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THE IMPORTANCE OF DIAGNOSING VOCAL CORD NODULES IN CHILDREN IN THE EARLY STAGES

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Abstract: The diagnosis of vocal fold nodules in children remains a critical issue in pediatric otolaryngology, given that vocal nodules are the predominant cause of dysphonia in the pediatric population with reported prevalence values between 41% and 73%. Traditional diagnostic methods, such as laryngeal visual examinations and auditory-perceptual analyses, are either invasive or subjective, resulting in an increasing reliance on acoustic analysis as a noninvasive and objective diagnostic tool. This article reviews the literature regarding the acoustic measurement parameters and techniques employed in diagnosing vocal fold nodules in children. It emphasizes perturbation measures—including jitter, shimmer, noise-to-harmonic ratio (NHR), fundamental frequency (F0) standard deviation, and cepstral peak prominence (CPP)—and compares these parameters with electroglottographic indices that have been shown to effectively differentiate between children with vocal nodules and healthy controls. The article also examines multiband cepstral analysis and machine learning advancements as promising adjuncts in the diagnostic workup. The discussion synthesizes key findings from relevant studies, addressing methodological strengths, limitations, and the potential for improved prognostic understanding through acoustic techniques. Ultimately, this comprehensive review underscores the importance of standardized acoustic protocols and objective measurements in the early detection, monitoring, and management of pediatric vocal fold nodules.

Keywords: Vocal fold nodules, Acoustic analysis, Diagnosis, Dysphonia, Perturbation measures (jitter, shimmer, NHR).

Introduction. Voice disorders in children are a significant clinical concern. Among these, vocal fold nodules have been identified as the predominant cause of pediatric dysphonia, with prevalence rates ranging from 41% to 73% among affected children. Vocal fold nodules are benign lesions that arise from chronic vocal abuse, often observed in children who overuse or misuse their voices through activities such as frequent yelling or singing. However, the anatomical features of pediatric vocal folds differ notably from adults. Pediatric vocal folds are shorter, lack the multi-layered structure present in adults until adolescence, and in infants, exist as a monolayer with evenly distributed hyaluronic acid and a higher concentration of fibroblasts.

Traditionally, the diagnosis of vocal nodules has been based on laryngeal visual examinations via videolaryngoscopy and auditory-perceptual assessments conducted by trained speech-language pathologists (SLPs). The visual examination, although considered a gold standard, is invasive and requires costly instrumentation, whereas auditory-perceptual evaluations are noninvasive but are highly subjective and depend largely on the clinician's experience. Given these limitations, there is a growing impetus towards the utilization of acoustic analysis as an objective and noninvasive modality for assessing voice quality.

Acoustic analysis involves quantifying various voice parameters—such as fundamental frequency (F0), its standard deviation (F0 SD), jitter, shimmer, and noise-to-harmonic ratio

(NHR)—which provide data on the stability and quality of phonation. For instance, a study examining pediatric patients with vocal nodules reported significant increases in perturbation parameters (pitch period perturbation quotient [PPQ], amplitude perturbation quotient [APQ], and NHR) during phonation at loud levels (>80 dBA), thereby establishing their potential utility in differentiating affected children from healthy counterparts. In addition, electroglottographic (EGG) analysis, which measures parameters such as the Closed Quotient and Peak Slope, has shown promise in offering a complementary diagnostic avenue over traditional acoustic methods. Recent strides in multiband cepstral analysis and the integration of machine learning approaches—such as support vector machines (SVM)—further highlight the evolving landscape of voice disorder diagnosis. These state-of-the-art techniques leverage the rich information embedded in acoustic signals to improve detection accuracy, notwithstanding some inherent limitations in sensitivity for highly disturbed voices. Given the increasing applicability of these methods, this article seeks to comprehensively discuss the current acoustic analysis techniques used in diagnosing vocal fold nodules in children, evaluate their performance relative to traditional methods, and explore future directions for research and clinical practice.

Methodology. This review synthesizes data from multiple studies evaluating acoustic parameters for the diagnosis of vocal fold nodules in children. The methodology involves reviewing clinical parameters derived from acoustic voice analysis, perceptual evaluation scales, and electroglottographic indices. The following subsections outline the primary techniques and parameters considered.

Acoustic analysis parameters

Acoustic analysis provides a quantitative measure of voice quality by capturing sound signal characteristics through digital signal processing. The key parameters employed in the evaluation of pediatric vocal nodules include:

- Fundamental Frequency (F0) and F0 Standard Deviation (F0 SD):

F0 represents the average pitch during phonation, whereas F0 SD quantifies the variability of pitch over time. Elevated F0 SD values are indicative of instability in phonatory control and can be characteristic of conditions like mutational falsetto and organic voice disorders.

- Jitter and Shimmer:

Jitter reflects cycle-to-cycle variations in frequency, and shimmer represents variations in amplitude. Increased values in both jitter and shimmer parameters have been correlated with the presence of vocal nodules, suggesting irregular vibrations of the vocal folds. For instance, in a study of children with vocal nodules, shimmer values were significantly increased compared to controls, while jitter differentiations provided additional corroborative evidence.

