A Preliminary Quantitative Comparison of Vibratory Amplitude Using Rigid and Flexible Stroboscopic Assessment

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Summary: Study Objective. The purpose of this study was to establish preliminary, quantitative data on amplitude of vibration during stroboscopic assessment in healthy speakers with normal voice characteristics. Amplitude of vocal fold vibration is a core physiological parameter used in diagnosing voice disorders, yet quantitative data are lacking to guide the determination of what constitutes normal vibratory amplitude.

Methods/Study Design. Eleven participants were assessed during sustained vowel production using rigid and flexible endoscopy with stroboscopy. Still images were extracted from digital recordings of a sustained /i/ produced at a comfortable pitch and loudness, with F_0 controlled so that levels were within ±15% of each participant's comfortable mean level as determined from connected speech. Glottal width (GW), true vocal fold (TVF) length, and TVF width were measured from still frames representing the maximum open phase of the vibratory cycle. To control for anatomic and magnification differences across participants, GW was normalized to TVF length. GW as a ratio of TVF width was also computed for comparison with prior studies.

Results. Mean values and standard deviations were computed for the normalized measures. Paired *t* tests showed no significant differences between rigid and flexible endoscopy methods. Interrater and intrarater reliability values for raw measurements were found to be high (0.89–0.99).

Conclusions. These preliminary quantitative data may be helpful in determining normality or abnormality of vocal fold vibration. Results indicate that quantified amplitude of vibration is similar between endoscopic methods, a clinically relevant finding for individuals performing and interpreting stroboscopic assessments.

Key Words: Amplitude–Vibratory amplitude–Stroboscopy–Rigid stroboscopy–Flexible stroboscopy.

INTRODUCTION

Vocal fold vibration patterns determine the acoustic and perceptual characteristics of the voice. Vibratory parameters assessed during stroboscopic evaluations include mucosal wave propagation, phase symmetry, periodicity, phase closure, and vocal fold amplitude.[1–4] Amplitude of vibration is defined as the extent of horizontal excursion from the midline during phonation and is a critical feature in evaluating vocal fold movement.[5] Normal extent and range of vocal fold amplitude are needed for appropriate voice intensity and intensity variation in speech. Changes in vibratory amplitude can significantly impact an individual's vocal quality, resulting in increased breathiness, hoarseness, or altered pitch.[6–11] Abnormal amplitude of vibration may also be indicative of a vocal pathology or recurrent disease in individuals previously diagnosed with a vocal pathology.[6,10] Having a better understanding of amplitude of vibration in normal voices could provide baseline information for clinicians who are treating individuals whose vibratory amplitude may be impacted secondary to a voice disorder.

Stroboscopic parameters are commonly evaluated in an observational manner through the use of nominal or ordinal rating systems.[1,3,4,12–14] Assessment of vocal fold amplitude is typically done by rating each vocal fold separately through designation of either a percentage of excursion or a number within a specified range for each respective fold. The Stroboscopy Examination Rating Form (SERF) introduced by Poburka[1] uses a grid-based diagram of the vocal folds in combination with an ordinal percentage scale (2–10, in multiples of 2) when rating amplitude of vibration. However, amplitude of vibration has been shown to have the lowest interrater reliability among the stroboscopic measures on the SERF, as well as a higher incidence of intrarater variability.[14] Researchers have also developed custom ordinal[12] or continuous scales[3] when rating amplitude of vibration. Although these methods provide important ways to characterize amplitude of vibration, they remain qualitative in nature and rely on subjective assessment. This subjectivity can be problematic for the reliability of such ratings when used with stroboscopic evaluation.[14–17] For improved reliability, objective methods for the assessment of vocal fold amplitude from stroboscopic examinations are needed.

The limited number of studies addressing quantified measurement of vocal fold amplitude may be related to the challenges that are inherent in those measurements when performed on human endoscopic recordings. Differences in lens to vocal fold tissue distance, size, and position of anatomic structures, as well as examiner differences, present challenges in measuring and comparing vibratory parameters across individuals.[6,18,19] To address these issues, vocal fold measurement requires the use of normalization, in which the variable of interest is normalized to a standard measure such as vocal fold length or glottal area within the same image or

