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Research Article

The Reliability of Vocal Intensity and Pitch Range in Unilateral Vocal Fold Palsy Patients

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Abstract

Objectives: 1) to evaluate the reliability of measurements of maximum vocal intensity (maxVI), reading pitch range (RPR) and singing pitch range (SPR); 2) to determine the parameters' correlation with voice handicap index-10 (VHI-10); and 3) to compare the difference of the parameters between pathology and healthy group.

Methods: This cross-sectional study that was performed in a tertiary centre included 30 patients diagnosed with unilateral vocal fold palsy (UVFP) and 30 healthy volunteers (n = 60 participants). The participants' voices were measured for maxVI (dB) using Sound Level Meter (SLM) at 100cm, and RPR and SPR (Hertz) using OperaVOX at 30cm distance, from lips. The phonation tasks were vowel /a/ at maximum loudness (maxVI), reading a standard passage (RPR) and glissando mode /a/ (SPR). The measurements were repeated within 30 minutes interval. Voice handicap index-10 (VHI-10) was documented for all participants. The internal consistency of the measurements was evaluated using intraclass correlation (ICC). Correlation of parameters with VHI-10 was assessed with Spearman Correlation Coefficient. The comparison between two groups was done with Mann Whitney U Test.

Results: The reliability of maxVI, RPR and SPR was substantial to excellent with ICC of 0.83 (0.7,0.89), 0.9 (0.94,0.97) and 0.62 (0.44, 0.61) respectively. There was a significant difference for maxVI and SPR between the UVFP and healthy volunteers ($p < 0.01$). MaxVI showed good significant negative correlation with VHI-10 (r -0.63, $p < 0.05$) whereas RPR and SPR were poorly correlated with VHI-10 ($r = -0.126$ and $r = -0.28$, $p > 0.05$).

Conclusions: MaxVI showed good results depicted by its excellent reliability, ability to differentiate between UVFP and healthy volunteers and good correlation with VHI-10. Thus, MaxVI is may be a potential primary outcome measure in future clinical trials related to UVFP.

Keywords: Unilateral Vocal Cord Paralysis; Vocal Fold Palsy; Hoarseness

Introduction

Unilateral vocal fold paralysis (UVFP) is one of the causes of voice disorder that results in hoarse and breathy voice. A 20-year review by Ko., *et al*, 2009 showed iatrogenic origin is the leading etiology in 48% of patients with UVFP in Taiwan (n = 161) in which

thyroidectomy is the commonest (65%) [1]. The hoarseness in UVFP is due to gap in between the vocal folds as the paralysed vocal fold is unable to make a firm contact with the normal contralateral vocal fold that leads to difficulty to sustain vibration or generate mucosal waves.

Patients with UVFP frequently complain of inability to project their voice and change its pitch [2,3]. This condition is distressing and often affects the patients' quality of life. In noisy environment, the voice issues may become worse due to the reduced conversational speech intensity [4]. Hence these patients suffer greater disability of social performance than other patients with conventional medical problems such as renal dialysis or bone marrow transplantation [5]. Therefore, voice rehabilitation to improve vocal intensity and pitch range is pertinent by means of surgical or non- surgical methods. The evaluation of pitch range and vocal intensity is done by measuring the acoustic voice parameters.

Vocal intensity is expressed in decibel (dB) and useful in documenting the dynamics of the voice. Reduced vocal intensity may indicate incomplete glottal closure or reduced tissue pliability restricting vocal fold vibratory amplitude that is frequently seen in UVFP [6]. Vocal intensity may be improved by closing the phonatory gap to allow firm contact between vocal folds. The closure of phonatory gap can be achieved with surgical interventions such as type I thyroplasty with or without arytenoid adduction, injection laryngoplasty or laryngeal reinnervation that subsequently may improve the social function of patients with UVFP [4,7-9].

Pitch range is the change of voice frequency between the lowest pitch in modal register and the highest pitch in falsetto that is expressed in either Hertz (Hz) or semitones. Normal voice frequency depends on symmetrical mucosal waves of two normal vocal folds produced when there is complete closure of the glottis. Spector., *et al*. depicted a significant increase in pitch range of patients with UVFP following Isshiki type 1 thyroplasty [4] and documented the improvement of patients' emotional, functional and social outcome. Therefore, both vocal intensity and pitch range are two important measurements that reflect the handicap level of UVFP patients.

