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Acoustic Voice Quality Index fordiscriminating Normal and different Vocal Pathological Conditions: A Preliminary Study

Abstract

The Acoustic Voice Quality Index (AVQI) is a multiparametric measure (Maryn et al., 2010) to assess the overall voice quality using both *sustained and continuous speech*.The study was aimedto compare the AVQI values across normal voice and dysphonic voice due to different pathological conditions, and to compare the values obtained from constituent parameters of AVQI across normal and different vocal pathological conditions. 74 participants in the dysphonic group and 28 in the normal voice group were considered for the study. Phonation samples of /a/ and reading samples were recorded using *Praatversion 6.0.40,* and acoustic analysis was carried out using *PraatAVQI script version 2.03*. The perceptual analysis was done by three Speech-Language Pathologists using the GRBAS scale. The results revealed thatamong the dysphonic group, higher AVQI values were seen in unilateral vocal cord (VC)palsy, followed by bilateral mass lesion, unilateral mass lesion, MTD-I, MTD-II & III, and acute laryngitis. The higher AVQI value suggests the overall poor voice quality. CPPs and HNR values were found to be least in the unilateral VC palsy group indicating high breathiness and noise component, respectively. Shimmer local and shimmer local dB values were high in the unilateral VC palsy group and mass lesion groups suggesting maximum aperiodic vibration of vocal folds in these groups. To conclude,AVQI and constituent parameters might help in discriminatingvocal pathological conditions acoustically. As the present study is preliminary in nature, future research can be carried out with a greater sample size, restricted age range, and by considering the perceptual dysphonia severity. Further studies in this regard can assist the speech-language pathologist in screening and diagnosis of voice disorders, and monitoring the prognosis during the voice therapy effectively.

Introduction

A voice disorder occurs when a person's voice quality, pitch, and loudness vary from those of people of similar age, gender, cultural background, and geographic location (Aronson, 1980; Boone, 1977).The Diagnostic Classification System of Voice Disorders (DCSVC)grossly divides the voice disorders into two groups, i.e., Organic voice disorder (OVD) and Functional voice disorder (FVD). Further, FVD consists of two groups, i.e., psychogenic voice disorders (PVD) and muscle tension voice disorder(MTVD) (Baker, Ben-Tovim, Butcher, Esterman, McLaughlin, 2007). The prevalence of voice disorders among communication disorders found to be around 4-7% in the Indian context ((Sinha, Shivaswamy, Barman, Seth, Seshadri& Savithri, 2017; Konadath, Chatni, Lakshmi, & Saini, 2017).The prevalence rate of voice disorders among the professional voice users is quite high; 86 % of the politicians, 74% vendors, 59% singers, and 49% of teachers found to have voice problems (Boominath, Rajendran, Nagarajan, Seethapathy&Gnanasekar, 2008).These studies suggest that voice disorder is a prevalent condition in the Indian context and hence needs attention regarding precise diagnosis and effective intervention.

The perceptual and acoustic analyses of voice are a vital part of the voice evaluation carried out by Speech-Language Pathologists as they provide excellent measures of intervention outcome(Stemple, Roy, &Klaben, 2014).Perceptual analysis of voice is a process of listening to recorded voice samples or live patient's voice and describing the abnormalities of a voice, specifically the deviations in terms of pitch, loudness, and quality. Acoustic analysis of voice provides quantitative data on vocal fold vibration in terms of pitch and amplitude, perturbation measures, harmonics to noise ratio, spectral, and cepstral measures, which in turn provide a better understanding of the pattern of vocal fold vibrations (Maryn, Roy, De Bodt, Van Cauwenberge, &Corthals, 2009).

Acoustic Voice Quality Index (AVQI) is a multiparametric acoustic model to measure overall voice quality using both *sustained and continuous speech*.Maryn, Corthals, Van Cauwenberge, Roy, De Bodt (2010) developed AVQI to improve the ecological validity, perceptual, and instrumental assessment of dysphonia, considering both sustained vowel and continuous speech. For this purpose, sustained and continuous speech (reading phonetically balanced text) samples were collected from the 251 participants (229 with dysphonia and 22 without dysphonia) and were linked together.Then the samples were given to

five experience voice clinicians for the perceptual rating of overall voice quality. The non-voiced segments within the continuous speech were removed using a custom voicing detection algorithm, and concatenated samples were analyzed using 13 acoustic parameters based on fundamental frequency perturbation, amplitude perturbation, spectral and cepstral analyses. The AVQI equation consists of six acoustic parameters (smoothened cepstral peak prominence, shimmer local, harmonics-to-noise ratio, shimmer local dB, general slope of the spectrum, the tilt of the regression line through the spectrum).

