Voice Outcome Following Carbon Dioxide Laser Assisted Microlaryngeal Surgery

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Abstract Very few studies have been conducted in South Indian population to evaluate glottic function and voice outcome following carbon dioxide (CO₂) laser assisted microsurgery for benign lesions of the larynx. This is a descriptive study which aims at assessing the voice outcome (perceptual and acoustic) and vocal fold function (stroboscopic) following CO₂ laser excision in benign vocal fold lesions. 50 adult patients with benign laryngeal lesions were selected to undergo CO₂ laser excision in super-pulse mode at power setting of 6 watts. Perceptual analysis was done using GRBAS score. Voice analysis was done using Praat software and fundamental frequency, jitter, shimmer and harmonics to noise ratio were assessed. Stroboscopy was done to evaluate vocal fold function using glottic closure and mucosal wave pattern as parameters. Evaluation of these parameters was done pre-operatively and at 2, 6 weeks and 3 months post-operatively. Perceptual analysis revealed a significant improvement in the GRBAS score after surgery ($p < 0.001$). Acoustic analysis showed that all the parameters improved significantly after surgery ($p < 0.001$). Stroboscopy showed that vocal fold function improved in 98 % of patients in terms of completeness of glottic closure and regular, periodic mucosal wave. Super-pulse micro-spot carbon dioxide laser is a safe and effective treatment option for benign lesions of vocal folds, with excellent voice outcome.

Keywords Lasers · Benign vocal fold lesions · Carbon dioxide laser · Hoarseness of voice · Vocal cords

Introduction

Restoration of normal vocal function in patients with benign glottic lesions is of fundamental importance in vocal fold surgery. A generally accepted principle of vocal fold surgery is that any intervention should be as conservative as possible. Preservation of both healthy mucosa and intermediate and deep layers of lamina propria is important for voice restitution. Injury to these layers can lead to scarring and irreversible stiffening of vocal cords, resulting in diminished or even absent mucosal wave.

Medical management includes anti-reflux measures such as proton pump inhibitors and speech therapy. The lesions that do not or are unlikely to resolve with speech therapy are treated with surgery. Surgical treatment can be with cold steel microlaryngeal surgery or with CO₂ laser. The CO₂ laser is now the surgical instrument of choice for several varied microlaryngeal operative procedures. With the development of Super-pulse CO₂ lasers with micro-spot beam, which deliver laser beam with spot size of 0.25 mm or less, precise microsurgery can be done with minimal risk of injury to deeper layers.

This study is designed to evaluate glottic function and voice outcome following CO₂ laser assisted microsurgery for benign lesions of the larynx, as very few studies have been conducted in Indian population.

Objectives of the Study

1. To assess the voice outcome (perceptual and acoustic) following CO₂ laser excision in benign vocal fold lesions.
2. To assess vocal fold function following CO₂ laser excision in benign vocal fold lesions using video stroboscopic analysis.

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Materials and Methods

The patients were recruited from Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER), a tertiary care government hospital which caters to people from Puducherry and Tamil Nadu in southern India, from November 2011 to April 2013. Approval was obtained from Institute Ethical Committee. Participants of the study were selected from adult patients who attended ENT OPD, JIPMER, with benign lesions of vocal cord like vocal fold polyps, nodules, papilloma, cysts and Reinke's oedema as diagnosed by mirror indirect laryngoscopy and videolaryngoscopy using 70° rigid endoscope. Patients with malignant lesions of vocal cord and co-morbidities like uncontrolled diabetes or hypertension were excluded from the study.

Brief Procedure

All participants were explained regarding the study and informed consent was obtained. A detailed history was taken regarding symptoms, vocal abuse, smoking and other etiological factors followed by careful clinical examination. Laryngoscopy using 70° endoscope, video stroboscopy, acoustic and perceptual analysis of voice was carried out for all patients pre-operatively and at the scheduled follow-ups. All patients were operated under general anaesthesia and intubated with laser-safe endotracheal tube. Laser precautions and safety procedures for the patient and the operating room staff were strictly followed at all times during laser surgery.

Surgery was performed with Zeiss operating microscope at 400-mm focal length through a suspension laryngoscope. Laser microsurgery was performed using CO₂ surgical laser (Acublade®, Lumenis Ltd, Santa Clara, CA, USA) at a power setting of 6 W in super-pulse mode.

Post-operatively, all patients were advised complete voice rest for 48 h. Anti-reflux medication was given to all patients for 2 weeks. Post-operative follow-up was carried out at 2, 6 weeks and 3 months after surgery. Voice outcome after surgery was assessed by perceptual and acoustic voice analysis and vocal cord function was assessed by stroboscopic analysis at each follow up visit.

