The Journal of Laryngology and Otology
December 1983. Vol. **97.** pp. 1139–1144

Phonatory function following unilateral laser cordectomy

by

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Introduction

Phonatory function following surgical unilateral cordectomy in our experience always differs from normal voice production and results in various degrees of hoarseness. The most frequent reason for voice dysfunction in these cases is incomplete glottal closure, combined with various compensatory mechanisms which tend to exaggerate the voice even more (Večerina, 1981).

We have been greatly impressed by the quality of the voice in our patients in whom laser cordectomy has been performed in cases of T_1 cancers of one vocal fold, and it is the aim of the present investigation to discover the exact phonatory mechanism responsible for this good voice quality.

Material and Methods

Six male patients with different durations of post-operative follow-up were selected for this retrospective study. Their ages and the dates of testing their phonatory function are shown in Table I. In all these patients the following surgical procedure was carried out: The vocal folds were visualized by means of microlaryngoscopy under general endotracheal anaesthesia; the vocal fold affected by cancer was displaced medially and resected in its most lateral portion by laser beam (Coherent CO_2 Surgical Laser, System 400). Histology revealed that the cancer had not reached the lateral margin of the resected vocal fold.

The phonatory function was investigated by the following method: 1. Laryngeal stroboscopy (Timcke KS 3); 2. Frontal tomography of the larynx: (a) during sustained expiratory phonation, (b) during sustained inspiratory phonation; 3. Acoustic three-dimensional voice analysis: narrow analysis (filter width 45 Hz.) and wide analysis (filter width 300 Hz.) within the frequency range of 80 to 8,000 Hz. In order to investigate the glottal voice periodicity thoroughly, the voice was slowed down by the tape recorder and then analysed by wide filter (300 Hz.) within the range of 16 to 16,000 Hz. The fundamental frequency and voice range were extracted from the narrow sonagraphical analysis of the vowel A. Glottal periodicity was studied in different samples of wide analysis, while harmonic frequencies, their extent and distribution throughout the sonagram, and the degree of hoarseness (after Yanagihara, 1967) were studied in the narrow analysis samples.

Results

Indirect laryngoscopy demonstrated that in all cases a new fold closely resembling the normal vocal fold had been formed at the operative site, and adduction of both folds seemed to be adequate. In only one patient was the new fold markedly reddish, and in another one a significant degree of ventricular fold hypertrophy had developed at the operative site.

Stroboscopy revealed that, in six cases,

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TABLE I

AGE, TNM CLASSIFICATION AND DATE OF PHONATORY ANALYSIS IN PATIENTS FOLLOWING LASER CORDECTOMY

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Age and sex	Male 52	Male 58	Male 60	Male 56	Male 53	Male 48
TNM classification	$T_1N_0M_0$	$T_1N_0M_0$	$T_1N_0M_0$	$T_1N_0M_0$	$T_1N_0M_0$	$T_1N_0M_0$
Interval between operation and phonatory analysis (months)	24	12	24	1.5	7	6

not only did the preserved (healthy) vocal fold vibrate, but the newly created fold was also involved in the vibratory process. The vibrations of both folds (the vocal fold and the new one) were simultaneous and in phase, although the new fold vibrated with shorter amplitude in all cases analysed. The vibratory amplitude of the healthy vocal fold appeared to be shorter than normal in four of the six cases.

Frontal phonatory tomography confirmed that the newly created fold had practically the same configuration and thickness as the healthy vocal fold. Even the configuration of its free margin (with its superior and inferior lips) could be demonstrated at the operative site (Fig. 1). Neither fold changed its configuration or the shape of its free margin simultaneously with attempts to change vocal pitch. On the contrary, during inspiratory phonation, the configuration of both folds and their margins changed significantly (Fig. 2). The phonatory activity as expressed by medial movement of both ventricular folds was recorded in three out of six cases. Acoustic analysis (Table II) showed that the fundamental frequencies, the extent of harmonic acoustic energy and the degree of hoarseness varied considerably, regardless of the uniform morphological and stroboscopic findings in all examinees. However, a constant phenomenon seen in all six patients was preserved glottal periodicity and an extremely narrow voice range (Figs. 3 and 4).

Discussion

Acoustic analysis of the voice has demonstrated that after laser cordectomy the voice still shows some elements of the pathological voice. Our auditory impression revealed a satisfactory voice quality and this observation prompted us to undertake a detailed analysis of the phonatory function.