AVQI= [3.295 – (0.111*CPPs) - (0.073*HNR) – (0.213*shimmer local) + (2.789*shimmer local dB) – (0.032*slope) + (0.077*tilt)]*2.571.

Heman-Ackah, Michael, Goding (2002) and Maryn, et al. (2010)have supported the diagnostic usefulness of combining voice samples from both continuous speech and sustained vowels in the acoustic and perceptual analysis of disordered voice. Studies have also reported that AVQI possesses concurrent validity, diagnostic accuracy, and responsiveness to change(Heman-Ackah, Michael, Goding, 2002; Maryn, et al., 2010; Maryn, De Bodt, Roy, 2010). AVQI has been validated and found reliable in different languages such as Dutch, Japanese, Lithuanian, German, Korean, Spanish, and Kannada (Maryn, et al., 2010; Hosokawa, Barsties, Iwahashi, Iwahashi, Kato, Iwaki, Sasai, Miyauchi, Matsushiro, Inohara, Ogawa, 2017; Uloza, Petrauskas, Padervinskis, Ulozaitė, Barsties, Maryn, 2017; Barsties, Lehnert, Janotte, 2020; Kim, Barsties, Lee, 2019; Delgado, Leon, Jiménez, Izquierdo, Barsties, 2018; Benoy, 2017; Pebbili, Shabnam, Pushpavathi, Rashmi, Sankar, Nethra, Shreya, Shashish, 2019).AVQI is found to be useful in discriminating normophonic and dysphonic voices.However, there is a dearth of research on whether AVQI can be a useful tool to discriminate across the different vocal pathological conditions.Currently, laryngeal/ vocal imaging is considered as a standard tool for understanding vocal fold physiology, its' pathologies, and in differential diagnosis. Visual examination using endoscopy or stroboscopy are commonly used instruments for vocal imaging.

Many vocal pathologies can be treated through voice therapy, and the prognosis can be assessed through acoustic evaluation and vocal imaging. However,for monitoring the prognosis of voice therapy, frequent evaluations are required. In this scenario, the feasibility of endoscopy/stroboscopy reduces because of high operational time and cost factors. Also, most of the time, younger children with voice problems do

not cooperate for endoscopic procedures. Hence, to overcome the concerns mentioned above, apreliminary attempt was made to investigate ifAVQI and its constituent parameters can help discriminate normal voice and different vocal pathological conditions. Acoustic measures provide information about different vocal aspects like reduced ease of mucosal vibration, phonatory gap, irregularity in vocal cord vibration, and vocal fatigue. Hence, it is hypothesizedthat AVQI and its constituent parameterscan also help in differentiating variousvocal pathological conditions.The present study was aimedto investigate AVQI and its constituent parameters for discriminating normal voice and different vocal pathological conditions. The specific objectives of the study were to compare the AVQI values acrossnormal voice and dysphonic voice due to different pathological conditions, and to compare values obtained from constituent parameters of AVQI across normal and different vocal pathological conditions.

Methods

Participants

There were 74participants in the dysphonicgroup (51 males and 23 females, Age range=11 to 82 years, mean age= 39.4±15.5 years).The details of the dysphonic group are summarized in Table 1. The bilateral and unilateral mass lesion group majorly consisted of individuals with vocal nodule and vocal polyp. There were 28 in normal voice group with 13 males and 15 females (Age range= 19 to 39 years; Mean age= 24.7±4.2 years).

Table 1. Demographic detailsof dysphonic group

	Males	Females	Total
Bilateral mass lesion	9	4	13
Unilateral mass lesion	13	3	16
Unilateral vocal cord (VC) palsy	7	3	10
MTD II & III co-existed	5	4	9
MTD-I	10	8	18
Acute laryngitis	7	1	8
Total	51	23	74

All the participants considered for the study were native Kannada speakers.The individuals under the dysphonic group had to undergo the routine clinical examination which involved case history and detailed evaluation under the perceptual, acoustic, aerodynamic, and vocal imaging domains. The underlying vocal pathologywasdiagnosed by the team consisting of a Speech-Language Pathologist (SLP), and an Otolaryngologist using the videostroboscopyXionEndostrob E with a 70-degree rigid scope and the Xenon R-180 LED light source for illumination. The individuals with normal hearing abilities, with dysphonia ranging from slight to severe, and with organic and functional voice disorders were included in the dysphonic group. For the normal voice group, the individuals had to undergo an informal interview and perceptual voice analysis by an experienced SLP. The individuals with perceptually normal voice (G=0 on GRBAS scale; Hirano, 1981), with no complaints of voice problem or presence of upper respiratory tract infections/ asthma, or allergic disease on the day of recording and with normal hearing and cognitive abilities were consideredfor the normal group. The written consent was obtainedfrom each participant, where information regarding the aim, objectives, method of the research, and approximate duration of the procedure was mentioned.