Parameters Studied

Perceptual voice assessment was done by a speech pathologist using GRBAS score (Grade, Roughness, Breathiness, Asthenia and Strain score)

Each rated in a four-point scale

0—No perceived abnormality

1—Mild abnormality

2—Moderate abnormality

3—Severe abnormality

Acoustic analysis—fundamental frequency (F₀), jitter, shimmer and harmonics to noise ratio (HNR) were measured using PRAAT software. Patients were asked to sustain the vowel/a/at a comfortable pitch. All measures were made with the microphone placed at 15 cm from lips.

Stroboscopic analysis—mucosal wave pattern and glottic closure pattern were studied.

Statistical Analysis

Repeated measures of ANOVA were used to compare the relation between time and procedure. To compare all normally distributed continuous clinical variables between the subgroups, independent student *t* test was used. Mann–Whitney U-test was used for comparing non-Gaussian variables between the subgroups. *p* value <0.05 was considered as significant.

The study was approved by the Institute Research Council and the Institute Ethics Committee.

Results

The present study consisted of 50 patients who underwent carbon dioxide laser excision for various benign lesions of vocal fold. The mean age of the study population was 43 years with a standard deviation of 11.847. The youngest patient in the study was 19 years and the eldest was 67 years. The overall male:female ratio in the study population was 1.9:1. The maximum number of patients was found in the age group 31–40.

Types of Lesions

The most common lesion that was found in our study was vocal polyp, in 40 % (20 patients). The most common lesion in males was vocal polyp (42 %). In females both polyps and nodules were seen with equal frequency (35 %). The least common lesion was keratosis larynx, which was seen only in men (Table 1).

Symptomatology and Clinical Evaluation

All patients in the study population presented with the chief complaint of hoarseness of voice. The second most common complaint was strain while speaking, which was present in 25 patients (50 %). History of vocal fatigue was given by 23 patients (46 %). A total of 19 patients (38 %) gave history of voice abuse, of which 13 were males and 9 were females. Only two patients (4 %) gave history of previous laryngeal surgery, both of whom were diagnosed

Table 1 Vocal fold lesions—gender-wise distribution

Lesion	Males (%)	Females (%)	Total (%)
Vocal polyp	14 (42.4)	6 (35.2)	20 (40)
Vocal nodule	5 (15.1)	6 (35.2)	11 (22)
Papilloma	4 (12.1)	2 (11.7)	6 (12)
Vocal cyst	5 (15.1)	3 (17.6)	8 (16)
Keratoses larynx	5 (15.1)	0 (0)	5 (10)
Total	33 (100)	17 (100)	50 (100)

Table 2 Distribution of symptoms and relevant history in the study population

History	Males (%)	Females (%)	Total (%)
Hoarseness	33 (66)	17 (34)	50 (100)
Voice abuse	13 (31.6)	6 (68.4)	19 (38)
Vocal fatigue	16 (69.6)	7 (30.4)	23 (46)
Strain while speaking	14 (56)	11 (44)	25 (50)
Smoking	12 (100)	0	12 (24)
GERD	4 (33.3)	8 (66.7)	12 (24)
Previous surgery	1 (50)	1 (50)	2 (4)

with Recurrent Laryngeal Papillomatosis. There were 12 patients in the study who were smokers and had quit smoking at the time of diagnosis. History suggestive of gastro-esophageal reflux was present in 12 patients (24 %). The symptomatology is depicted in Table 2.

Perceptual Evaluation

Perceptual voice analysis was done by a speech pathologist using GRBAS score. The pre-operative median GRBAS score was 9 with a range of 6–13. The median score improved to 6 by the second post-operative follow up visit. There was consistent improvement in the GRBAS score in all post-operatives (Table 3). By the last follow-up visit, i.e. in the third month, the median GRBAS score was 2. Repeated measures of ANOVA was used to analyse the data. There improvement in the mean GRBAS score after the surgery and at each post-operative visit was found to be significant ($p < 0.001$). The analysis also revealed significant difference between mean scores at each follow-up visit ($p < 0.001$).