The fundamental frequency, the extent of the harmonic energy and the degree of hoarseness varied from patient to patient. Fairly high fundamental frequencies in four examinees could be attributed to the compensatory mechanisms which developed regularly, even in minor degrees, of glottic dysfunction or insufficiency (Sedláčková, 1969; Večerina, 1981). This provided indirect proof of the slightly disturbed glottal function after laser cordectomy although clinical methods of investigation failed to demonstrate it. Moreover, hypertrophy and activity of the ventricular folds in four patients were an expression of a compensatory hyperkinetic mechanism. In two patients with normal fundamental frequencies and with minimal noise in the sonagram, no compensatory hyperkinesia interfered with normal voice production. This should be achieved by early post-operative voice therapy.

An extremely narrow voice range was recorded in all voice samples after laser cordectomy. This indicates that the healthy vocal fold and its corresponding mate at the operative site are not capable of complicated and rapid adjustments as part of the complex neuromuscular processes during phonation. This was also visible in frontal tomograms of the larynx during phonation of tones at different pitch: the configuration and margins of the folds did not change at all. Conversely, both folds and their margins

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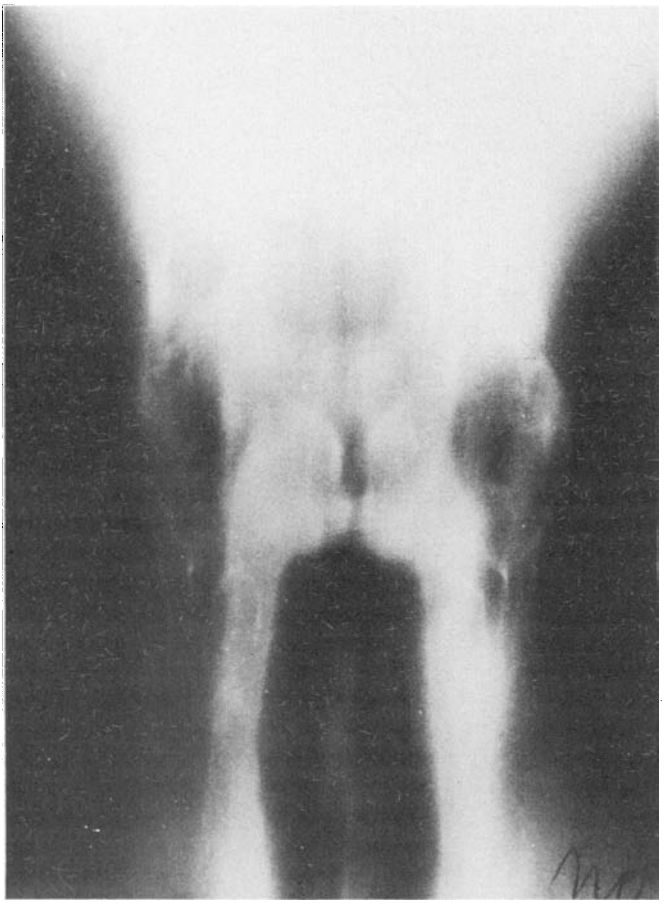


FIG. 1

Frontal tomography of the larynx during expiratory phonation (after laser cordectomy).

showed marked changes during sustained inspiratory phonation. This could be explained speculatively by assuming that inspiratory phonation is not associated with complicated neuromuscular laryngeal adjustments. Thus, both fold configurations may change and their margins may become thin by a passive process resulting from deformation under the influence of the inspiratory air stream.

Mikashi *et al.* (1980), investigating the interaction between CO_2 laser and the soft tissues experimentally, demonstrated crater formation resulting from rapid vaporization of laser water and ejection of solid component. They concluded that the CO_2 laser enabled precise destruction of pre-selected areas of tissue with extraordinary haemostatic effect but without damaging the underlying tissue. This presents a great advantage and is helpful in function-preserving surgery. We have tried to explain the mechanism of the new fold formation with regard to this laser effect and to contemporary knowledge of laryngeal physiology. The Bernoulli effect and its significance in normal phonatory physiology has nowadays become a widely accepted scientific fact (Sawashima and Hirose, 1981; Titze, 1981; Fujimura, 1981). Initially the vocal folds are brought to the prephonatory (paramedian) position; this

