

Vocal Fold Paresis: Incidence, and the Relationship between Voice Handicap Index and Laryngeal EMG Findings

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Summary: Objective. To determine whether there is a correlation between Voice Handicap Index 10 (VHI-10) and degree of vocal fold paresis as determined by laryngeal EMG. Secondary objective was to determine the incidence of vocal fold paresis in a tertiary laryngology practice.

Methods. A retrospective chart review of all new voice patients seen by the senior author (RTS) from January 1, 2016 to December 31, 2017. Subjects completed VHI at their initial visit. Patients were examined with flexible and rigid laryngoscopy and videostroboscopy and referred for laryngeal electromyography (LEMG) if neuromuscular weakness was suspected. LEMG was used to identify the affected nerves and to quantify subjectively the degree of paresis. Patients who did not complete LEMG and or handicap index were excluded from the correlation analysis.

The prevalence of vocal fold paresis was determined by reviewing the records of each subject. The number of patients diagnosed clinically with paresis or paralysis and referred for LEMG was documented.

Results. The subjects, who had paresis confirmed on LEMG ($n = 210$) were grouped according to the nerves involved and by the degree of paresis. The unilateral superior laryngeal nerve and ipsilateral recurrent laryngeal nerve paresis group ($n = 29$) had a reasonably even distribution of patients in each sub-group ($n = 11; 12; 6$) and was analyzed for correlation. There was a strong positive correlation between the degree of paresis and the VHI score ($r = 0.59, P < 0.001$). Other groups did not have an even distribution among sub-groups and could not be to be analyzed for correlation.

The senior author examined 344 new voice patients during years of 2016 and 2017. Based on laryngoscopy, 335 patients were referred for LEMG (97.4%). Two hundred thirty-seven patients had LEMG performed, and 234 patients confirmed to have vocal fold paresis were confirmed (98.7%). The incidence of vocal fold paresis in subjects who underwent LEMG or who had normal motion during laryngoscopy was 95.1% (234 out of 246). The incidence in the 98 subjects who did not complete the recommended LEMG is unknown.

Conclusion. The unilateral superior laryngeal nerve with ipsilateral recurrent laryngeal nerve paresis was the only group that allowed for analysis whether patient's perception of their voice problem as measured VHI-10 correlated with increasing degree of vocal fold paresis. A strong significant positive correlation in this group was identified. Additional studies with a larger patient cohort are recommended.

Key Words: Vocal fold paresis—Voice handicap index—Hoarseness—Dysphonia—Laryngeal electromyography—Electromyography.

INTRODUCTION

Vocal fold paresis is a complex vocal impairment the importance of which was not recognized until the last couple of decades. Previously, otolaryngologists regarded the concept of vocal fold paralysis as an all or none phenomenon that manifested as vocal fold immobility with the absence of neural input.^{1,2} However, electrophysiologic studies have demonstrated that vocal fold paresis exists on a continuum of neurologic dysfunction. Vocal fold paralysis is on one end of the spectrum with a complete lack of neural input and voluntary vocal fold immobility, while

vocal fold paresis includes of various degrees of denervation that can result in grossly preserved vocal fold mobility on routine examination.^{1,3,4} As a result, it is often challenging to identify and diagnose mild vocal fold hypomobility especially when bilateral weakness and or compensatory behaviors are present.

Diagnosing vocal fold paresis involves laryngoscopy and stroboscoped laryngoscopy, as well as laryngeal electromyography (LEMG). It is often difficult to diagnose paresis definitively from laryngoscopy alone because of the preserved vocal fold mobility.^{5–8} However, an examination with repetitive phonatory gestures that is long enough to cause mild fatigue usually reveals motion abnormalities if paresis is present.^{9,10,11} It is important to be certain that the laryngeal motion impairment seen on laryngoscopy is not caused by a mechanical impairment such as arytenoid cartilage dislocation or subluxation, cricoarytenoid arthritis, or ankylosis, or neoplasm.^{6,12,13} LEMG is used routinely to evaluate the integrity of neural input to the muscles of the larynx.^{8,12,13} LEMG can help differentiate disorders affecting the superior and recurrent laryngeal nerves from those

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affecting laryngeal joints, neuromuscular junctions, or muscles of the larynx. It also can determine the etiology and severity of some vocal fold mobility disorders. LEMG is the gold standard to confirm paresis, with decreased recruitment as the most reliable indicator of paresis.^{12–14}

