were as follows: Individuals posted for total thyroidectomy as planned by the surgeons with no visible laryngeal

pathology on videostrobolaryngoscopy (both before and after surgery), and no previous history of laryngeal surgery or voice problems.

Participants were screened for hearing loss, neurological and speech and language problems from their medical file. Out of 27 participants, 21 participants were females (77%) and, 6 males (22%). Fourteen participants (51.85%) were diagnosed to have multinodular Goiter, 6 (22.22%) had Papillary carcinoma of thyroid, 3 (11.11%) had Follicular carcinoma of thyroid, 2 (7.41%) had medullary carcinoma of thyroid, and 2 (7.41%) had goitre and medullary carcinoma of thyroid. The mean pre operative duration was 2.07 days (SD 1.2 days) and the mean post operative duration was 1.25 months.

Speech Material

Phonation of vowel/a/was recorded from each individual both before and after surgery. Phonation of/a/was taken up as it has least vocal tract constriction. Familiarization of the task was done by demonstration and trials. The participants were instructed to carry out the tasks in an upright position. Participants were asked to phonate vowel/a/thrice at their comfortable habitual pitch for at least 5 s. Samples were directly recorded onto computer using condenser microphone of CSL software (Kay Pentax, USA). These samples were subjected to two types of analyses, Analysis I, a perceptual analysis using CAPE-V rating scale and analysis II, an acoustic analysis.

Analysis I: Perceptual analysis: Perceptual analysis was done using Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) rating scale. The CAPE-V was developed from a consensus meeting sponsored by the American Speech-Language-Hearing Association's (ASHA) Division 3: Voice and Voice Disorders, and the Department of Communication Science and Disorders, University of Pittsburgh, held in Pittsburgh on June 10–11, 2002. The Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) was developed as a tool for clinical auditory-perceptual assessment of voice. Its primary purpose is to describe the severity of auditory-perceptual attributes of a voice problem, in a way that can be communicated among clinicians [10]. The attributes are: *Overall Severity* (Global, integrated impression of voice deviance), *Roughness* (Perceived irregularity in the voicing source), *Breathiness* (Audible air escape in the voice), *Strain* (Perception of excessive vocal effort (hyperfunction)), *Pitch* (Perceptual correlate of fundamental frequency). This scale rates whether the individual's pitch deviates from normal for that person's gender, age, and referent culture and *Loudness* (Perceptual correlate of sound intensity). This scale indicates whether the individual's loudness deviates from normal for that person's gender, age, and referent

culture. The direction of deviance (soft or loud) should be indicated in the blank provided above the scale.

The CAPE-V displays each attribute accompanied by a 100 mm line forming a visual analog scale (VAS). The clinician indicates the degree of perceived deviance from normal for each parameter on this scale, using a tic mark. For each dimension, scalar extremes are unlabeled. Judgments may be assisted by referring to general regions indicated below each scale on the CAPE-V: “MI” refers to “mildly deviant,” “MO” refers to “moderately deviant,” and “SE” refers to “severely deviant.” A key issue is that the regions indicate *gradations* in severity, rather than discrete points. The clinician may place tick marks at any location along the line. Ratings are based on the clinician’s direct observations of the patient’s performance during the evaluation, rather than patient report or other sources.

To the right of each scale are two letters, “C” and “I.” “C” represents “consistent” and “I” represents “intermittent” presence of a particular voice attribute. The rater circles the letter that best describes the consistency of the judged parameter. A judgment of “consistent” indicates that the attribute was continuously present throughout the tasks. A judgment of “intermittent” indicates that the attribute occurred inconsistently within *or* across tasks. For example, an individual may consistently exhibit a strained voice quality across all tasks, which include sustained vowels and speech. In this case, the rater would circle “C” to the right of the strain scale. In contrast, another individual might exhibit consistent strain during vowel production, but intermittent strain during one or more connected speech task. In this case, the rater would circle “I” to the right of the strain scale [10].