Vocal intensity and pitch range were used in numerous studies to measure voice quality of patients with voice disorder [4,10-12]. However, to the authors' knowledge, there were no studies in the literature rigorously assessed the reliability of these two measurements. Good reliability may confirm its use in assessing the severity of voice problems and effectiveness of voice rehabilitation in these patients. It may also potentially be used as a primary outcome measure in future clinical trials in patients with UVFP. Hence the purpose of the present study is to investigate the reliability of vocal intensity and pitch range measurements in UVFP patients.

Materials and Methods

Ethical considerations

The ethical approval to conduct this study was obtained from the local ethics committee.

Participants

A cross-sectional study was conducted from November 2015 to February 2017 at University Kebangsaan Malaysia Medical Centre (UKMMC). The study sample included 30 patients with UVFP and 30 healthy volunteers who had no voice issues. They were recruited based on convenience sampling.

Prior to the vocal intensity and pitch range measurements, both groups went through a complete history taking and otorhinolaryngological examination. For UVFP patients, those with vocal fold masses or lesions or any severe bronchopulmonary pathologies were excluded from this study as both may interfere the acoustic analysis results. While for healthy volunteers, those who are smokers or have severe bronchopulmonary disease or with history of upper respiratory tract infection within 2 weeks or history of endotracheal intubation within 1 month prior the recruitment process were excluded from the study.

Study procedure

Each participant was required to complete the Voice Handicap Index -10 (VHI-10) and the total score of the voice specific questionnaire was recorded. The score of 0 to 11 is considered normal and the increment of score indicates worse voice. Supervised voice measurements were performed in a quiet room with noise threshold of 30dB. The vocal intensity was measured using the Sound Level Meter (SoundPro®, QUEST Technologies, USA) placed at 100 centimeters from the participants. They were then instructed to phonate and sustain vowel /a/ at comfortable intensity for 3 seconds. Subsequently, the participants were asked to say /a/ again at maximum intensity. This maxVI was then recorded.

The pitch range measurement was done using OperaVOX. The OperaVOX is a software that was installed on an iPod touch 6th Generation that able to record as well as perform onsite acoustic analysis. The iPod touch has an internal microphone with a sampling rate of 45kHz. The participants were instructed to do recording

while sitting on a chair without any accessories worn on the wrist so as to avoid any background noise from being recorded onto the recorded voice. The standardisation of lips to microphone distance was done by holding the iPod taut with a lanyard 30cm from the lips. For measurements of the RPR, the participants were asked to read the 'Rainbow passage' or 'Kampung saya' according to their preference and for SPR, they were asked to sustain the vowel /a/ in glissando mode. The pitch range was calculated from the difference between the minimum and maximum pitch.

These tests of measuring maxVI, RPR and SPR were repeated within 30 minutes to assess the test-retest reliability.

Statistical analysis

The data was analysed using the statistical software SPSS (Statistical Package for the Social Science) for Window version 22.0. Intraclass correlation (ICC) was used to evaluate the test-retest reliability of maxVI, RPR and SPR. The correlation between each parameter and VHI-10 was analysed using Spearman correlation while Mann Whitney U test was used to compare the mean of the parameters between the UVFP and healthy volunteer group.

ICC was considered almost perfect for the values of 0.81 to 1.00, substantial for ICC values of 0.61 to 0.8, and moderate for ICC values of 0.4 to 0.6. For Spearman correlation coefficient, correlation was deemed good for the r-value approaching -1 for evaluation of correlation between the parameters and VHI-10. Statistical tests were considered significant when $p < 0.05$.

Results

Demography

In the present study, 60 participants were recruited that comprised 30 patients with UVFP and 30 healthy volunteers. The UVFP group comprised 15 males and 15 females while the healthy volunteers group consist of 8 males and 22 females. The mean age for UVFP patients and healthy volunteers was 42.4 (14.4) and 32.0 (10.0) respectively. Thyroidectomy was the commonest cause of UVFP (n = 11). Other etiologies of UVFP were summarised in Table 1. About 57% of the UVFP patients had undergone some surgical interventions namely injection laryngoplasty, Isshiki type 1 thyroplasty and laryngeal reinnervation (Table 1).

