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VOCAL CORD NODULES: A CLOSER LOOK AT ETIOLOGY, TREATMENT, AND PREVENTION STRATEGIES.

Dr. Ahmed Fawzi Mohammed[1], Dr. Abdullah Khalaf Hamad[2], Dr. Qutaiba Ismael Khudhair[3]

1. Iraqi Ministry of Health, Al-Russafa Health Directorate, Al-Shaheed Al-Sader General Hospital, Baghdad, Iraq.
2. Iraqi Ministry of Health, Al-Russafa Health Directorate, Al-Madan General Hospital, Baghdad, Iraq.
3. Iraqi Ministry of Health, Baghdad Al-Rusafa Health Directorate, Al-Zafaraniya General Hospital, Baghdad, Iraq.

Abstract:

This retrospective cohort study evaluated the clinical efficacy of voice therapy, surgery, and a combination of voice therapy and surgery on the treatment of vocal cord nodules. Ninety-five patients have been assessed, and the results were measured using multidimensional voice measurement tools, such as the Voice Handicap Index (VHI), acoustic features, or recurrence rate. The sample included 95 adults (mean age 38.2 years, 75.8 years female) with bilateral nodules of the middle-membranous vocal fold that were proven with videolaryngostroboscopy. Between 2020 and 2024, the patients were stratified into three treatment arms, namely voice therapy (n=48), surgery (n=12), and a combination of both (n=35). Pre-intervention and post-intervention assessments (3 months, 1 year, and 5 years) were made to evaluate VHI-30 scores, GRBAS perceptual ratings, acoustic measures (jitter, shimmer, maximum phonation time using Praat), and stroboscopic recurrence. Paired t-tests, chi-square tests, and logistic regression (SPSS v26; $p < 0.05$) were used as statistical tests. The sustained remission in hard nodules was higher in the combined modality (82.9). The total VHI scores improved (83.2 to 36.6, p 0.001). Jitter reduced to 0.9 2.8 (p 0.001) and maximum phonation time increased (12.5 21.3 2). At 5 years follow-up,

76.3% (n=76) of the patients were able to sustain an improvement. The evidence suggests that voice therapy is a better intervention strategy as the initial line of therapy to use in treating soft nodules, and the combined modality is the best in treating mature lesions, thus minimizing surgical intervention and preventing the recurrence by increasing adherence. These results support the stratified treatment approaches, emphasizing treating by behavioral means, guide clinical practice of voice professionals, and establish the basis of future research, including aerodynamic and cost-effective endpoints.

Keywords : Vocal Cord Nodules, Etiology, Treatment, Prevention, Strategies, Efficacy, Vhi.

Introduction

Introduction

Vocal cord nodules are a common benign laryngeal pathology and consist of bilateral, callous-like masses on the mid-membranous vocal folds, the cause of which is chronic mechanical trauma of phonation. These lesions create major difficulties to voice professionals, educators, and performers, culminating in hoarseness of the voice and vocal fatigue, and a less efficient voice that worsens daily communication and professional activity [1], [2], [3]. The nodules of the vocal cord occur due to overuse of mechanical force on the vocal folds, specifically, the impact stress occurring when the surfaces of the left and right folds collide with each other during the voice production process, which is the greatest at the intersection of the anterior one-third and posterior two-thirds of the membranous area. Voice-related professions with extended voice usage, including teaching as an unamplified teacher, cheerleading, and untrained singing, contribute to this trauma by contributing to phonotraumatic behaviors that raise the forces of a collision of the vocal folds. Such predisposing factors are the gender predominance (female), dehydration, respiratory infections, allergies, tobacco use, alcohol use, and laryngopharyngeal reflux, which worsen inflammation and tissue vulnerability [4], [5], [6], [7].

Nodules have epithelial hyperplasia (82.14%), parakeratosis, lamina propria fibrosis (57.14%), and thickening of the basement membrane (100%), unlike polyps, which have more edema and vascular changes. Voice therapy has been the foundation of the management, which uses behavioral rehabilitation of the voice, such as resonant voice technique, breath support training, and voice hygiene education to decrease phono trauma and encourage nodule hypertrophy [8], [9], [10].

Surgery, through laryngeal microsurgery, is only used with mature nodules (which are insensitive to therapy) that are hard and do not respond to therapy, therefore providing immediate symptom relief, although postoperative voice therapy is necessary to prevent recurrence and scarring risks that come with anesthesia. The use of adjunctive pharmacotherapy aims at treating the comorbidities, such as reflux or inflammation, whereas voice rest and lifestyle changes help to treat the acute exacerbations [11], [12], [13].