Procedure for voice recording

For the acoustic analysis, the voice samples were recorded in a sound-treated roomwhere the average ambient noise level was 25 dB. The participants were made to sit comfortably, and the table-mounted dynamic microphone Shure SM48 (Shure Incorporated Product Support Niles, IL) was placed at a distance of 4 to 5 cm and30º angle from the participant's mouth. All the recordings were done at a sampling frequency of 44.1 kHz, 16-bit resolution, in the mono channel using the program *Praat*version 6.0.40, and were saved in *.wav* format.For AVQI calculation, both phonation, as well as continuous speech sample, was required. For this purpose: the participants were instructed to phonate vowel /a/ for more than three seconds,and three trials were taken at their comfortable pitch and loudness. The most stable recording was considered foranalysis. An interval of 2 minutes was given between each recording. Next, they were asked toread the first paragraph of the standardized Kannada passage (Shasidhar, 1984) at their comfortable pitch and loudness. As the AVQI requires sustained phonation of three seconds to be named as 'sv' and continuous speech sample to be named as '*cs*,' the obtained samples opened in the *Praat program* and were truncated, renamed and were saved *.wav* format accordingly. The second sentence of the first paragraph of

the standardized passage (/i: u:rannunammara:ʤjaḍabamba:Iennuvaru/) was considered for the continuous speech sample.

Acoustic Analysis of voice samples

For the calculation AVQI, both '*sv*' and '*cs*' were opened in the*Praat*program, the *Praat*script of AVQI version 02.03 (Maryn, 2013)was run in the *Praat* program, and then AVQI value and values of constituent parameters are obtained on output window (Fig 1).