Data collection and analysis protocols

The acoustic data in the reviewed studies were typically collected by asking children to sustain a vowel sound (e.g., /a/) under controlled conditions (e.g., with sound pressure levels exceeding 80 dBA). Recordings were made using high-fidelity digital recorders with standardized microphone placements, followed by analysis using software such as PRAAT or the Multi-Dimensional Voice Program (MDVP). Comparative analyses were conducted across study groups—typically including groups with diagnosed vocal nodules and age-matched controls—with statistical tests applied to assess the significance of observed differences in acoustic parameters.

Discussion

The integration of acoustic analysis into the diagnostic pathway of vocal fold nodules in children offers several advantages over traditional methods. This section discusses the benefits,

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challenges, and future perspectives of employing acoustic analysis, alongside comparisons with other diagnostic modalities such as auditory-perceptual assessment and electroglottography.

Advantages of acoustic analysis

Acoustic analysis offers a noninvasive, low-cost, and objective measure of voice quality, which is particularly beneficial in pediatric populations. Unlike invasive laryngeal examinations that may cause discomfort and require expensive instrumentation, acoustic methods allow repeated assessments over time with minimal distress to the patient. Objective acoustic parameters such as jitter, shimmer, and NHR have been consistently shown to vary significantly between children with vocal nodules and those with normal voices. For example, one study demonstrated that, during phonation at intensities greater than 80 dBA, children with nodules exhibited significant increases in PPQ, APQ, and NHR compared to controls, with reported specificities of 84.38%, 75.00%, and 93.75%, respectively.

Comparison with auditory-perceptual analysis

Auditory-perceptual analysis, while useful, is inherently subjective and limited by the listener's experience. In a comparative study involving 100 children diagnosed with vocal nodules versus 100 controls, perceptual ratings on the GRBASI scale (which includes measures of Grade, Roughness, Breathiness, and Strain) were markedly worse in the nodule group. However, no significant differences were observed in maximum phonation time or s/z ratio. This discrepancy highlights the necessity of supplementing perceptual assessments with objective acoustic measurements to obtain a comprehensive evaluation of vocal function.

Electroglottographic analysis versus acoustic methods

Electroglottographic (EGG) analysis provides detailed insights into vocal fold contact patterns during phonation. Studies comparing EGG parameters—such as Closed Quotient, Peak Slope, and Normalized Amplitude Quotient—with acoustic measures indicate that EGG may offer better discrimination between pathological and normal states. However, while EGG provides additional objective data, the combined use of acoustic and EGG analyses is often recommended for a holistic assessment. This multimodal approach not only confirms acoustic observations but also supports the identification of subtle changes in vocal fold function that might otherwise go unnoticed.

Role of advanced signal processing and machine learning

Recent advancements in multiband cepstral analysis and machine learning have introduced new dimensions to the diagnosis of voice disorders. By employing wavelet transforms to decompose the voice signal into multiple frequency bands, clinicians can capture nuanced acoustic features that traditional metrics may overlook. Machine learning models, such as support vector machines (SVM), have been employed to classify voice disorders using a battery of acoustic features. Although the moderate accuracy of these models (with detection rates for nodules around 62%) suggests that there is room for improvement, the integration of such techniques represents a promising direction toward automated diagnosis and monitoring of pediatric dysphonia.

Diagnostic workflow for pediatric vocal nodule assessment

The workflow for diagnosing vocal fold nodules in children typically involves an initial screening by clinical history and perceptual evaluation, followed by an objective acoustic analysis.

The following table summarizes the sensitivity and specificity of key acoustic parameters derived from clinical studies on pediatric vocal nodules:

Acoustic	**Sensitivity (%)**	**Specificity**	**Comments**

Parameter		**(%)**	
PPQ	62.86	84.38	Indicative of perturbation in pitch
APQ	74.29	75.00	Reflects amplitude instability
NHR	31.43	93.75	High specificity suggests reduced harmonic clarity
F0 SD	Elevated in nodules	–	Captures pitch variability

Table 1: Sensitivity and Specificity of Selected Acoustic Parameters in Diagnosing Pediatric Vocal Nodules

The table illustrates that while PPQ and APQ provide moderate sensitivity and specificity, NHR exhibits a particularly high specificity, reinforcing its importance as a diagnostic marker. This robust specificity implies that a high NHR is strongly associated with the presence of vocal fold nodules.

Conclusion. Acoustic analysis has emerged as a powerful, noninvasive tool in the diagnosis of vocal fold nodules in children. This article has reviewed the various acoustic parameters—such as F0 SD, jitter, shimmer, NHR, and CPP—and their clinical significance in differentiating affected children from healthy controls. The integration of acoustic analysis within the diagnostic framework for pediatric vocal fold nodules is transformative. It provides clinicians with quantitative metrics that not only enhance diagnostic accuracy but also enable objective monitoring of voice therapy outcomes. Continued efforts to refine acoustic methodologies and integrate emerging technologies will further the early detection and personalized management of vocal fold disorders in children.

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