Maximum vocal intensity, pitch range and VHI-10

The mean of the maxVI for UVFP patients and healthy volunteers was of 73.4 (± 8.9) dB and 82.6 (±4.9) dB respectively.

Dermographic data	UVFP patients (n = 30)	Healthy volunteers (n = 30)
Gender		
Male	15	8
Female	15	22
Age		
<55 year old	23	28
>55 year old	7	2
Race		
Malay	19	24
Chinese	8	3
Indian	3	1
Others	0	1
Causes of UVFP		
Thyroidectomy	11	NA
Parathyroidectomy	2	NA
Head and neck surgery	3	NA
Trauma	1	NA
Idiopathic	5	NA
Others	8	NA
Treatment for UVFP patients		
Surgical treatment		
Injection laryngoplasty	10	NA
Isshiki Type 1 thyroplasty	6	NA
Injection laryngoplasty with Reinnervation of the nerve	1	NA
Non surgical treatment	13	NA
Speech therapy		

Table 1: This table depicts the demography data of the participants of this study.

† UVFP= Unilateral vocal fold palsy, ‡ n = number,

§ NA= not applicable.

For the pitch range, the mean of the RPR and SPR for UVFP patients and healthy volunteers respectively was: 1) RPR, 144.5 (±68.9) Hz and 165.7 (±59.4) Hz; and 2) SPR, 191.5 (±168.3) Hz and 266.4 (±105.9) Hz.

And for the VHI-10, the mean score was 15.5 (SD±10.9) for the UVFP patients and 0 (± 0) for the healthy volunteers. These results were shown in table 2.

Variables	UVFP patients n = 30 Mean (SD)	Healthy volunteers n = 30 Mean (SD)	Mann- Whitney U test p-Value
VHI-10	15.5 (±10.9)	0 (± 0)	0.00
RPR (Hz)	144.5 (±68.9)	165.7 (±59.4)	0.40
SPR (Hz)	191.5 (±168.3)	266.4 (±105.9)	0.00
maxVI (dB)	73.4 (±8.9)	82.6 (± 4.9)	0.00

Table 2: This table represents the comparison of mean in VHI-10, RPR, SPR, maxVI between healthy subjects and UVFP patients. † SD= standard deviation, ‡VHI-10= voice handicap index-10, § RPR = reading pitch range, ¶ SPR = singing pitch range, ⌘ maxVI=maximum vocal intensity.

Test-retest reliability

The mean of the first and second measurements of maxVI, RPR and SPR for both groups was summarized in table 3. The results of test-retest reliability evaluation showed excellent value for maxVI and RPR with ICC of 0.87 (0.79, 0.92) and 0.94 (0.9, 0.94) respectively. The reliability for SPR was substantial with ICC of 0.62 (0.44, 0.61).

	First test Mean (SD)	Second test Mean (SD)	ICC	Cronbach's alpha
maxVI (dB)	78.0 (±8.5)	77.7 (±9.6)	0.87 (0.79, 0.92)	0.93
RPR (Hz)	165.8 (±154.2)	169.9 (±150.6)	0.94 (0.90, 0.94)	0.97
SPR (Hz)	228.9 (±144.5)	231.9 (±141.5)	0.62 (0.44, 0.61)	0.76

Table 3: This table depicts the test-retest reliability for maxVI, RPR and SPR.
† ICC= intraclass correlation, ‡ maxVI=maximum vocal intensity, **§** RPR = reading pitch range, ¶SPR = singing pitch range.

Comparison of parameters between UVFP and healthy volunteers group

The results for comparison of the parameters (Table 2) between the two groups revealed that the maxVI and SPR was significantly higher in the healthy volunteers ($p < 0.05$).

On the other hand, RPR measurements were also higher in the healthy volunteers but it was not statistically significant ($p > 0.05$). For the VHI-10, the mean score is significantly worse in the UVFP ($p < 0.05$) than the healthy volunteer group.

Correlation of parameters with VHI-10

The findings of correlation between maxVI and VHI-10 showed that as each parameter increased, the VHI-10 improved with significant negative correlation ($r = -0.63$, $p < 0.05$). The RPR and SPR also depicted similar trend like the maxVI but was only weakly correlated with the VHI-10 with $r = -0.126$ and $r = -0.28$ respectively (Figure 1).