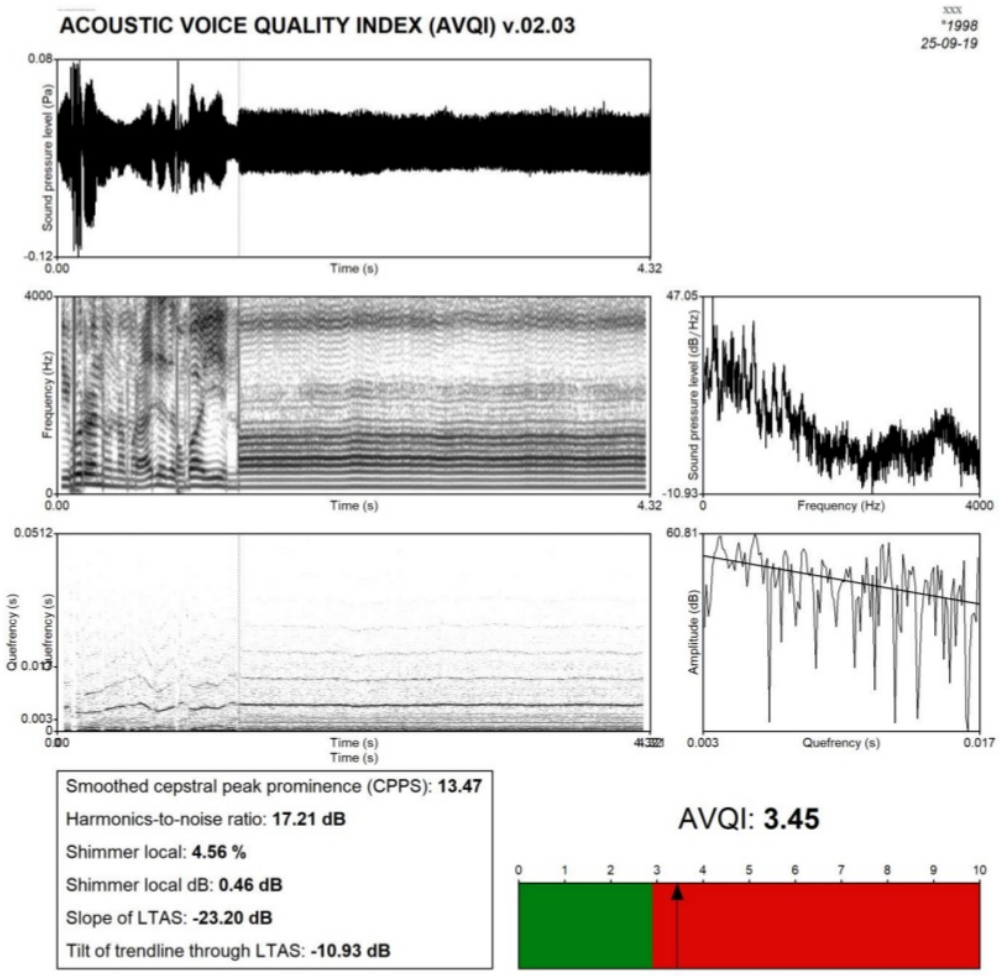

Figure 1: An illustration of the AVQI 02.03 output

Perceptual analysis of voice samples

The perceptual analysis was done by three Speech-Language Pathologists (raters).They had a minimum of 5 years of clinical experience in dealing with diagnosis and management of voice disorder. The GRBAS scalewas used for the perceptual analysis where the overall grade (severity of dysphonia) was rated on 0-3 scale (0, 1, 2, 3 representing normal, slight, moderate, and severe, respectively). Based on the consensus across at least two of the three raters, a particular grade was assigned to each sample. The voice samples were categorized into the normal, slight, moderate, and severe categories using overall Grade of dysphonia (G) from the GRBAS scale. The results of the perceptual analysis revealed 28 samples under the normal, 40 under slight, 25 under moderate, and nine under the severe category. The distribution of the perceptual category across the pathological conditions has been depicted in Table 2. Also, to confirm the consistency among the raters, inter-rater agreement was assessed for each pair using Cohen's Kappa.

Table 2. Distribution of overall Grade of dysphonia severity across different pathological conditions

	Normal	Slight	Moderate	Severe
Bilateral mass lesion (n=13)	-	5	6	2
Unilateral mass lesion (n=16)	-	11	3	2
Unilateral VC palsy (n=10)	-	-	6	4
MTD II & III co-existed (n=9)	-	7	2	-
MTD-I (n=18)	-	11	6	1
Acute laryngitis (n=8)	-	6	2	-
Normal voice (n=28)	28	-	-	-
Total	28	40	25	9

Statistical Analysis

The Shapiro -Wilks' test was carried out to test the assumption of normality for AVQI and its constituent parameter across all the normal and vocal pathological groups. Descriptive statistics were done to obtain the mean and standard deviation (SD) values for AVQI and its constituent parameters across all the groups. A

one-way analysis of variance (ANOVA) with Tukey post hoc analysis was carried out to determine the group mean difference for AVQI. MANOVA and Tukey post hoc test was carried out to investigate the main effect of type of pathology on the acoustic measures. Mann Whitney U test was used to observe the effect of type of pathology on shimmer local and shimmer local dB.

Results

Inter-rater agreement

The inter-rater agreement was computed using Cohen's Kappa coefficient for the overall grade (G) of dysphonia severity, and the coefficient ranged from 0.64 to 0.76, indicating good agreement among the judges (Table 3).

Table 3. Results of Cohen's Kappa across the Raters

	Cohen's Kappa Coefficient
Rater 1 vs. Rater 2	0.66
Rater 1 vs. Rater 3	0.64
Rater 2 vs. Rater 3	0.76

Test of Normality

The results of the Shapiro-Wilks' test revealed that all the measures except for shimmer local and shimmer local dB followed a normal distribution (p-value > 0.05) across all the vocal pathological and normal groups. The measures shimmer local and shimmer local dB did not follow normal distribution for the normal and unilateral mass lesion groups (p-value < 0.05), while for rest of the groups followed a normal distribution (p-value > 0.05).

Comparison of AVQI values across different groups:

The results of descriptive statistics suggest that higher AVQI values were obtained for the dysphonic group compared to normal. Among the dysphonic group, higher values were obtained for unilateral VC palsy, followed by bilateral mass lesion, unilateral mass lesion, MTD-I, MTD-II & III and laryngitis(Table

4).Higher the AVQI value indicates poorer the overall voice quality. The unilateral mass lesion, MTD-I, MTD-II & III, and laryngitis found to have similar AVQI values. The results of ANOVA showed that there is a significant effect of pathologies on AVQI values ($F(6, 95) = 11.77$, $P < 0.001$). The result of the Tukey post hoc test suggested that the normal group had significantly lower AVQI values compared to unilateralVC palsy, bilateral mass lesion, and unilateral mass lesion groups ($P < 0.05$). Moreover, unilateral VC palsy had significantly higher AVQI values compared to other pathological groups ($P < 0.05$).