Although vocal fold paresis has been accepted as a clinical entity distinct from paralysis, its prevalence remains unknown. There are few studies in the literature that utilize laryngeal electrography routinely to confirm or refute suspected vocal fold paresis or paralysis to establish incidence accurately. Heman-Ackah et al identified 19 cases of vocal fold paresis in 22 (86%) suspected patients with a clinical diagnosis of vocal hypomobility over a 13-month period.¹⁵ Koufman et al had similar results and identified 50 patients with vocal fold paresis over a 4-year period.¹⁶ The senior author (RTS) published a study on the incidence of superior laryngeal nerve paresis over 20 years ago, which identified 71 cases of superior laryngeal nerve (SLN) paresis and 55 cases of SLN paralysis over a 7-year period.¹⁷ Simpson et al diagnosed 13 patients with LEMG confirmed paresis out of 195 patients with clinically suspected paralysis over a 4-year period.¹⁸

Vocal fold paresis can be a debilitating condition that may have a considerable impact on a patient's voice, swallowing and airway function.¹² Sataloff et al reported a correlation between the severity of paresis and the treatment required to achieve satisfactory outcomes.^{12,14} In another study, Harris et al compared the mean Voice Handicap Index (VHI) between patients with vocal fold paresis and paralysis and found no difference between the groups.¹⁹ However, there have been no studies exploring a potential relationship between the degree of paresis and the VHI score. Our clinical experience leads us to believe that vocal fold paresis is still underdiagnosed and needs to be examined in greater detail. The senior author (RTS) evaluates all new patients presenting with a voice complaint with a comprehensive examination including laryngoscopy, stroboscopy, and if paresis is suspected, LEMG. The objective of this study was to determine the incidence of vocal fold paresis and to examine whether the degree of paresis correlates with the patient's perception of his/her vocal handicap as assessed by VHI-10.

METHODS

A retrospective chart review of all new voice patients examined by the senior author (RTS) from January 1, 2016 to December 31, 2017 was performed. Patients were classified as new if they had never been seen in the practice, if they had not been seen for over a year, or if they had been referred to the senior author from another member of the practice and the patients had not been evaluated previously by the senior author (RTS). The patients completed a VHI-10 questionnaire during the initial office visit.²⁰ Each patient's chart was reviewed, and data on age, sex, chief complaint, medical history, surgical history, stroboscopy findings, VHI-10 score, and LEMG results were

collected. Patients with incomplete records and patients under 18 years of age were excluded from the study. This study was approved the Drexel University of College of Medicine Institutional Review Board.

Patients were examined with laryngoscopy and stroboscopy using both flexible chip-tip and rigid laryngoscopes. Our previously published examination protocol includes multiple maneuvers to assess laryngeal dynamics performed with all new patients and intended to identify weakness.^{9–11} Patients were referred for LEMG if neuromuscular weakness and laryngeal movement abnormalities were suspected. The LEMGs were performed by either the senior author (RTS) or referred to another laryngologist in the practice experienced in electromyography. LEMG were performed using monopolar electrodes (Natus) with XLTEK NeuroMax 1002 laptop.^{12,14,21} LEMG was used to sample the thyroarytenoid, cricothyroid, and posterior cricoarytenoid muscles, identify weakness in the distribution of the affected nerves, and to quantify the degree of paresis using techniques described previously.^{5,6}

The incidence of vocal fold paresis was determined by reviewing the records of each new voice patient evaluated by the senior author during this time period (2016–2017). The number of patients diagnosed clinically with paresis on stroboscopy and referred for LEMG was documented, and the number of patients with paresis confirmed by LEMG was used to calculate the incidence of vocal fold paresis.

Patients were grouped into cohorts based on nerve dysfunction, and subdivided further by the degree of paresis into mild, moderate, and severe groups. A decrease in recruitment of 1%–30% was classified as mild paresis, 31%–60% was moderate paresis, and 61%–100% was severe paresis.¹⁰ These groups were assigned scores of one, two and three, respectively, in order to perform statistical analysis. In patients with more than one nerve involved, the subgroup was determined by the most severely affected nerve. IBM SPSS statistical software was used for the analysis. A Pearson correlation was calculated only in groups with a normal distribution of severity. The mean VHI of each cohort was calculated, and comparisons were made using Student's *t* test.