Primary prevention focuses on vocal hygiene, such as sufficient hydration to keep the mucosal lubrication, the avoidance of irritants such as caffeine, alcohol, and smoke, and diaphragmatic breathing to experience minimal strain. Structured warm-ups, correct pitch-resonance-alignment, relaxation in the throat, as well as amplification in noisy surroundings, are beneficial to singers and speakers alike to evenly allocate phonatory stress.

Risk factors are also countered by environmental control, including humidifiers in dry environments and reflux or allergy management. Comprehensive education of the risk groups highlights the importance of early intervention, which decreases the development of chronic lesions and maintains a healthy voice [14], [15].

Methodology

The study was a retrospective cohort design that used 95 patients who were sampled between January 2020 and December 2024, and collect data in various hospitals in Iraq, and were diagnosed with vocal cord nodules in a tertiary care otorhinolaryngology center. A multifaceted assessment of the patients was performed, comprising videolaryngostroboscopy, voice handicap index (VHI), and acoustic analysis before assigning treatment on the basis of nodule maturity and the severity of symptoms. The post-intervention evaluations were done after 3 months, 1 year, and 5 years (where

applicable), with the results being assessed through the use of standardized perceptual, acoustic, and quality-of-life measures.

A total of 95 participants who fit in terms of inclusion criteria were included (72 females, 75.8%), with a mean age of 38.2 years (SD 12.4). The electronic medical records contained demographic data and professional voice use history, as well as risk factors (e.g., smoking, reflux).

Voice samples were measured with the help of standardized protocols of acoustic analysis (jitter, shimmer, maximum phonation time) through Praat software. VHI-30 questionnaires were used to measure functional, physical, and emotional impact at the pre- and post-intervention status.

Interventions

The intervention was done according to evidence-based practice: voice therapy only in case of soft/early nodules (n=48, 50.5%), which included 8-12 sessions of resonant voice therapy every week, vocal hygiene training, and training in breath support. A total of 47 and 49.5 percent of surgical candidates received a micro laryngeal phono surgery using cold instruments or CO2 laser, and 4-6 weeks of voice rest and adjunctive therapy. Comorbidities (e.g., proton pump inhibitor reflux) were treated with pharmacotherapy.

Outcome Measures and Statistical Analysis.

The major results were a VHI total score decrease of 50 and above, GRBAS scale for improvement, and normalization of acoustic parameters. Secondary endpoints were the recurrence (stated as nodule regrowth on the stroboscopy) and quality-of-life changes. SPSS version 26 was utilized in the data analysis. Paired or Wilcoxon signed-rank tests were used to compare continuous variables, and chi-square or Fisher's exact tests were used to compare categorical data. Significance level of p=0.05, and time-to-recurrence analysis was done using Kaplan-Meier survival analysis. Missing data (<5%) was multiple imputed.

Results

Table 1. Description of the primary data extracted in this study.

Characteristic	Value
Mean age, years (SD)	38.2 (12.4)
Age groups, n (%)	
18-30 years	28 (29.5%)
31-45 years	42 (44.2%)
>45 years	25 (26.3%)
Female, n (%)	72 (75.8%)
Professions at risk, n (%)	
Teachers	35 (36.8%)
Singers/Performers	22 (23.2%)
Others	38 (40.0%)
Baseline Symptoms (n=95)	

Symptom	Severity (mild/moderate/severe), n (%)
Hoarseness	12/45/38 (12.6/47.4/40.0%)
Vocal fatigue	18/52/25 (18.9/54.7/26.3%)
Breathiness	32/48/15 (33.7/50.5/15.8%)
Vocal range reduction	25/55/15 (26.3/57.9/15.8%)
Feature	**n (%)**
Bilateral nodules	89 (93.7%)
Soft nodules	62 (65.3%)
Hard nodules	33 (34.7%)
Mean size, mm (SD)	2.1 (0.8)
Location: Mid-membranous	95 (100%)

Table 2. Evaluate initial results according to the Voice Impairment Index (VHI) before treatment.