Table 4. Mean (SD) AVQI values across different pathological conditionsand Normal

Groups	Mean	Lowest	Highest
Unilateral VC palsy	5.62 (1.56)	2.81	8.26
Bilateral mass lesion	4.07 (1.41)	2.27	6.69
Unilateral mass lesion	3.60 (1.68)	1.49	6.50
MTD-I	3.48 (1.32)	1.06	5.72
MTD II & III co-existed	3.08 (1.14)	1.06	4.91
Laryngitis	3.06 (1.12)	1.25	4.60
Normal voice	1.94 (0.83)	0.26	3.50

Comparison of CPPs, HNR, Slope, and Tilt values across different groups:

The CPPs valueswere found to be least for unilateral VC palsy, and the value increases respectively in thebilateral mass lesion, unilateral mass lesion, MTD-I, acute laryngitis, MTD-II & III, and maximizesfor the normal group (Table 5). Similarly, HNR values found to be least for unilateral VC palsy, followed by bilateral mass lesion, unilateral mass lesion, MTD-I. MTD-II & III, acute laryngitis, and maximum for normal group. CPPs and HNR values found to be least for the unilateral VC palsy group. The values obtained for slope and tilt did not vary much across the groups. The MANOVA showed an overall significant main effect of type of pathology on the acoustic measures, Wilks' Lambda = 0.38, $F(24, 322.16) = 4.20$, $P < 0.001$. The subsequent ANOVA result for each parameter has been summarized in Table 6.

Table 5. Mean (SD) of CPP, HNR, Slope values across different pathological conditions and Normal

Groups	CPPs	HNR	Slope	Tilt
Unilateral VC palsy	8.39 (3.35)	12.15 (5.73)	-23.24 (4.09)	-11.49 (2.34)
Bilateral mass lesion	10.74 (2.86)	18.35 (5.23)	-24.12 (7.02)	-11.44 (1.62)
Unilateral mass lesion	11.85 (2.73)	18.85 (6.03)	-25.35 (4.19)	-12.43 (0.72)
MTD-I	11.96 (2.89)	19.58 (4.17)	-25.79 (4.72)	-12.84 (0.64)
MTD II & III co-existed	12.90 (1.57)	21.95 (3.64)	-27.67 (6.10)	-11.45 (1.39)
Laryngitis	13.74 (1.04)	20.63 (2.82)	-24.01 (4.06)	-10.59 (2.51)
Normal	14.82 (1.71)	22.87 (3.38)	-23.42 (5.61)	-12.53 (1.25)

Table 6 ANOVA results for CPPs, HNR, Slope and Tilt differentiating across the groups

Parameters	F (6, 95)	Sig.	Partial Eta Squared
CPPs	10.86	.000	.407
HNR	7.67	.000	.326
Slope	1.08	.375	.064
Tilt	3.85	.002	.196

The results of the Tukey post hoc test indicated that CPPs values were significantly high for the normal group compared to unilateral VC palsy, unilateral mass lesion, and bilateral mass lesion ($P< 0.05$). The unilateral VC palsy group found to have significantly lesser CPPs values compared to other pathological groups ($P< 0.05$). The CPPs values obtained for MTD-I, MTD-II& III, acute laryngitis and normal did not differ significantly. HNR values found to be significantly less in theunilateralVC palsy group compare to normal and other pathological groups ($P< 0.05$). The values obtained for slope found to have no significant difference across the groups. Tilt values varied significantly across the groups ($P< 0.05$), but no definite pattern could be obtained.

Comparison of Shimmer local and shimmer local dB values across different groups:

The shimmer local and shimmer local dB values were high for the unilateral VC palsy group, followed by bilateral mass lesion, unilateral mass lesion, MTD-I, MTD-II & III co-existed, acute laryngitis and least for the normal group (Table 7). The MANOVA showed a significant main effect of type of pathology on shimmer local and shimmer local dB, Wilks' Lambda = 0.67, F (8, 104) = 2.84, $P = 0.007$. The subsequent ANOVA result for shimmer local and shimmer local dB is summarized in Table 8.The results of the Tukey post hoc test suggested that shimmer local found to be significantly high for unilateralVC palsy compared to acute laryngitis and MTD type II & III ($P< 0.05$). There was no significant difference across the bilateral mass lesion, MTD type I, MTD type II & III, and acute laryngitis groups for shimmer local. Shimmer local dB found to be significantly high for unilateral VCpalsy compared to acute laryngitis, MTD-I, and MTD-II & III co-existed. At the same time,there was no significant difference between unilateral palsy and bilateral mass lesion groups.