Discussion

Overview

UVFP patients commonly suffer loudness-limited and reduced pitch range of voice that causes conversation or communication predicament in places with background noise [2-4]. The vocal loudness or vocal intensity and pitch range issues is a major contributor of poor quality of life function [5-13]. Surgical treatments for UVFP are aimed to enable a firm contact between the normal and opposite paralysed vocal fold, to improve the vocal fold vibration hence enhance the vocal intensity and pitch range. The vocal intensity and pitch range measurements reflects the amplitude and frequency of vocal fold vibration [12,14,15]. These parameters may be a good outcome measure in evaluating the effectiveness of intervention for UVFP. The present study investigated the reliability of these measurements.

Strength of the study

In the present study, the reliability of maximum vocal intensity (maxVI) and pitch range (reading: RPR, and singing: SPR) as measured with SLM and OperaVOX respectively in UVFP patients as well as healthy volunteers was rigorously investigated. The study also investigated: 1) the ability of maxVI, RPR and SPR in differentiating the vocal intensity and pitch range between the two groups; and 2) the correlation of the parameters with the participant's perception of voice that was measured with VHI-10. To the authors' knowledge, results of such study are scarce in the literature.

Figure 1: The graphs represent the correlation of VI, RPR and SPR with VHI-10. A:shows the correlation of maxVI with VHI-10, B: correlation of RPR with VHI-10, C: correlation of SPR with VHI-10.
†VHI-10= voice handicap index-10, ‡ maxVI=maximum vocal intensity, §RPR= reading pitch range, ¶SPR= singing pitch range.

Synopsis

The results had shown excellent reliability for maxVI and RPR with ICC 0.87 (0.79, 0.92) and 0.94 (0.9, 0.94) respectively, while substantial reliability for SPR (ICC = of 0.62 (0.44, 0.61). This indicates a small variation between the first and second measurements for first two parameters. The parameters except RPR were good in detecting differences between the two groups in which the measurements were significantly lower or worse in the UVFP group ($p < 0.01$). Of all the evaluated parameters, only maxVI showed significant good negative correlation with VHI-10 ($r = -0.63$, $p < 0.01$). Here, the results depict that maxVI may be the best parameter compared to RPR and SPR as it persistently showed good results in all statistical analysis.

Comparison with previous study

Studies that evaluated the reliability of vocal intensity and pitch range are limited in the literature. Chen., *et al*. had investigated the difference in voice frequency and intensity as well as reading and voice range profile between healthy male and female adults. The measurements were taken from 80 healthy groups (40 male, 40 female), with the mean age of 26.4 years. They also studied the reliability of speaking vocal intensity using a Kay Phonetegram. The results showed excellent reliability of the measurement with ICC of 0.8 which is similar to the present study [16]. However there was no pathology group in the study was included which is pertinent as the reliability of acoustic measurements may be affected by dysphonic voices [13]. The documented normative value of speaking vocal intensity for male and female from this study was (98.68 ± 3.55 dB) and (100.69 ± 3.24 dB), respectively ($p < 0.05$) which generally was higher than our healthy volunteers' maxVI. These results may due to the distance of microphone from the participants' lips. In the present study, the sound level meter was placed 100 cm from the participant that may simulate voice projection in a crowd or big room. This method may be better in representing the vocal intensity in daily life. Furthermore, the use of voice range profile is limited by its task variations, requirement to repeat instructions and time consumption that may be difficult to carry out in a busy clinic setting.

Oguz., *et al*. conducted a study on acoustic voice measurement using Praat software in 18 UVFP patients and 72 healthy volunteers. The participants were asked to sustain vowel /a/ at a comfortable pitch, constant amplitude and flat tone, by using a Shure C606N cardioid microphone (Shure Inc., Niles, IL, USA). This study results showed that the mean vocal intensity recorded at comfortable loudness was lower in the UVFP group (66.79 ± 4.02 dB) compared to the healthy group (68.72 ± 4.85 dB) but it was not statistically significant. The phonation task was performed in their usual daily pitch without background noise. This kind of phonation may

contribute to the non-statistical different results between the UVFP and healthy group. Therefore, the author proposed that measuring maxVI using sustained vowels may be a better tool and easy to perform in voice monitoring of UVFP patients. Phonating sustained vowels may avoid the dialectical and articulatory variations biases among speakers [17].