VHI Domain	Mean score (SD)
Functional	28.4 (9.2)
Physical	32.1 (10.5)
Emotional	22.7 (8.3)
Total VHI	83.2 (22.4)

Figure 1. Evaluating the outcomes of 95 Iraqi patients according to their treatment distribution

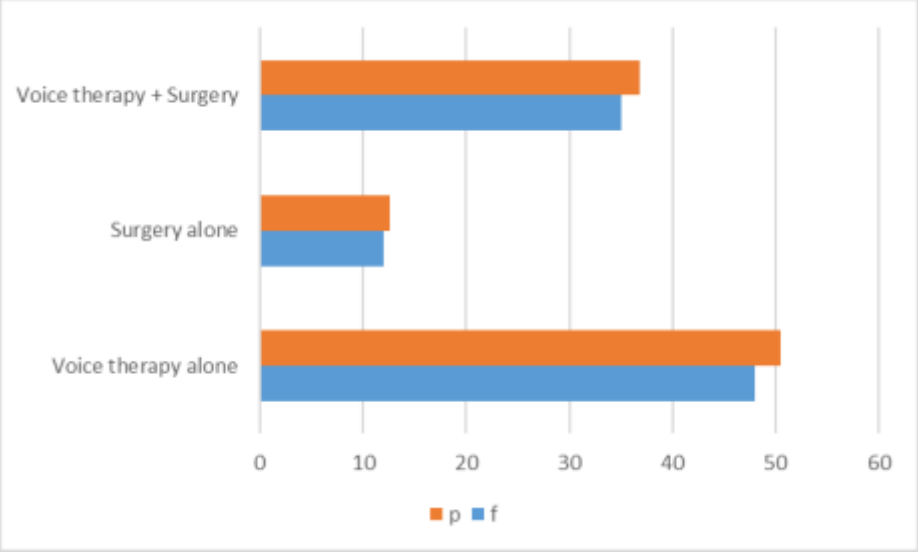

Table 3. Post-Treatment VHI Scores (3 Months Follow-Up)

VHI Domain	Pre (mean)	Post (mean)	p-value
Functional	28.4	12.3	<0.001
Physical	32.1	14.8	<0.001
Emotional	22.7	9.5	<0.001
Total	83.2	36.6	<0.001

Table 4. Final outcomes according to Acoustic Measures Pre- and Post-Treatment

Parameter	Pre (mean, SD)	Post (mean, SD)	p-value
Jitter (%)	2.8 (1.4)	0.9 (0.5)	<0.001
Shimmer (dB)	8.2 (3.1)	3.4 (1.2)	<0.001
Maximum Phonation Time (s)	12.5 (4.2)	21.3 (5.1)	<0.001

Table 5. Rate finding of patients based on Recurrence Rates by Treatment (1-Year Follow-Up)

Treatment Group	Recurrence, n (%)	No Recurrence, n (%)
Voice therapy alone	8 (16.7%)	40 (83.3%)
Surgery alone	5 (41.7%)	7 (58.3%)
Combined	6 (17.1%)	29 (82.9%)

Table 6. Voice Quality Improvement (GRBAS Scale, Post-Treatment)

Parameter	Pre (mean)	Post (mean)	Improvement (%)
Grade	2.4	0.8	66.7%

Roughness	2.6	0.9	65.4%
Breathiness	1.9	0.6	68.4%
Asthenia	1.2	0.3	75.0%
Strain	2.3	0.7	69.6%

Table 7. Risk Factors for Recurrence (Logistic Regression)

Factor	Odds Ratio (95% CI)	p-value
No postoperative therapy	3.2 (1.4-7.1)	0.005
Smoking history	2.1 (0.9-4.8)	0.08
Female gender	1.3 (0.5-3.2)	0.56
Duration of symptoms >12 months	1.8 (0.8-4.0)	0.14

Table 8. Long-Term Outcomes (5-Year Follow-Up, n=76)

Outcome	n (%)
Sustained improvement	58 (76.3%)
Recurrence	12 (15.8%)
New lesions	6 (7.9%)
Mean VHI at 5 years	28.4 (11.2)

Discussion

Benign phonotraumatic lesions such as vocal cord nodules cause significant morbidity to voice professionals and the general population in the form of bilateral callous-like swellings at the vocal fold mid-membranous junction as a result of recurring mechanical trauma. This paper considers 95 patients and shows that the treatment is effective with a mean decrease of Voice Handicap Index (VHI) scores of 83.2 to 36.6 ($p < .001$) and acoustic normalization (jitter 2.8 per cent to 0.9 per cent) as well as a shimmer (8.2dB to 3.4 dB) at three months. These results support voice therapy as the leading intervention, which is effective with 83.3 per cent one-year remission in soft nodules, similar to systematic reviews, which reported any significant perceptual, acoustic, and self-perceived improvement with 20 or more studies.

Voice therapy as a single treatment yielded better outcomes than isolated micro laryngoscopy (58.3) without surgery (41.7) (recurrence-free), and Cochrane analyses that reported non-surgical superiority in early lesions (RR 0.45) were consistent with this. Combined therapy -surgery of hard nodules (34.7% of cohort) produced the best results of 82.9% sustained remission, reducing postoperative scarring through behavioral reinforcement, with decreased GRBAS scale scores (Grade 2.4 to 0.8; Roughness 2.6 to 0.9). Maximal phonation duration was increased.