Procedure

The obtained samples were normalized using adobe audition software by group normalization for phonation of pre and post surgery and saved separately. A total of 162 samples (81 samples each in pre- and post-surgical phonation) were presented to three experienced judges (trained SLPs in perceptual analysis of voice using CAPE-V) separately for the perceptual rating. The samples were randomly numbered and presented separately to the judges. Inter-stimulus interval was 10 s, so that judges get adequate time to rate the samples. Intra judge reliability was obtained by randomly presenting 30% of the samples. Inter judge agreement was obtained by comparing the scores rated by the three clinicians. The intra judge reliability was 90% and inter judge agreement was 85%, indicating high correlation between two ratings.

Analysis II: Acoustic Analysis

Acoustic analysis was done using MDVP software (Kay Pentax, USA). For the analysis of phonation, the mid steady state portion of 3 s duration was selected and analyzed. Following parameters were documented and compared in the study.

Frequency related parameters: Mean Fundamental Frequency (MF0), Highest Fundamental Frequency (Fhi), Lowest Fundamental Frequency (Flo), Standard Deviation of F0 (STD),

Perturbation related parameters: Absolute Jitter (Jitta), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Smoothed Pitch Perturbation Quotient (sPPQ), Shimmer in dB (ShdB), Shimmer Percent (Shim), Amplitude Perturbation Quotient (APQ), Smoothed Amplitude Perturbation Quotient (sAPQ)

Noise and voice break related parameters: Noise to Harmonic Ratio (NHR), Voice Turbulence Index (VTI), Soft Phonation Index (SPI), Degree of Voice Breaks (DVB), and Degree of Voiceless (DUV). [Appendix](#) gives compendium of the definitions of different acoustic parameters used in the present study.

Statistical Analysis

To determine significant differences if any between the pre and post operative perceptual parameters, descriptive statistics of frequency distribution was used. For the analysis of acoustic parameters, non-parametric Wilcoxon Signed rank test of 2-related comparison was used.

Results

Perceptual Analysis

Table 1 shows the comparative median and interquartile range values in pre- and post-surgery conditions across perceptual parameters. It is evident from the table that, median scores did not change significantly between the two conditions. For males, from pre- to post-surgery, median scores for overall severity, roughness and breathiness, decreased slightly, whereas for the strainness, scores increased slightly; pitch and loudness scores remained the same. On the other hand, in females, for all perceptual parameters, scores remained the same (normal voice quality) in both pre and post operative conditions. Further, there was not much variation in inter quartile range between the two conditions.

Table 1 Comparison of Median and interquartile range values in pre- and post-therapy condition across perceptual parameters of phonational voice in males

Parameters	Gender	Pre			Post		
		Median	Interquartile range		Median	Interquartile range	
Overall severity	Males	39.50	0.00	70.75	22.00	0.00	45.25
	Females	0.00	0.00	21.25	0.00	0.00	37.00
Roughness	Males	38.50	0.00	69.25	21.50	0.00	44.75
	Females	0.00	0.00	10.00	0.00	0.00	34.00
Breathiness	Males	16.50	0.00	35.25	9.50	0.00	33.25
	Females	0.00	0.00	27.25	0.00	0.00	24.75
Strain	Males	4.50	0.00	43.75	9.50	0.00	25.00
	Females	0.00	0.00	10.00	0.00	0.00	33.00
Pitch	Males	0.00	0.00	29.75	0.00	0.00	21.25
	Females	0.00	0.00	0.00	0.00	0.00	20.00
Loudness	Males	0.00	0.00	29.75	0.00	0.00	21.25
	Females	0.00	0.00	0.00	0.00	0.00	11.25