Table 7. Mean (SD) and Median values for across Shimmer local and shimmer local dB different pathological conditions and Normal

Groups	Shimmer local		Shimmer local dB	
	Mean (SD)	Median	Mean (SD)	Median
Unilateral VC palsy	10.51 (8.03)	10.13	.98 (.52)	0.91
Bilateral mass lesion	6.94 (3.52)	6.27	.66 (.29)	0.55
Unilateral mass lesion	6.47 (4.69)	4.80	.66 (.43)	0.51
MTD Type I	5.87 (2.80)	5.32	.58 (.21)	0.53
MTD Type II & III	4.89 (2.07)	4.75	.48 (.15)	0.46
Laryngitis	4.39 (1.36)	4.07	.46 (.14)	0.44
Normal	3.22 (1.18)	3.13	.35 (.46)	0.32

Table 8.ANOVA results for shimmer local and shimmer local dB differentiating across the groups

Parameter	F (4, 53)	Sig.	Partial Eta Squared
shimmer local	3.328	.017	.201
shimmer local dB	4.863	.002	.268

The results of the Mann Whitney U test indicated that the unilateral mass lesion group has a significantly higher value compared to the normal group. At the same time,there was no significant difference observed between unilateral mass lesion when compared with other pathological conditions for both shimmer local and shimmer local dB.Also, thenormal group found to have significantly lower shimmer local and shimmer local dB values compared to all pathological conditions(Table 9 and Table 10).

Table 9. Result of Mann Whitney U test across groups for shimmer local

Groups	Unilateral palsy	Bilateral mass lesion	Unilateral mass lesion	MTD-I	MTD II & III	Laryngitis	Normal
Unilateral mass lesion	1.37	1.09	-	0.83	0.51	0.36	2.34*
Normal	3.08	4.20*	2.34*	3.34*	2.33*	2.35*	-

*$p < 0.05$

Table 10. Result of Mann Whitney U test across groups shimmer local dB

Groups	Unilateral palsy	Bilateral mass lesion	Unilateral mass lesion	MTD Type I	MTD II & III	Laryngitis	Normal
Unilateral mass lesion	1.84	0.61	-	0.73	0.51	0.67	2.30*
Normal	4.14*	3.92*	2.30*	3.91*	2.26*	2.24*	-

*$p < 0.05$

Discussion

Comparison of AVQI values across different groups

The first objective of the present study was to compare the AVQI values across normal voice and dysphonic voice due to different pathological conditions. The results of the present study suggests thatthenormal group had significantly lower AVQI values compared to dysphonic group. These results are in consensus with previous studies where they had obtained significantly lower AVQI values for normophonic group compared to the dysphonic group (Pebbili et al., 2019; Benoy, 2017).

The unilateral VC palsy group had significantly higher AVQI values compared to other pathological groups.This can be due to the presence of largerglottic chink and asynchronous vocal fold vibration compared to other pathological conditions. This result can be supported by literature, which reports that the majority of palsy cases have type 4 voice quality wherein, there is a wide phonatory gap, and voice quality is extremely breathy (Dedo,1992). The unilateral mass lesion, MTD-I, MTD-II & III, and acute laryngitis

found to have similar AVQI values.AVQI values in these groups were significantly lower than the unilateral VC palsy group and significantly higher than the normal group. The other pathological groups had lesser AVQI values in comparison to unilateral VC palsy, which can be attributed to a lesser extent of phonatory gap and irregularity in vocal fold adduction in them.For example, nodules and polyps will have increased mass and stiffness of the vocal folds, as well as hourglass closure pattern with decreased vibratory amplitude and mucosal wave (Hirano and Bless, 1993). Acute laryngitis is reported to have generalized edema, reduced or absent mucosal wave and a slight reduction in vibratory amplitude (Sapienza, & Hoffman-Rudy, 2009). MTD will have an excessive glottic and supraglottic medial contraction, anterior-posterior contraction of the supraglottic musculature, decreased vibratory amplitude, or psychogenic bowing of vocal folds (Altman, Atkinson, & Lazarus, 2005; Lee, & Son, 2009). While unilateral VC palsy is characterized with weakened or bowed vocal fold, presence of passive vibration around the paralyzed vocal fold, arytenoid cartilage on the affected side will not abduct or adduct; also there will be asymmetry characterized by slower initiation of the mucosal wave on the affected side along with a slower period and reduced amplitude of vibration (Sercarz, Berke, Gerratt, Ming, &Natividad, 1992). Hence, the extent of pathology seems to be more in unilateral VC palsy resulting in higher AVQI value in them compared to other pathological conditions.