RESULTS

The senior author (RTS) examined 344 new voice patients during the years 2016 and 2017. Based on a comprehensive history, physical and stroboscopy examination, 335 (97.4%) were diagnosed clinically with suspected vocal fold paresis. He referred all of these patients for LEMG. 98 of those referred patients did not complete LEMG and were removed from the analysis. Of those who completed LEMG, 234 (98.7%) patients had confirmed vocal fold paresis with evidence of neuropathy in one or more nerves. Therefore, the incidence of vocal fold paresis in our population of patients who completed evaluation was 95.1% (234 out of 246). The average age of patients with vocal fold paresis was 48.9 ± 18.05 years; 96 (41%) of

TABLE 1.
Demographic Data of All Patients With Vocal Fold Paresis

| Characteristic | Value |
|------------------|---------------------|
| Mean age (years) | 48.9 (\pm 18.05) |
| Female gender | 138 (59%) |

TABLE 2.
Incidence of Vocal Fold Paresis

| Type of Paresis | N | Female | Mean Age |
|-------------------------|------------|------------|----------|
| Unilateral SLN | 102 (43%) | 61 (59.8%) | 47.0 |
| Unilateral RLN | 10 (4.2%) | 6 (60%) | 51.9 |
| Bilateral SLN | 44 (18.6%) | 26 (59%) | 48.6 |
| Bilateral RLN | 4 (1.7%) | 3 (75%) | 39.3 |
| Ipsilateral SLN + RLN | 31 (13.1%) | 18 (58%) | 53.1 |
| Contralateral SLN + RLN | 10 (4.2%) | 4 (40%) | 47.2 |
| Bilateral SLN + RLN | 13 (5.5%) | 9 (69.2%) | 43.1 |
| SLN + Bilateral RLN | 10 (4.2%) | 5 (50%) | 49.4 |
| 4 nerves | 10 (4.2%) | 6 (60%) | 52.6 |
| none | 3 (1.26%) | 2 (66.7%) | 57.0 |

the patients were men and 138 (59%) were women. The patient demographics are summarized in [Table 1](#).

LEMG was utilized to identify the affected nerves and determine the different groups of vocal fold paresis. The LEMG results and demographics of patients with confirmed paresis ($n = 234$) are summarized in [Table 2](#). The most common type of paresis identified was unilateral superior laryngeal nerve (SLN) paresis, with a total of 102 (43.5%) patients who underwent LEMG, 61 of whom were female (59.8%). Bilateral SLN paresis ($n = 44$, 18.8%) was the second most common type of paresis identified. Vocal fold paresis isolated to only a unilateral recurrent laryngeal nerve (RLN) was relatively rare in our cohort ($n = 10$, 4.3%). There were four (1.7%) patients with bilateral RLN paresis, which was the least common type of paresis identified. There were 31 (13.2%) patients identified with ipsilateral SLN and RLN paresis. Contralateral RLN and SLN

TABLE 4.
Showing All Vocal Fold Paresis Groups Used for Statistical Analysis

| Type of Paresis | Mean Age | Mean VHI | Female Gender |
|--------------------------------|----------|----------|---------------|
| Mild ipsilateral SLN + RLN | 51.5 | 11.45 | 6 (54.5%) |
| Moderate ipsilateral SLN + RLN | 51.1 | 20.83 | 7 (58.3%) |
| Severe ipsilateral SLN + RLN | 53.8 | 28.86 | 4 (66.7%) |
| Mild unilateral SLN | 46.1 | 15.58 | 53 (59.5%) |
| Mild bilateral SLN | 49.6 | 15.49 | 22 (55%) |

paresis was less common ($n = 10$, 4.3%). Vocal fold paresis that involved three or more affected nerves was relatively uncommon. There were 13 (5.6%) patients with bilateral SLN and unilateral RLN paresis, 10 (4.3%) patients with unilateral SLN and bilateral RLN paresis, and 10 (4.3%) patients with all four nerves affected (bilateral SLN and bilateral RLN). The incidence of vocal fold paresis is summarized in [Table 2](#).

Patients with complete records who had paresis confirmed on LEMG and completed a VHI at their initial visit ($n = 210$) were grouped according to the nerves involved and by the degree of paresis, as summarized in [Table 3](#). The unilateral SLN and ipsilateral RLN paresis group ($n = 29$) had an adequate distribution of patients across subgroups of severity (11 mild, 12 moderate, and six severe) to allow for correlation analysis. The mean VHI of each subgroup of ipsilateral SLN and RLN was 11.45 for mild, 20.83 for moderate, and 28.86 for severe, as summarized in [Table 4](#). There was a strong positive correlation found between the degree of paresis and the VHI score ($r = 0.59$, $P < 0.001$) which can be seen in [Figure 1](#). High VHI scores indicate worse voice as perceived by the patient than low scores.