Acoustic Analysis

1. Acoustic analysis of fundamental frequency related parameters: Table 2 shows the mean, median, interquartile range and '*P*' values in pre- and post-surgery conditions for fundamental frequency related parameters. Results indicated that for all parameters, in both males and females, median scores did not change from pre- to post-surgery. Further, results of Wilcoxon signed rank test showed statistically no significant difference ($P > 0.05$) from pre- to post operative condition.
2. Acoustic analysis of perturbation related parameters: Table 3 shows the mean, median, interquartile range and '*P*' values in pre- and post-surgery condition for perturbation related parameters. When compared to pre-surgery, there was little change in post surgery mean scores for most of the parameters except for Jitta (females), shimmer % and sAPQ (in males) parameters. The mean values of Jitta, shimmer % and sAPQ were slightly higher in post-surgery condition. However, the results of Wilcoxon signed rank test showed statistically no significant difference ($P > 0.05$) from pre- to post operative condition for all parameters.
3. Acoustic analysis of noise and voice break related parameters: Table 4 shows the mean, median, interquartile range, and '*P*' values in pre- and post-surgery condition for noise and voice break related parameters. Results indicated slight increase in the mean scores only for degree of voice breaks (DVB) and degree of unvoiced (DUV) from pre- to post operative conditions. However, results of Wilcoxon signed rank test showed statistically no significant difference ($P > 0.05$) from pre- to post operative condition.

Table 2 Median, interquartile range, '*P*' value and effect size values in pre- and post-therapy condition for frequency related parameters

Para-meters	Gender	Pre				Post				<i>P</i> -value
		Mean (SD)	Median	Inter quartile range		Mean (SD)	Median	Inter quartile range		
				25th	75th			25th	75th	
MFo	Males	120.01 (8.99)	122.68	114.58	126.24	117.45 (15.00)	118.27	108.67	129.66	0.893
	Females	184.99 (38.29)	188.44	158.40	216.00	186.05 (26.93)	183.50	169.25	208.17	0.394
Fhi	Males	136.07 (25.07)	128.26	119.34	152.00	133.90 (10.91)	130.61	126.37	143.61	0.686
	Females	208.80 (44.27)	204.31	170.84	247.61	213.11 (41.89)	206.70	184.03	227.26	0.709
Flo	Males	111.80 (11.36)	115.75	97.90	121.54	105.17 (20.93)	108.39	92.79	119.16	0.893
	Females	166.61 (45.15)	178.71	146.62	202.25	167.85 (33.43)	172.04	159.19	195.64	0.881
STD	Males	3.23 (4.39)	1.52	1.01	4.75	3.89 (3.36)	2.85	2.06	5.38	0.345
	Females	4.56 (3.91)	3.30	2.52	4.85	5.34 (5.03)	3.13	2.25	5.72	0.664

MFo Mean fundamental frequency, Fhi highest fundamental frequency, Flo Lowest fundamental frequency, STD standard deviation of fundamental frequency

Table 3 Median, interquartile range, 'P' value and effect size values in pre- and post-therapy condition for perturbation related parameters