Comparison of CPPs, HNR, shimmer local, shimmer local dB, Slope, and Tilt values across different groups

The next objective of the study was to compare values obtained from constituent parameters of AVQI across normal and different vocal pathological conditions. The CPPs values were significantly high for the normal group compared to unilateral VC palsy, unilateral mass lesion, and bilateral mass lesion. Literature reports high CPP value for normophonic individuals due to the presence of well-defined harmonic structure, and low in severe dysphonic voices as the harmonic formation is restricted by irregular adduction of vocal folds (Heman-Ackah et al., 2002).The unilateral VC palsy group found to have significantly lesser CPPs values compared to other pathological groups.Lesser CPPs values can be because CPPs have a high correlation with breathiness (Hillenbrand and Houde, 1996),and unilateral VC palsy will have a high breathiness component due toa large phonatory gap. The CPPs values obtained for MTD-I, MTD-II &III;

acute laryngitis and normal did not differ significantly, which can be due to lesser severity of dysphonia and lesser extent of pathologyin MTD and acute laryngitis compared to palsy and mass lesion conditions.

HNR values found to be significantly less in theunilateralVC palsy group compare to normal and other pathological groups due to the presenceof high noise components in palsy conditions. Even this can be because ofthe presence of a wide phonatory gap in unilateral VC palsy. At the same time, other conditions would have better vocal fold closure as both the vocal cords would have mobility.The high noise component results from incomplete glottal closure that creates excess air during phonation, which increases the noise amplitude, in turn, lowers the HNR (Hartl, Hans, Vaissiere, Riquet, Brasnu, 2001; Oguz, Demirci, Safak, Arslan, Islam, Kargin, 2007).

Shimmer local and shimmer local dB found to be significantly high value for unilateral VCpalsy compared to other groups suggesting maximum aperiodic vibration of vocal folds in them.Patel and Parsram(2005) had reported significantly higher shimmer values in individuals with vocal cord paralysis compare to normophonic individuals, which results from asynchronous vibration of vocal cords. The study reports highershimmer values in the mass lesion group compared to normal. This can be attributed to the inflammation or small masses on vocal folds leading to inconsistent glottal closure, and poorer vocal fold median edge contact(Oguz, Tarhan, Korkmaz, Yilmaz, Safak, Demirci, &Ozluoglu, 2007).The result of the study agrees with Davis(1979), where amplitude perturbation quotient (APQ) values were higher for unilateral paralysis followed by nodules and then laryngitis. Lieberman(1963)reports that inflammation and very small growth on vocal folds only minimally affects the perturbation measures, while larger masses can produce increased perturbation.

Spectral slope and spectral tilt are measures obtained from Long-term Average Spectrum (LTAS) analysis. The signal attained through LTAS represents the vocal function taking place at larynx as sound and transfer through the vocal tract (Lofqvist and Mandersson, 1987). The spectral slope has been identified as a correlate of hoarseness in the voice. The smaller values of the spectral slope values indicate a slower decline of energy with frequency, which is associatedwith vocal fold hyperfunction. In comparison, larger values of spectral slope indicate a faster decline of energy with frequency, which can be associated with vocal hypofunction(Ludlow, Kent, &Gray, 2018).

Similarly, spectral tilt was found to be associated with glottal closure during phonation. A reduction in spectral tilt value is associated with hyperadduction and high values associated with hypoadduction(Ludlow, Kent, &Gray, 2018). Although, in the current study, the values obtained for slope and tiltdid not vary much across the groups, indicating that slope and tiltmight not help discriminate the pathological conditions when considered in isolation.

Conclusion

AVQI and constituent parameters mighthelp in discriminating pathological conditions acoustically.The results of the study have shown that CPPs, HNR, and Shimmer parameter values are well discriminated across the pathological conditions. The values obtained for palsy, mass lesion, and muscle tension dysphonia are well demarcated. However, the current study is preliminary and hence future studies can consider following points such as (i) higher and an equal number of participants in each group; (ii) restricting the age range, as age affect the acoustic measures (children, individuals in pubertal age, adults and geriatric populationvary in their acoustic norms);(iii) overall perceptual dysphonia severity; and (iv) the size of mass lesionsalso might provide us with some remarkableand supporting results.Further studies in this regard can assist Speech language pathologist in screening and diagnosis of voice disorders,and monitoring the prognosis during the voice therapy effectively. AVQI 02.03 is a non-commercial tool, that runs in the *Praat* program, making it cost-effective; also, it is less time consuming, and non-invasive.