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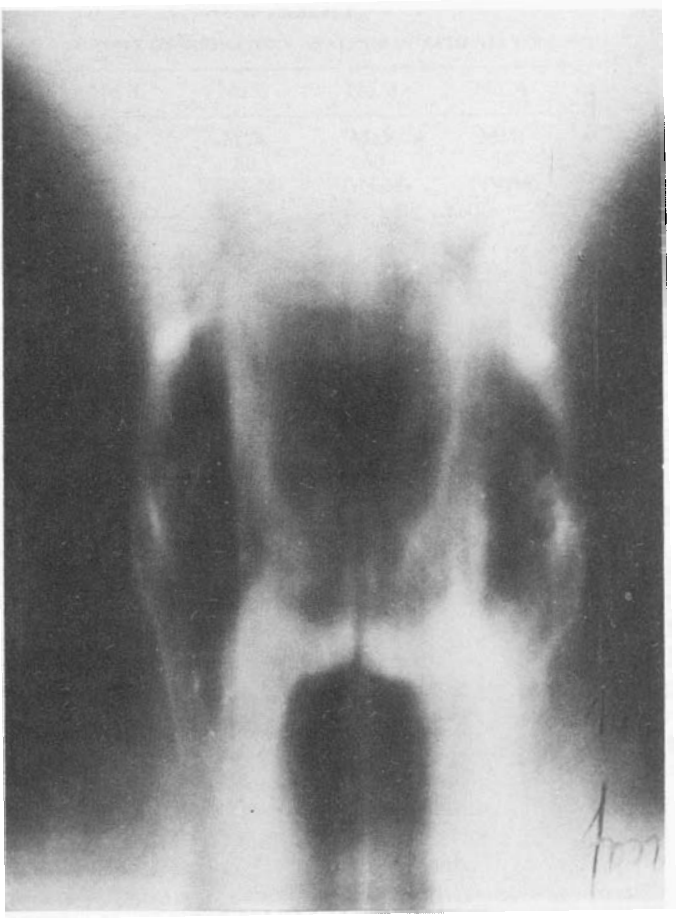


FIG. 2

Frontal tomography of the larynx during inspiratory phonation in a patient following laser cordectomy (demonstrating caudal displacement of the vocal folds).

TABLE II

PARAMETERS EXTRACTED FROM ACOUSTIC ANALYSIS OF VOICE SIGNAL IN PATIENTS FOLLOWING LASER CORDECTOMY

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Fundamental frequency (Hz.)	250	240	130	133	200	227
Vocal range (Hz.)	242–326	200–300	106–161	100–171	183–200	255–288
Harmonic acoustic energy (Hz.)	to 2,500	to 1,500	to 7,000	to 1,500	to 2,500	to 2,500
Glottal periodicity	+	+	+	+	+	+
Classification of hoarseness (Yanagihara)	3	2	0	1	3	2

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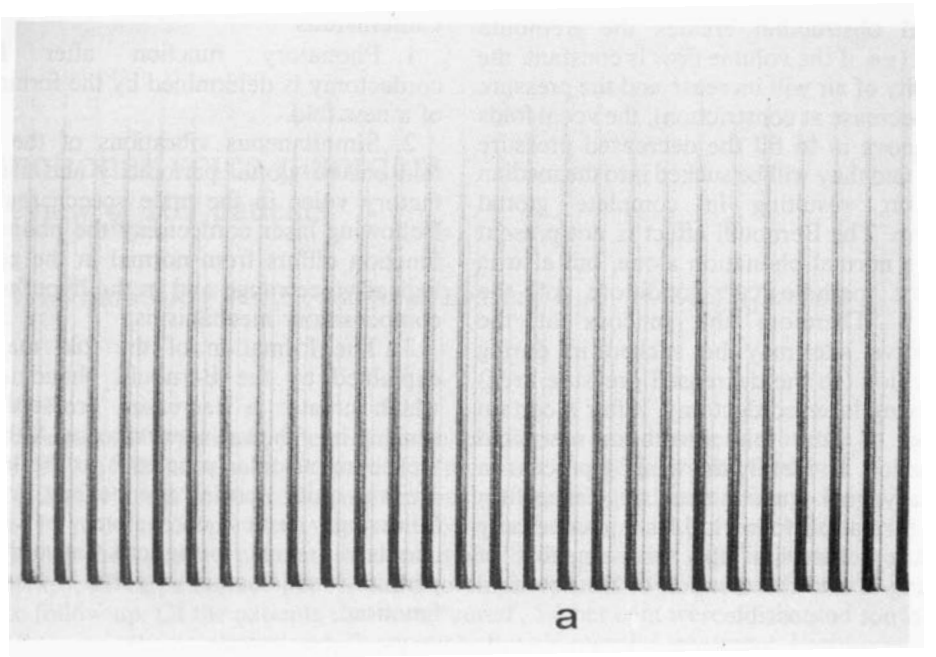


FIG. 3

Acoustic analysis of the voice signal in a patient with laser cordectomy with clearly visible glottal periodicity.