Acoustic Analysis

Voice quality before and after surgery was evaluated by electroacoustic voice recording and spectrographic analysis of fundamental frequency (F_0), jitter, shimmer, and HNR using PRAAT software. The acoustic parameters were

Table 3 Median GRBAS scores with range at each visit

Time	G	R	B	A	S	T (range)
Pre-op	3	2	2	2	1	9 (6–13)
2 weeks	2	1	0.5	1	1	6 (2–9)
6 weeks	1	1	0	1	0	2 (1–6)
3 months	1	1	0	0	0	2 (1–6)

Table 4 Distribution of fundamental frequency (F_0)—mean with SD

F_0	Males Mean (SD)	Females Mean (SD)
Pre-op	140.7 (12.3)	193.04 (20.5)
2 weeks	124.47 (13.9)	215.25 (12.7)
6 weeks	122.86 (15.1)	218.76 (10.9)
3 months	125.65 (14.8)	223.06 (11.8)

analysed separately for males and females using repeated measures analysis of variance.

The mean pre-operative fundamental frequency (F_0) for females was 193.04 Hz, which increased to 223.06 Hz at the third month. For males, the fundamental frequency changed from 140.7 Hz in the pre-operative period to 125.65 Hz at the third follow up (Table 4). F_0 was analysed using repeated measures analysis of variance, which showed significant difference in the pre- and each follow-up F_0 values ($p < 0.0001$). There was, however no significant difference among the F_0 values of each follow-up visit ($p > 0.05$).

The pre-operative mean shimmer was 10.8 % in both males and females, which reduced to 4.6 % in males and 5.0 % in females by the third follow-up visit (Table 5). There was significant improvement in shimmer values following surgery, compared with pre-operative measurements ($p < 0.001$). There was significant difference in the mean shimmer values between each follow-up visit ($p < 0.001$).

The pre-operative mean jitter was 3.26 % in males and 3.4 % in females (Table 5). There was significant difference in the pre-operative mean jitter and each of the follow-up visits ($p < 0.0001$). However, there was no statistically significant difference between the jitter values at each follow-up visit ($p > 0.05$).

The mean HNR in males was 3.6 pre-operatively, which improved to 20.9 at the third month. In females, the pre-operative HNR was 3.7 which increased to 20.8 by the third month. The overall HNR showed significant difference ($p < 0.0001$) between pre-operative and each follow-up visits as well as among all the follow-up visits (Table 5).

Table 5 Distribution of Shimmer, Jitter and HNR—mean with SD

Parameter (%)	Follow-up visit	Males Mean (SD)	Females Mean (SD)
Shimmer	Pre-op	10.8 (2.3)	10.8 (2.53)
	2 weeks	7.8 (1.9)	7.8 (2.5)
	6 weeks	6.3 (2.1)	6.4 (2.6)
	3 months	4.6 (1.8)	5.0 (1.9)
Jitter (%)	Pre-op	3.26 (1.34)	3.4 (1.5)
	2 weeks	0.58 (0.38)	0.5 (0.3)
	6 weeks	0.37 (0.19)	0.3 (0.1)
	3 months	0.19 (0.06)	0.2 (0.27)
HNR	Pre-op	3.6 (1.3)	3.7 (1.04)
	2 weeks	11.6 (3.4)	12.2 (2.7)
	6 weeks	13.8 (2.7)	14.1 (2.1)
	3 months	20.9 (2.5)	20.8 (2.9)

Stroboscopic Parameters

Pre- and post-operative morphology was studied using stroboscopy for all patients. Only one patient was found to have recurrent lesion after the third follow-up visit, who was diagnosed with recurrent papillomatosis. Mucosal wave and glottic closure patterns were studied. The pre-operative glottis closure was incomplete in 98 % (49 patients). After surgery, all patients achieved complete glottis closure. However, one patient had recurrent papillomatous lesion in the third month, and therefore had incomplete glottis closure. Mucosal wave pattern was studied to look for amplitude, periodicity and symmetry. Post-operative stroboscopy revealed regular, symmetric normal waves for all patients except one (98 %), who had developed recurrent lesion.

Discussion

Voice outcome following microlaryngeal surgery is the major concern for the patient as well as the surgeon. Refinement in micro-surgical techniques as described by Strong, Hirano, Bochayer etc. have helped a great deal in providing satisfactory improvement in voice [1–3]. Since its introduction in laryngeal surgeries, carbon dioxide laser is being increasingly used for surgery of such lesions. In spite of various studies showing good voice outcome with carbon dioxide laser, in many centres laser is not used due to concerns regarding lateral thermal damage produced by it.

Our study was undertaken to evaluate voice outcome and vocal fold function following carbon dioxide laser excision for benign lesions of vocal fold. The most common age-group in our study was 31–40 years, with male preponderance. As the most important etiological factor

that is implicated is voice abuse or overuse, these lesions are found in the most active age-group and more commonly in males. This observation is supported by the findings of Stewart et al. [4]. The most common lesion was vocal polyp, as was observed in other studies by Geyer, Benninger et al. [5–7].