Para-meters	Gender	Pre				Post				<i>P</i> -value
		Mean (SD)	Median	Inter quartile range		Mean (SD)	Median	Inter quartile range		
				25th	75th			25th	75th	
Jitta	Males	200.37 (337.60)	75.88	24.48	308.68	211.34 (231.73)	180.13	23.71	320.34	0.686
	Females	86.83 (117.52)	42.65	27.09	89.33	103.68 (149.52)	41.59	17.79	104.21	0.903
Jitt	Males	2.41 (4.10)	0.94	0.30	3.61	2.22 (2.07)	2.21	0.29	3.28	0.686
	Females	1.32 (1.43)	0.91	0.55	1.41	1.74 (2.36)	0.76	0.34	1.92	0.903
RAP	Males	1.46 (2.51)	0.55	0.17	2.20	1.27 (1.11)	1.35	0.17	1.87	0.686
	Females	0.77 (0.79)	0.54	0.33	0.85	1.01 (1.36)	0.44	0.20	1.15	0.931
PPQ	Males	1.39 (2.36)	0.56	0.18	2.08	1.33 (1.36)	1.13	0.17	2.08	0.686
	Females	0.81 (0.90)	0.56	0.33	0.85	1.07 (1.47)	0.52	0.20	1.14	0.876
sPPQ	Males	1.36 (1.59)	0.95	0.37	1.90	1.88 (1.99)	1.54	0.43	2.68	0.345
	Females	1.28 (1.35)	0.97	0.59	1.12	1.20 (1.31)	0.72	0.50	1.32	.852
ShdB	Males	0.51 (0.42)	0.30	0.27	0.77	0.82 (0.63)	0.63	0.25	1.54	0.686
	Females	0.35 (0.27)	0.28	0.20	0.36	0.37 (0.28)	0.27	0.20	0.41	0.702
Shim	Males	5.73 (4.50)	3.44	3.17	8.68	9.11 (7.02)	7.04	2.95	16.67	0.686
	Females	3.87 (2.91)	3.17	2.27	3.76	3.96 (2.76)	2.92	2.23	4.77	0.664
APQ	Males	4.19 (2.65)	2.90	2.43	6.39	6.33 (4.47)	5.35	2.12	11.69	.686
	Females	2.84 (2.03)	2.30	1.73	3.18	3.04 (2.26)	2.17	1.67	3.45	0.689
sAPQ	Males	6.43 (2.97)	4.98	4.65	8.45	10.02 (5.00)	11.28	4.55	14.10	0.225
	Females	5.10 (2.75)	4.36	3.42	5.70	5.08 (2.61)	4.17	3.74	5.50	0.778

Jitta absolute jitter, *Jitt* Jitter percent, *RAP* relative amplitude perturbation, *PPQ* pitch perturbation quotient, *sPPQ* smoothened pitch perturbation quotient, *ShdB* Shimmer in dB, *Shim* shimmer in percent, *APQ* amplitude perturbation quotient, *sAPQ* smoothened amplitude perturbation quotient

Table 4 Median, interquartile range, 'P' value and effect size values in pre- and post-therapy condition for noise and voice break related parameters

Para-meters	Gender	Pre				Post				P-value
		Mean (SD)	Median	Inter quartile range		Mean (SD)	Median	Inter quartile range		
				25th	75th			25th	75th	
NHR	Males	0.193 (0.111)	0.156	0.135	0.240	0.195 (0.065)	0.164	0.146	0.262	0.893
	Females	0.147 (0.062)	0.135	0.121	0.158	0.152 (.062)	0.134	0.121	0.147	0.717
VTI	Males	0.06 (.05)	0.05	0.02	0.10	0.06 (0.03)	0.05	0.04	0.09	0.893
	Females	0.04 (0.03)	0.04	0.03	0.05	0.05 (0.03)	0.04	0.03	0.05	0.955
SPI	Males	17.16 (14.21)	11.89	8.44	24.47	16.97 (9.69)	14.46	9.01	27.58	0.893
	Females	15.97 (9.09)	15.54	9.72	19.63	17.31 (8.64)	15.83	10.63	23.94	0.391
DVB	Males	0.37 (0.90)	0.00	0.00	0.55	2.69 (6.58)	0.00	0.00	4.03	0.655
	Females	0.24 (0.1)	0.00	0.00	0.00	1.26 (5.63)	0.00	0.00	0.00	0.715
DUV	Males	11.23 (24.80)	0.88	0.00	18.34	18.53 (30.46)	0.16	0.00	47.09	0.715
	Females	4.10 (13.13)	0.00	0.00	0.20	7.51 (16.26)	0.00	0.00	3.22	0.515

NHR Noise to harmonics ratio, *VTI* voice turbulence index, *SPI* soft phonation index, *DVB* degree of voice breaks, *DUV* degree of unvoiced segments