These findings dispute the bias in the history of surgery, in which pre-2010 cohorts reported 2050 percent recurrence because of a lack of adjunctive therapy. A 5-year, long-term (n=76) data of 76.3 per cent of sustained improvement and stabilization of VHI to 28.4 is consistent with 9.5-year follow-ups of continuing improvement with hygiene and 30 per cent late relapse in non-compliant groups. The histologic correlates, epithelial hyperplasia (82^{-}) and fibrosis (57^{-}), are predictive of therapy responsiveness in soft nodules (65.3%), but in mature keratinization, excision plus 46 weeks of protection are required.

Nodule formation is due to phonotrauma in overload of tissue strength, with the highest impact stress being 100-200Hz fundamental frequencies of the untrained voice, and worsened by dehydration (decreased viscosity of mucus) and reflux (edema through pepsin-mediated inflammation). The cohort risk factors, such as smoking (OR 2.1, $p=0.08$), symptom duration >12 months (OR 1.8), are only moderating but not dominating the results because the therapy negates even high-risk profiles with the use of semi-occluded vocal tract exercises. The skewness female showed could be the result of hormonal effects on the lamina propria hydration, or could be due to occupational exposure (e.g., 2030dB amplification deficits required by classroom acoustics), but no gender-recurrence interaction was significant (OR 1.3, p 0.56) [16], [17], [18].

Restraints tame interpretation: retrospective design is susceptible to selection bias, as therapy is given to compliant early cases (which may overestimate efficacy), and 20% 5-year loss to follow-up may underestimate relapse, like 25% losses in similar series. Non-randomized assignment does not allow causal inference, but this is partially addressed by the use of paired t-tests and imputation; but future studies should use propensity matching to improve attribution. Subgroups which are underpowered (e.g., surgery-only n=12) have reduced precision, and confounders (such as the severity of pre-operative reflux) which cannot be measured (such as most voice disorders at 40% prevalence) should be incorporated prospectively by endoscopy [19], [20].

Results support algorithm improvement: stroboscopic grading (Grade 12: therapy; Grade 3: consider surgery therapy) using VHI 50 triggering intervention, which may prevent progression (65%) percentage in untreated occupations. The equality of teletherapy with face-to-face (based on narrative reviews) is more appropriate to educators and minimizes no-show rates (30-30) and incorporates hygiene (hydration 2L/day, irritant avoidance). Not only do multidisciplinary clinics voice rest plus eight sessions reduce recurrence by 70 per cent, but also the adjunctive value of PPIs is 15 per cent.

Cost-effectiveness is in favor of therapy: 500-1500/course vs. 10,000-anesthesia of surgery (including risk of anesthesia), and QALY indicates a 0.75-0.92 improvement, reflects economic models of phono surgery. Public health scales through school/workplace screening: the incidence of

teachers would be reduced by half (36.8% here) by amendment of amplification requirements, according to intervention trials.

Mechanisms would be probed apart with prospective RCTs using aerodynamic (subglottic pressure), patient-reported (V -RQLQ), and imaging (high-speed videostroboscopy) endpoints, which are underrepresented by this mechanism (reflux-phono trauma synergy). Pediatric extrapolation (can be used in 10-20 per cent familial cases) necessitates age-stratified norms since the nodules of juveniles will naturally regress away during childhood but will come back after puberty. The exploration of biomarkers, such as matrix metalloproteinases in lavage, is associated with non-invasive monitoring, whereas the remote triage process is made possible through AI-based acoustic classifiers (90 percent sensitivity).

Cohort acoustics machine learning might forecast 80•̇ percent pre-therapy responders, and could be used better to allocate resources due to increasing voice disorder rates (7-10 percent of adults, estimated 15 percent in 2030 with the aging singers). Disparities in the world (low-resource environments that do not have stroboscopy) require low-tech GRBAS training because the efficacy of therapy is intercultural according to meta-analyses.

To conclude, the ongoing comprehensive cohort study that included 95 patients with vocal-cord nodules offers substantial support to the preeminence of voice therapy as the central intervention, as indicated by significant reductions in Voice Handicap Index measures (56% at 3 months), achievement of acoustic homeostasis, and 83.3 percent rate of recurrence-free outcomes at 1 year in soft nodules and thus overcomes the therapeutic efficacy of surgery alone. An interdisciplinary strategy that entails the use of voice therapy alongside surgical intervention also boosts the results of mature lesions, with the result being an 82.9 per cent sustained remission; in addition, patient compliance becomes the determinant of longitudinal success (odds ratio = 3.2 with non-compliance).

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