D'alatri., *et al.* studied speech range profile in 148 dysphonic patients that includes 25 UVFP patients [18]. The speech range profile involved measurements of the lowest and highest frequency of voice as well as minimum vocal intensity using a Computerized Speech Lab (model 4300B; Kay Elemetrics), recording with a Shure model SM48 microphone (Evanston, IL). The participants were instructed to read aloud standardised sentences, and say /a/ at maximum loudness. Three repeated recordings were done and the mean value of parameters for each recording was analyzed using ANOVA. Although this is not the recommended statistical analysis in assessing variations between repeated measurements of the three parameters, the results showed small difference between readings thus not statistically significant. It may indicate that these parameters were reliable to be used as outcome measures. However, this study exclusively investigated objective acoustic parameters without evaluating the parameters' correlation with the participants' voice perception.

In the present study, the authors chose VHI-10 in evaluating the correlation between the studied objective parameters and subjective participants' voice perception. Rosen., *et al*. validated VHI-10 in 2004 which is a tool or questionnaire to measure the score of perception of voice [19]. It is a concise tool for initial and follow-up assessment for all types of patients with dysphonia. Studies comparing the level of voice handicap in UVFP and other voice disorder groups observed that the handicap score was persistently higher in the UVFP than the latter [19-21]. Although the VHI-10 has been good in differentiating between voice disorder and healthy group but Gillespies., *et al*. documented its weak correlation with objective parameters of acoustic and aerodynamic analysis except for average airflow in speech (dB SPL). In this study, the aerodynamic analysis was done using PAS6600 KayPENTAX while the participants say /pa pa pa pa pa/. On the other hand, the present study depicted significant good negative correlation between VHI-10 and maxVI ($r = -0.63$, $p < 0.01$) in which the latter was measured using sound level meter at 100cm from the participants.

Limitation of study

About 50% of the UVFP group in the present study had received surgical interventions with various methods. This may confound the study results as treated patients may have improved dysphonic voices. Nevertheless, although there was a mixture of treated and non-treated cases, the maxVI and VHI-10 of the UVFP group were significantly less and worse, respectively, than the healthy volunteers ($p < 0.01$). This observation was similarly found in other studies [20,21]. Future studies are recommended to investigate the correlation between the severity as well as change of voice perception over time, and vocal intensity by recruiting untreated UVFP patients undergoing treatment prospectively is recommended to investigate.

The RPR of the UVFP patients was not significantly different from the healthy volunteers. This result shows that there is similarity of voice pitch between UVFP and healthy volunteers when they are talking in a comfortable voice in a silent room. This normal voice pitch is common in compensated UVFP. On the other hand, SPR managed to show the difference between the two groups in which, it was significantly lower in the UVFP than the healthy volunteers ($p < 0.01$). Therefore, the SPR may be a better method of measurement, but, its internal consistency was only substantial with the lower bound of the ICC was of 0.44. This unfavourable results may be attributed to the artifacts produced by the recorded glissando voices [13].

Clinical applicability

Vocal intensity at maximum loudness (maxVI) is a parameter that can easily be measured in a silent room in clinics. The test to measure this does not require a high skill hence it can be done by any support staffs with brief training. The instrument that is used to measure the maxVI is available in most of ORL clinics that provide pure tone audiometry test as it is used to monitor the ambient noise in a sound treated room. Evaluating UVFP patients' maxVI together with assessment of voice perception using a validated questionnaire like VHI-10 may help with treatment decision-making, monitoring progress and outcome in clinical settings as well as trials.

Conclusion

Vocal intensity at maximum loudness (maxVI) persistently showed good study results depicted by its excellent reliability, ability to differentiate between UVFP and healthy volunteers and good correlation with VHI-10. Thus, MaxVI may potentially be used as a primary outcome measure in future clinical trials related to UVFP.

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Declaration of Conflicting Interest

The authors declared no conflicting interest in executing the research and writing the manuscript.

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