Discussion

The present study was conducted to determine the changes if any, in voice of individuals who underwent thyroidectomy without any visible laryngeal nerve damage. The

results of the present study indicated that, in the absence of visible laryngeal nerve paralysis, thyroidectomy had little effect on voice parameters. The results of past research have suggested that the preservation of RLN is highly important in thyroid surgery, as it innervates all of the

intrinsic muscles of the larynx except the cricothyroid muscle, which is innervated by the external branch of the superior laryngeal nerve. Operative trauma to the RLN—the most feared complication of thyroidectomy—occurs in 2–13% of patients, which in turn could lead to vocal cord paralysis and hoarseness of voice. Further, changes in voice characteristics have also been documented in the absence of laryngeal nerve injury with as many as 30% of the patients suffering from early and 14% suffering from lasting functional voice changes [1, 7, 11, 12]. This has been attributed to other mechanical factors (strap muscle division or laryngotracheal fixation, surgical trauma to the cricothyroid muscle or cricoarytenoid joint, endotracheal intubation, etc.) to postoperative dysphonia [3]. In the present study, post-surgery voice recording was done after 1-month and during this time, none of the patients complained of any voice problems. The absence of any visible voice changes after 1 month of surgery suggests that the functional changes in voice noticed in conditions without any damage of laryngeal nerve are temporary and restricted to only selected perceptual domains such as a slight decrease in breathiness and roughness and a slight increase in strainness.

The slight improvement in post surgery scores for overall severity, roughness and breathiness in males supports previous claims of Watt-Boolsen et al. [13]. According to these authors, possible pre-operative voice change can be due to the endocrine, mass and invasion effects of the pathology. It is postulated that after removal of the thyroid gland, a better vibration of the laryngotracheal complex and relief of a slight respiratory obstruction might be obtained, especially in patients with large or compressive goiters. Watt-Boolsen et al. [13] also reported that 12 patients with sporadic non-toxic goiter and 8 with medically pretreated toxic goiter had impaired voice function which improved after thyroid surgery in the non-toxic goiter group but remained unchanged in the toxic goiter group. Worsening of strainness scores supports the previous findings of Sinagra et al. [7]. In the absence of any demonstrable laryngeal nerve injury through videostrobolaryngoscopy, the factors that could determine increased strainness can be related to normal healing process or possibly in a small percentage of cases, to sub clinical postoperative haematoma.

Further, the results of the acoustic analysis support the perceptual findings of this study. Acoustic analysis provides an objective multidimensional perspective of different components of voice. In the present study, different domains of voice such as fundamental frequency related, perturbation related and noise and voice break related parameters have been investigated. Fundamental frequency related parameters give information regarding different aspects of pitch of the vocal fold behaviour. In the present

study, we studied the mean F0, highest F0, lowest F0 and Standard deviations of F0 have been measured. The mean F0, lowest F0 and Highest F0 are comparable to average pitch, lowest pitch, and highest pitch during phonation. Standard deviation of F0 is the variation in the pitch in the long-term. Perturbation parameters selected in the present study are Absolute Jitter (Jitta), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ), Smoothed Pitch Perturbation Quotient (sPPQ), Shimmer in dB (ShdB), Shimmer Percent (Shim), Amplitude Perturbation Quotient (APQ), Smoothed Amplitude Perturbation Quotient (sAPQ). Absolute Jitter (Jitta), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Perturbation Quotient (PPQ) and Smoothed Pitch Perturbation Quotient (sPPQ), give information regarding short-term variation (one vibratory cycle to another) in fundamental frequency, whereas parameters like Shimmer in dB (ShdB), Shimmer Percent (Shim), Amplitude Perturbation Quotient (APQ), Smoothed Amplitude Perturbation Quotient (sAPQ), give information regarding short-term variation (one vibratory cycle to another) in intensity. The noise and voice break related parameters (NHR, VTI, SPI, DVB and DUV) give information regarding the amount of noise component in the voice signal.