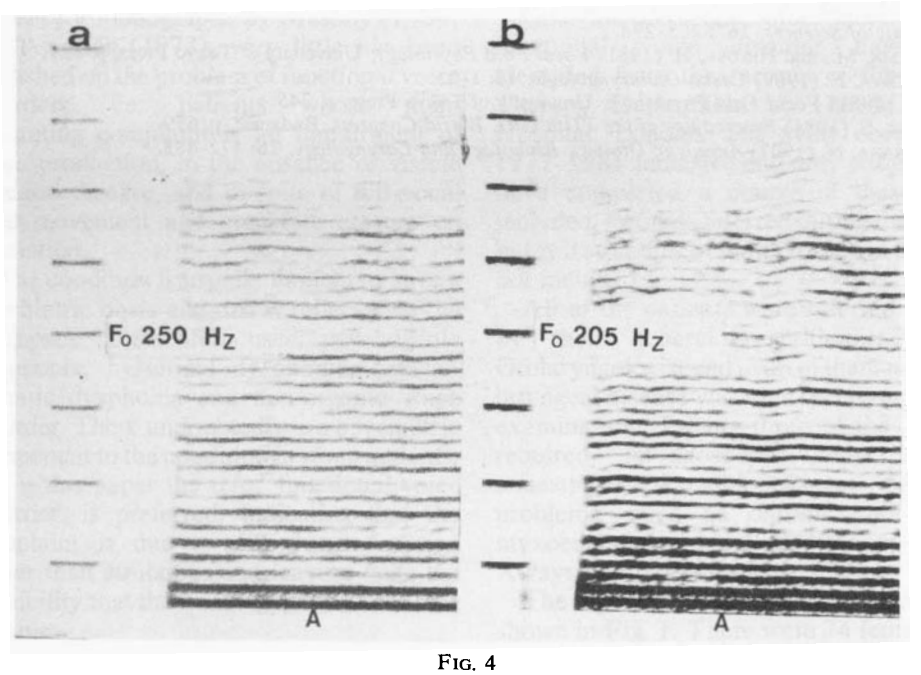


FIG. 4

Narrow three-dimensional acoustic analysis of the vocal range in a patient after laser cordectomy.

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partial obstruction creates the Bernoulli effect (i.e. if the volume flow is constant, the velocity of air will increase and the pressure will decrease at constriction), the vocal folds will move in to fill the decreased pressure area, and they will be sucked into the median position, resulting in complete glottal closure. The Bernoulli effect is not present during normal phonation alone, but also in various pathological conditions of the larynx. Therefore the mucosa at the operative site may be sucked in during phonation (to the decreased pressure area) following laser cordectomy. After a certain period of time this results in new fold formation. Evidently the healing process in the laryngeal mucosa does not cause firm scar formation following laser cordectomy because otherwise the phenomenon of sucking-in and the creation of the new fold would not be possible.

Conclusions

1. Phonatory function after laser cordectomy is determined by the formation of a new fold.

2. Simultaneous vibrations of the new fold ensure glottal periodicity and a satisfactory voice in the male speech register. Following laser cordectomy the phonatory function differs from normal in the pathological voice range and in the hyperkinetic compensatory mechanisms.

3. The formation of the fold may be explained by the Bernoulli phenomenon, which creates a decreased pressure and sucking-in of the laryngeal mucosa. Although the neuromuscular processes in the larynx are not quite normal, the healing process following laser cordectomy (without excessive scar formation) nevertheless permits satisfactory glottal vibratory function.

References

BERG, J. U., ZANTEMA, J. T., and DOORNEBAL, P. (1957) *Journal of the Acoustical Society of America,* **29:** 626–631.

FUJIMURA, O. (1981) *Vocal Fold Physiology,* University of Tokyo Press, p. 271.

MIKASHI, S., JAKO, G. J., INCZE, J., STRONG, M. S., and VAUGHAN, C. W. (1980) *Annals of the New York Academy of Sciences,* **267:** 263–294.

SAWASHIMA, M., and HIROSE, H. (1981) *Vocal Fold Physiology,* University of Tokyo Press, p. 329.

SEDLÁČKOVÁ, E. (1969) *Česka Otolaryngologie,* **18:** 1–21.

TITZE, I. (1981) *Vocal Fold Physiology,* University of Tokyo Press, p. 245.

VEČERINA, S. (1981) *Proceedings of the XIIth ORL World Congress,* Budapest, p. 679.

YANAGIHARA, N. (1967) *Annals of Otology, Rhinology and Laryngology,* **76:** 472–488.

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