Perceptual Analysis

Various scoring systems are available for perceptual analysis of voice. GRBAS offers an easy scoring system for measuring degree of change of voice. In our study, GRBAS score showed consistent improvement in all parameters. The median overall GRBAS score was 9 pre-operatively, which improved to 2 by the last post-operative follow-up visit, which was found to be statistically significant (Table 3).

Acoustic Analysis

Voice outcome was objectively measured by acoustic analysis. The parameters studied were fundamental frequency, shimmer (%), jitter (%) and HNR. Jitter and shimmer are measures of level of perturbation of two important parameters voice—pitch and intensity. Objective record of these measures allows comparison between pre- and post-operative values. Both are considered as reliable indicators of vocal fold function [5, 8]. Both of these parameters showed significant improvement after surgery (Tables 4, 5).

Several studies have shown F_0 range as the measure of treatment efficacy. The normal F_0 for males is 107–146 Hz and for females is 197–227 Hz. Our study showed that mean F_0 tends to change towards more physiological values for both males and females after the surgery.

Harmonics to noise ratio (HNR) is a quantitative index of the degree of hoarseness. In our study, comparison of pre- and post-operative HNR showed improvement which was statistically significant. Similar findings with respect to F_0 , shimmer, jitter and HNR were observed by Benninger in their randomized prospective study [5].

Improvement in the acoustic parameters were also observed by Remacle [8] and more recently by Geyer et al. [9]. Acoustic characteristics of voice depend on the mass and tension of vocal folds. The improvement in the acoustic parameters can be explained on the basis of improved contact between the cord and better vibratory characteristics.

Stroboscopic Changes

Stroboscopy provides excellent endoscopic picture and helps in evaluating pattern of mucosal fold vibration. The

parameters selected were glottic closure pattern and mucosal wave as these are two important factors that affect quality of voice [10]. Our study confirmed that after surgery most of the patients achieve complete glottic closure and normal mucosal wave (98 % each). Complete glottic closure can be explained by improved contact between the vocal folds after excision of the lesion. Mucosal wave also tends to become regular and normal after surgery as the improved contact between vocal folds results in better generation of sub-glottic pressure, hence better amplitude of cord vibration [11].

Benninger [5] conducted a randomized prospective trial comparing microspot CO₂ laser with micro-dissection in treatment of benign lesions of vocal folds on 37 patients. Stroboscopic parameters, perceptual and acoustic analysis were performed in both groups. No statistically significant difference existed between the two groups over time. It was concluded that CO₂ laser is as effective as micro-dissection in treating benign vocal fold lesions [5]. Geyer et al. also reported similar findings with their data of CO₂ laser-assisted phonosurgery in benign glottic lesions of over 10 years. They concluded that CO₂ laser-assisted phonosurgery is an effective treatment option with negligible complications [9]. Both these studies had used microspot CO₂ laser in super-pulse mode, which may be responsible for the superior results obtained.

Debate still exists regarding the exact duration of voice rest required after surgery. We advised 48 h of absolute voice rest following surgery. Patients were slowly rehabilitated to full usage of speech over 2 weeks, but never to the full pre-operative extent. This was possible with the help of speech therapist. No studies exist that specify the exact duration of voice rest. Longer duration of voice rest is not advisable as patient compliance considerably decreases with longer voice rest. Future research needs to be directed in this direction to find out the optimal period of voice rest following surgery.

Conclusion

Benign lesions of vocal folds are the most common cause of hoarseness in young adults and cause considerable morbidity in this active age group. Management of such lesions not only aims at removal of lesions and providing an acceptable voice, but also preventing recurrence by adequately controlling the inciting factor(s).

The introduction of carbon dioxide laser is indeed a milestone in the surgery of benign vocal fold lesions.

Earlier worries regarding the safety of CO₂ laser has been eliminated with the implementation of strict laser safety protocols. With the development of scanner micromanipulator and super- and ultra-pulsed CO₂ laser; precise and controlled incisions can be made in the desired shape, size or depth.

Acoustic analysis and perceptual voice analysis are two methods which can be used to measure voice outcome and for comparison. On the basis of stroboscopy, perceptual and acoustic analysis, voice outcome was found to be excellent in our study. Carbon dioxide laser offers the advantage of precision, haemostasis and minimal post-operative oedema. Thus, this study confirms the notion that super-pulsed micro-spot carbon dioxide laser is a safe and effective treatment option for benign lesions of vocal folds, which provides excellent voice outcome.

Conflict of interest Dr. Arun Alexander, Dr. Sunil Kumar Saxena, Dr. Sabarinath Vijayakumar declare that they have no conflict of interest.

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