The mean VHI-10 score also was compared between those subgroups with an adequate number of patients to allow for analysis. There was no significant difference identified in VHI score between unilateral (15.58, range 0–40) and bilateral SLN (15.49, range 0–40) paresis ($P = 0.45$). Two groups with two nerves affected were analyzed, and no

TABLE 3.
Vocal Fold Paresis Patients and VHI

| Type of Paresis (N) | Mild | Mean Mild VHI | Moderate | Mean Moderate VHI | Severe | Mean Severe VHI | Total |
|-----------------------------|------|---------------|----------|-------------------|--------|-----------------|-------|
| Unilateral SLN (91) | 89 | 15.58 | 2 | 18 | 0 | N/A | 91 |
| Unilateral RLN (10) | 3 | 12.67 | 0 | N/A | 7 | 19.71 | 10 |
| Bilateral SLN (40) | 39 | 15.49 | 1 | 12 | 0 | N/A | 40 |
| Bilateral RLN (4) | 0 | N/A | 2 | 8.5 | 2 | 38 | 4 |
| Ipsilateral SLN + RLN (29) | 11 | 11.45 | 12 | 20.83 | 6 | 28.86 | 29 |
| Contralateral SLN + RLN (8) | 3 | 24.67 | 4 | 15.25 | 1 | 21 | 8 |
| Bilateral SLN + RLN (11) | 5 | 19 | 3 | 18 | 3 | 26 | 11 |
| SLN + Bilateral RLN (9) | 3 | 4 | 6 | 10.83 | 0 | N/A | 9 |
| 4 nerves (8) | 2 | 23.5 | 1 | 35 | 5 | 28.2 | 8 |

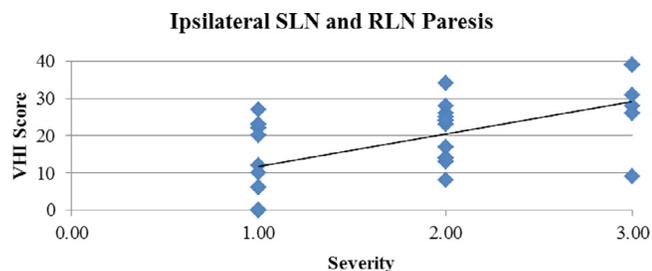


FIGURE 1. Correlation between vocal fold paresis severity and VHI score in patients with ipsilateral SLN and RLN paresis.

significant difference was found ($P = 0.13$) between the VHI in the 11 patients with a mild ipsilateral SLN and RLN paresis (10.29, range 0–27) and bilateral SLN paresis (15.49, range 0–38). The results are summarized in Table 5.

DISCUSSION

This study confirms that vocal fold paresis is a common and probably underdiagnosed condition that can be missed on routine examinations without a high degree of clinical suspicion and a lengthy, comprehensive examination, as well as the use of LEMG to confirm the diagnosis. Previously cited literature only reported 19 patients with vocal fold paresis over 13 months, and 50 patients with paresis over 4 years.^{15,16} The incidence of vocal fold paresis in our patient population was 97.4%, which may be surprisingly high. However, the majority of our patients were professional voice users who may have presented with subtle complaints that might not have led to a physician visit for other patients and might not have prompted a full evaluation during a general otolaryngology visit. Also, the examination protocol that we utilize is designed to fatigue the patient and bring out underlying vocal fold motion abnormalities.^{9–11} We reviewed the length of our flexible and rigid laryngoscopy evaluations and found that total examination time was approximately 6 minutes and 41 seconds, including 1 minute and 52 seconds for rigid examination. The length of our exams at initial evaluation can explain the high rate of suspected paresis and LEMG referrals. Vocal fold motion asymmetries may not present until after 30–60 seconds of phonation with repetitive phonatory tasks.¹¹

The most common type of vocal fold paresis identified in our patient cohort was unilateral SLN paresis (43.5% of patients). The SLN nerve was also the most commonly

affected nerve overall in our study. SLN paresis is likely the most common because it is a small nerve that innervates only the cricothyroid muscle. The cricothyroid muscle does not have substantial accessory innervation, thus slight dysfunction in the nerve can result in symptoms.^{12,13} Even mild paresis of the SLN can result in difficulty with phonation, difficulty projecting the voice, instability, other symptoms, and lead to compensatory muscle tension dysphonia, and sometimes structural injury.¹² Unilateral RLN paresis was the least common type of vocal fold paresis in our cohort (4.3%). The low incidence of unilateral RLN paresis and multiple nerve vocal fold paresis can be attributed to our patient population. The senior author sees primarily professional voice users with mobile vocal folds and mild nerve dysfunction. Patients who have vocal fold paresis secondary to surgeries that expose the SLN and RLN are likely to have a higher severity of paresis if the nerve is injured. Thus, the findings would be different in a practice in which many referrals come from cardiothoracic surgeons, vascular surgeons, neurosurgeons, and endocrine surgeons. The suspected cause of nerve paresis for each patient was not reviewed as part of this study, as it has been reported elsewhere in the literature.^{6,7}