Table 1. Demographic details of dysphonic group

	Males	Females	Total
Bilateral mass lesion	9	4	13
Unilateral mass lesion	13	3	16
Unilateral vocal cord palsy	7	3	10
MTD II & III co-existed	5	4	9
MTD-I	10	8	18
Acute laryngitis	7	1	8
Total	51	23	74

Table 2. Distribution of overall Grade of dysphonia severity across different pathological conditions

	Normal	Slight	Moderate	Severe
Bilateral mass lesion (n=13)	-	5	6	2
Unilateral mass lesion (n=16)	-	11	3	2
Unilateral VC palsy (n=10)	-	-	6	4
MTD II & III co-existed (n=9)	-	7	2	-
MTD-I (n=18)	-	11	6	1
Acute laryngitis (n=8)	-	6	2	-
Normal voice (n=28)	28	-	-	-
Total	28	40	25	9

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Table 3. Results of Cohen's Kappa across the Raters

	Cohen's Kappa Coefficient
Rater 1 vs. Rater 2	0.66
Rater 1 vs. Rater 3	0.64
Rater 2 vs. Rater 3	0.76

Table 4. Mean (SD) AVQI values across different pathological conditions and Normal

Groups	Mean	Lowest	Highest
Unilateral VC palsy	5.62 (1.56)	2.81	8.26
Bilateral mass lesion	4.07 (1.41)	2.27	6.69
Unilateral mass lesion	3.60 (1.68)	1.49	6.50
MTD-I	3.48 (1.32)	1.06	5.72
MTD II & III co-existed	3.08 (1.14)	1.06	4.91
Laryngitis	3.06 (1.12)	1.25	4.60
Normal voice	1.94 (0.83)	0.26	3.50

Table 5. Mean (SD) of CPP, HNR, Slope values across different pathological conditions and Normal

Groups	CPPs	HNR	Slope	Tilt
Unilateral palsy	8.39 (3.35)	12.15 (5.73)	-23.24 (4.09)	-11.49 (2.34)
Bilateral mass lesion	10.74 (2.86)	18.35 (5.23)	-24.12 (7.02)	-11.44 (1.62)
Unilateral mass lesion	11.85 (2.73)	18.85 (6.03)	-25.35 (4.19)	-12.43 (0.72)
MTD-I	11.96 (2.89)	19.58 (4.17)	-25.79 (4.72)	-12.84 (0.64)
MTD II & III co-existed	12.90 (1.57)	21.95 (3.64)	-27.67 (6.10)	-11.45 (1.39)
Laryngitis	13.74 (1.04)	20.63 (2.82)	-24.01 (4.06)	-10.59 (2.51)
Normal	14.82 (1.71)	22.87 (3.38)	-23.42 (5.61)	-12.53 (1.25)

Table 6. MANOVA results for CPPs, HNR, Slope and Tilt differentiating across the groups

Parameters	F (6, 95)	Sig.	Partial Eta Squared
CPPs	10.86	.000	.407
HNR	7.67	.000	.326
Slope	1.08	.375	.064

Tilt	3.85	.002	.196

Table 7. Mean (SD) and Median values for across Shimmer local and shimmer local dB different pathological conditions and Normal

Groups	Shimmer local		Shimmer local dB	
	Mean (SD)	Median	Mean (SD)	Median
Unilateral palsy	10.51 (8.03)	10.13	.98 (.52)	0.91
Bilateral mass lesion	6.94 (3.52)	6.27	.66 (.29)	0.55
Unilateral mass lesion	6.47 (4.69)	4.80	.66 (.43)	0.51
MTD Type I	5.87 (2.80)	5.32	.58 (.21)	0.53
MTD Type II & III	4.89 (2.07)	4.75	.48 (.15)	0.46
Laryngitis	4.39 (1.36)	4.07	.46 (.14)	0.44
Normal	3.22 (1.18)	3.13	.35 (.46)	0.32

Table 8. MANOVA results for shimmer local and shimmer local dB differentiating across the groups

Parameter	F (4, 53)	Sig.	Partial Eta Squared
shimmer local	3.328	.017	.201
shimmer local dB	4.863	.002	.268

Table 9. Result of Mann Whitney U test across groups for shimmer local

Groups	Unilateral palsy	Bilateral mass lesion	Unilateral mass lesion	MTD-I	MTD II & III	Laryngitis	Normal
Unilateral mass lesion	1.37	1.09	-	0.83	0.51	0.36	2.34*
Normal	3.08	4.20*	2.34*	3.34*	2.33*	2.35*	-

*$p < 0.05$

Table 10. Result of Mann Whitney U test across groups shimmer local dB

Groups	Unilateral palsy	Bilateral mass lesion	Unilateral mass lesion	MTD Type I	MTD Type II & III	Laryngitis	Normal
Unilateral mass lesion	1.84	0.61	-	0.73	0.51	0.67	2.30*
Normal	4.14*	3.92*	2.30*	3.91*	2.26*	2.24*	-

*$p < 0.05$

FIGURE LEGENDS

Figure 1: An illustration of the AVQI 02.03 output

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