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subject.[18–20] In a seminal study representing one of the first quantified videostroboscopic analyses, Woo[21] determined glottal area (normalized to glottal length) for 65 women and men with normal voice and laryngeal structure. Pitch and loudness were controlled through the use of target ranges for each subject. Although vibratory amplitude was not specifically measured in this study, Woo[21] described the amplitude of vibration as being approximately one-half to one-third the visible width of the true vocal folds (TVFs), similar to reports by Hirano and Bless.[22] Many subsequent researchers have used this approximation as a guideline for what is considered normal amplitude of vibration.[3,23] Recently, the American Speech-Language Hearing Association's Ad Hoc Committee on Instrumental Voice Assessment Protocols presented a recommendation that vibratory amplitude should be "approximately half (50%) of the visible width of the vocal fold at typical pitch and loudness."[24]

Improved technology has allowed for more accurate measures of vibratory amplitude during endoscopy, and additional studies have included quantified vibratory measurements in people with and without voice disorders.[25–28] Several vibratory measures can be quantified using high-speed videoendoscopy (HSV) with associated instrumentation or software for analysis. When using HSV with a laser projection device for calibration, excursion can be measured in millimeters and does not require normalization. Published studies using this coupled system *in vivo* have reported vibratory amplitudes of approximately 0.84 to 1.0 mm in adults.[25,26,28] However, these findings are difficult to interpret, as the variables of intensity and fundamental frequency were not controlled for. These factors can affect amplitude of vibration.

In a controlled study using an artificial vocal fold model and a laser projection device coupled to a standard rigid endoscope, Popolo and Titze[28] reported an average glottal width (GW) of 4.2 mm across three trials. When divided by 2 to account for the excursion of each vocal fold, this value of 2.1 mm is more than double the estimates provided by Schuberth et al[25] and Patel et al[26] from their *in vivo* measurements. These differences highlight the need for measuring amplitude of vibration *in vivo* while controlling for variables that affect amplitude. Furthermore, although the use of HSV coupled with a laser projection device is innovative, these combined technologies are not currently available for use in most clinical settings. It is important to determine whether human amplitude measurements, obtained in typical clinical recording conditions, are similar or different to absolute values that were derived from artificial vocal fold models or from advanced but limited-access technology.

In many voice clinic settings, laryngologists and speech-language pathologists have access to rigid and flexible endoscopy and will use one or both technologies to assess laryngeal structure and function. Because of advances in flexible endoscopes and the degree of light intensity that they can transmit, stroboscopic examinations can now be performed with both types of endoscopy. The resulting video image, however, can differ in degree of magnification, brightness, and clarity. Furthermore, positioning differences of the patient relative to each endoscopic method may alter the laryngeal parameters being assessed.[29] These differences may affect either subjective ratings or quantified pixel-based measurements of vibratory amplitude because the target measurement range is small (around 1–2 mm in prior studies), measurement depends on accurate demarcation of tissue boundaries, and measurement requires positioning of anatomic structures so that views of the glottis and vocal fold margins are maximized. To date, few studies have compared vibratory parameters as measured by both rigid and flexible endoscopy to determine the effect of endoscopic method.

Given the common clinical availability and use of both types of endoscopy, a comparative, quantified assessment of vibratory amplitude in healthy human speakers is needed. By quantifying vibratory amplitude under controlled but clinically realistic voice conditions, preliminary objective data can serve as a baseline from which abnormal amplitude can be better assessed. These data can then be compared with data produced from other *in vivo* studies. The objectives of the present study were to (1) obtain preliminary data regarding amplitude of vibration in nonprofessional voice users with normal voice and speech, (2) assess and quantify amplitude of vibration during controlled, typical phonation using pixel-based measurement, and (3) compare results between two methods of videostroboscopic imaging: rigid endoscopy and flexible endoscopy.

METHODS

Participants

The present study was approved by the institutional review board (IRB) at SUNY Upstate Medical University and Syracuse University. All participants provided informed consent and were paid for their participation. Participants were recruited from the university area using IRB-approved flyers and university online news postings. Before study enrollment, a brief phone screening was conducted to assess basic eligibility for individuals interested in enrolling. Participants qualified for the study if they met the following criteria: they were in good current health, were not previously diagnosed with a voice disorder or head/neck injury, did not report a sensitive gag reflex (to limit individuals who would not be able to tolerate endoscopy procedures), and showed no evidence of laryngeal pathology (per screening conducted by the laryngologist during the study). To limit age-related laryngeal changes, younger adults were recruited between the ages of 22 and 29 years.[5] In addition, individuals who considered themselves professional voice users were excluded from the present study to rule out any potential differences between trained and untrained voices. A brief questionnaire regarding basic voice and health history was completed by all participants.

A total of 17 participants enrolled in the study, with 11 participants who completed all study procedures and produced images that met quality requirements for both endoscopy tasks. Six participants were excluded because of difficulty completing