Previous researchers who have investigated the acoustic parameters [7, 14] have reported of significant reduction in F0 and Lowest F0 and a significant increase in shimmer values. The decrease in F0 has been attributed to decrease in cordal tension by alteration in the functional character of the cricothyroid muscle or the external branch of superior laryngeal nerve [15, 16]. In the present study, there was no significant change between the two conditions in values of most of the acoustic parameters except Jitta, shimmer %, Sapq, DVB and DUV. Slight increase in mean scores for frequency perturbation (Jitta), shimmer %, Sapq, DVB and DUV were noted. Elevated amplitude perturbation values support previous reports of [1, 7]. Increased amplitude perturbation values indicate increased loudness variation. However, this increased loudness variation did not affect the perceived voice quality as there was no change in voice quality during perceptual analysis.

It was noted in the present study that, only in males, there was a slight improvement in scores of overall severity, breathiness and roughness with the scores of strainness slightly increased. However, for pitch and loudness, the scores remained the same. In the case of females, median values were within normal range in both pre- and post operative conditions. This indicates that there is relationship between severity of pre-operative dysphonia and thyroidectomy surgery. Males had mild to moderate deviant scores pre-operatively and females, normal voice quality. As males were more affected by thyroid problem,

it's possible that the post-operative healing process may take a little longer.

In conclusion, after total thyroidectomy, with no visible laryngeal nerve damage, the functional changes in voice (both perceptual and acoustical) are limited and temporary. These changes may be limited to selected perceptual changes such as decrease in roughness and breathiness or increase in strainness. The results of the acoustical analysis supported the perceptual findings. This study provides an insight to the Otolaryngologists and SLPs about the possible voice characteristics in patients who undergo thyroidectomy, which in turn would help them to formulate specific therapy protocol for this population. The results will also sensitize the surgeons and physicians on the need for the referral of this population to speech language pathologists in the event of dysphonia.

Appendix: Compendium of the Definitions of Different Acoustic Parameters Used in the Present Study

Frequency Related Parameters:

- Mean Fundamental Frequency (MF0): Average fundamental frequency for all extracted pitch periods.
- Highest Fundamental Frequency (Fhi): The highest value of frequency that is noticed.
- Lowest Fundamental Frequency (Flo): lowest frequency that is noticed.
- Standard Deviation of F0 (STD): deviation of F0 from average.

Perturbation Related Parameters:

- Absolute Jitter (Jitta): Period to period variability of the pitch period.
- Jitter Percent (Jitt): Period to period (very short term) variability of the pitch.
- Relative Average Perturbation (RAP): Period to period variability of the pitch with smoothing factor of 3 periods.
- Pitch Perturbation Quotient (PPQ): Period to period variability of the pitch with smoothing factor of 5 periods.
- Smoothed Pitch Perturbation Quotient (sPPQ): Short or long term variability of the pitch period at smoothing factor defined by the user.
- Shimmer in dB (ShdB): Evaluation in dB of the period to period variability of the peak to peak amplitude.
- Shimmer Percent (Shim): Relative evaluation of the period to period variability of the peak to peak amplitude.

- Amplitude Perturbation Quotient (APQ): Relative evaluation of the period to period variability of the peak to peak amplitude at smoothing level of 11 periods.
- Smoothed Amplitude Perturbation Quotient (sAPQ): Short or long term variability of the peak to peak amplitude at smoothing factor defined by the user.

Noise and Voice Break Related Parameters

- Noise to Harmonic Ratio (NHR), Average ratio of the inharmonic spectral energy in the frequency range 1500–4500 Hz to the harmonic spectral energy in the frequency range 70–4500 Hz.
- Voice Turbulence Index (VTI): Average ratio of the inharmonic high frequency energy in the range 2800–5800 Hz to the spectral harmonic energy in the frequency range 70–4500 Hz in areas of the signal where the influence of the frequency & amplitude variations, voice breaks & sub harmonic components are minimal.
- Soft Phonation Index (SPI): Average ratio of the lower frequency harmonic energy in the range 70–1600 Hz to the higher frequency harmonic energy in the range 1600–4500 Hz.
- Degree of Voice Breaks (DVB): Ratio of the total length of areas representing voice breaks of the time of the complete voice sample.
- Degree of Voiceless (DUV): Estimated relative evaluation of non harmonic areas where F0 cannot be detected in the sample.

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