In our study, we determined that the severity of paresis does correlate with VHI-10 scores. Only one group had sufficient patients in each category of severity and was appropriate to analyze for potential correlation with VHI-10 scores. There was a strong positive correlation in the group of patients with superior laryngeal nerve and ipsilateral recurrent laryngeal nerve paresis. It is reasonable to suspect that the degree of impairment is correlated with the severity of vocal fold paresis, although we were only able to evaluate and show that in one of the permutations of nerves involved in our study. However, these results are consistent with previous research correlating LEMG severity with the extent of treatment required.¹⁴ Additional research with a larger subject pool may help determine whether the correlation exists across all combinations of nerve dysfunction. Vocal fold paresis, even when mild in severity and affecting only one muscle group in the larynx, can lead to a voice quality impairment reflected in elevated VHI score. Physicians should evaluate carefully patients presenting with elevated VHIs with voice complaints and have a high clinical suspicion for vocal fold paresis which can be missed easily, without sufficient length laryngoscopic examination using repetitive phonatory tasks and LEMG to confirm evidence of vocal fold paresis.⁵

We found no difference in VHIs between mild unilateral and bilateral SLN paresis. Although both had abnormal VHI scores (>11), it is unclear whether having weakness in one nerved compared to weakness in both superior laryngeal nerves, has an equivalent impact on voice quality, or if there would be a difference identified at higher degrees of paresis or with a larger number of subjects. However, often this may not be critical clinically as we found moderate and severe SLN paresis in the absence of RLN involvement to be rare. Our cohort had a limited range in severity of paresis

TABLE 5. Comparison of Mean VHI Between Groups and Corresponding P Values

| Comparison of Mean VHI | P Value |
|--|---------|
| Mild SLN versus mild bilateral SLN | 0.44 |
| Mild bilateral SLN versus mild SLN + RLN | 0.13 |

in patients with mild unilateral and bilateral SLN paresis, attributable to the patient population consisting of primarily professional voice users with subtle voice complaints. These professional voice users tend to have greater awareness of vocal dysfunction because of their occupational demands and are likely to seek treatment promptly.^{22,23} We also found no difference in VHI's between mild bilateral SLN paresis and mild Ipsilateral SLN and RLN paresis. This may indicate that weakness in SLN is as important as the RLN in vocal fold dysfunction.

There are several limitations in this study. The senior author (RTS) sees primarily professional voice users; and as a result, our patient population was fairly homogenous on the referral patterns. Thus, additional studies with larger and more varied cohorts perhaps multi-institutional appear advisable. Another, limitation in our study was the inability to control for all factors that can influence VHI. A patient's VHI can be affected by numerous conditions such as reflux, muscle tension dysphonia, and vocal fold pathology. We were unable to control for all these various variables that could also affect a patient's VHI. However, our patient population was uniform, and the majority of the patients in all groups of vocal fold paresis possessed multiple diagnoses. Last, the senior author (RTS) and another laryngologist in the practice performed all the LEMG; and as a result they were not blinded to the clinical history and examination of each patient as they had been in previous research.¹⁰ However, discrepancies between clinical and electrical finds were similar to those that were reported previously.¹⁰ Future prospective research could control for all the various conditions that could potentially affect VHI, blind the electromyographer to clinical findings and expand the diversity of the subjects through a multicenter collaboration.

CONCLUSION

We hypothesized that a patients' perception of his/her voice problems as measured by VHI-10 would correlate with increasing the severity of vocal fold paresis. The only group that allowed for this analysis was the unilateral SLN with ipsilateral RLN paresis group; a strong significant positive correlation in this group was identified. Although we could not demonstrate this correlation in all combinations of nerve dysfunction with our limited data, we believe that otolaryngologists should have a high clinical suspicion of vocal fold paresis in patients with an elevated VHI. Otolaryngologists should evaluate all patients with voice complaints comprehensively.

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