Utilization of laryngeal ultrasound and laryngoscopy for the diagnosis and management of bilateral vocal fold paralysis

Diaa M. El Hennawi[a], Mohamed R. Ahmed[a], Alaa M. Farid[a], Hassan Hal[b]

[a]Otolaryngology Unit, [b]Radiology Unit, Faculty of Medicine, Suez Canal University, Ismailia, Egypt

Correspondence to Mohamed R. Ahmed, MD, Assistant professor of Otolaryngology, Department of Otolaryngology, Faculty of Medicine, Suez Canal University, 002 Ismailia, Egypt
Tel: +20 128 504 3825; fax=0020663415603; e-mail: m_rifaat@hotmail.com

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Objective
Management of a severely compromised airway because of bilateral paralysis of the vocal cords represents a significant challenge. The aim of this study is to establish the validity and accuracy of ultrasonography in the evaluation of CO_2 laser surgery using optical endoscopy as the gold-standard technique.

Participants and methods
A thorough ultrasonographic examination of the vocal cords during different phases of respiration and phonation, both pre-CO_2 and post-CO_2 laser surgery, was performed. Endoscopic partial transverse cordectomy, using a CO_2 laser, was the operation of choice in the management of bilateral vocal cord paralysis. Thirty-six patients were included in this study; a control group of 125 normal volunteers was also included for standardization of the ultrasonographic technique.

Results
Patients with bilateral immobility of the vocal cords (36) in the adduction position were subjected to a CO_2 laser. Endoscopic partial transverse cordectomy was performed. Twenty patients required unilateral laser surgery because the anterior angle was 12° or greater by ultrasound measurement. Postoperative follow-up of the anterior angle increased from 14° to 26°, whereas 16 patients (45%) required bilateral laser surgery as the anterior angle was less than 12° on ultrasound. Postoperatively, the anterior angle increased from 16° to 26°.

Conclusion
Ultrasonography is the modality of choice in the evaluation of patients with bilateral vocal cord paralysis quantitatively and dynamically. These might improve the functional results of one-step CO_2 laser surgery.

Level of evidence:
4.

Keywords:
larynx, paralysis, ultrasound vocal fold

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Introduction

A rigid telescope has been used widely in otolaryngology outpatient clinics for endolaryngeal evaluation and has the following advantages: the image is larger, brighter, and clearer [1,2]. Unfortunately, not all patients tolerate laryngeal telescopic examinations, especially those with a sensitive gag reflex, limited jaw and neck mobility, or patients with stridor [3,4].

The management of patients with bilateral vocal cord paralysis presents a challenge to the otolaryngologist. Numerous surgical procedures have been developed in an attempt to improve patient airway insufficiency without leaving him/her with a raspy weak voice [5]. Dennis and Kashima [6] reported the successful use of CO_2 laser endoscopic posterior transverse cordectomy (EPPTC) in patients with severely compromised airways because of bilateral vocal cord paralysis. The EPPTC procedure was introduced to improve the functional results of CO_2 laser endoscopic arytenoidectomy, with a success rate in restoration of the airways ranging between 50 and 68% [6–8].

Ultrasound has become a very important widely used diagnostic tool for the diagnosis of head and neck diseases; however, ultrasound has rarely been used in the diagnosis of laryngeal diseases related to the visualization of endolaryngeal structures [9].

Laryngeal ultrasound has significantly improved the evaluation of vocal cord movement, functional assessment, and diagnosis of vocal cord paralysis [10,11]. Ultrasonography is considered a safe imaging modality, without exposing patients to the unnecessary

harmful effects of ionizing radiation of computed tomography [12].

The aim of this study was to quantitatively and dynamically assess vocal cord movement using laryngoscopy and ultrasonography in patients with bilateral vocal cord paralysis to improve the functional results of one-step CO_2 laser EPPTC for restoration of the airway.

Participants and methods

This was a prospective study carried out by the Department of Otolaryngology, Suez Canal University Hospital, located in Ismailia, Egypt, from July 2007 to 2011. The study group included 36 patients with bilateral paralysis of the vocal cords in the adduction position for at least 6 months to ensure that no spontaneous recovery occurred. This group was treated with CO_2 laser EPPTC, with a minimum follow-up of 1 year. Patients with glottis or thyroid tumors were excluded from the study; also, other causes of vocal cord immobility were excluded, for example, posterior glottic web and cricoarytenoid joint fixation. Patients with tracheostomy were excluded from the study. A control group of 125 nonsmoker volunteers without laryngeal symptoms and normal laryngoscopic appearance was included to standardize the normal appearance of the vocal cords on high-resolution laryngeal ultrasound. The study protocol was approved by the local ethics committee and written informed consent was obtained from each patient.

Methods

Patients in the study group and normal volunteers in the control group were subjected to the following:

(a) A full assessment of history with a complete head and neck examination,
(b) Rigid laryngoscopy (70°),
(c) High-resolution laryngeal ultrasound, and
(d) Routine lab investigations (which included complete blood count, and liver and kidney function tests) to determine whether patients are candidates for surgery or not fit the study group.

Laryngoscopy was performed using a Carl Storz, Hopkins, rigid laryngoscope 5.8 mm with a 70° angle, photodocumentation, and video recording using a Watec 221 S camera, Germany. The outcomes of examination of vocal cord position and degree of mobility were recorded on a computer for assessment and measurement of the anterior angle, and the distance between both vocal cords at the posterior commissure using Dr Speech, version 4.

High-resolution laryngeal ultrasound was performed by an expert radiologist using the General Electric Voluson – 730 – Expert Machine and Philips HD 11 XE, with evaluation of the vocal cords both with a small linear probe of 6–12 MHz frequency and with a high-resolution monitor and thermal page printer.

Patients or volunteers were placed in a supine position with the neck slightly extended. Gel was applied to the linear probe. The thyroid cartilage was first identified and the ultrasound evaluation was started by placing the probe transversely on the mid part of the thyroid cartilage and moving upwards and downwards until the image of the vocal cords was obtained. The vocal cords were examined during two phases:

(a) During quiet breathing, which enables better assessment of the vocal cords, and
(b) During phonation (by making a 'long E' sound), during which the mobility of the vocal cords was assessed.

In the study group, the vocal cords were studied preoperatively and postoperatively at different phases of respiration and phonation with identification of the following:

(i) Position of both vocal cords (whether symmetrical or asymmetrical),
(ii) Angle of deviation,
(iii) Distance between both vocal cords at the posterior compartment near the arytenoids (respiratory component),
(iv) Degree of movement (vibration) of the cords at different phases of phonation (e.g. 'Ahhh, Ohh,' and graded as weak, moderate, and good to differentiate between paralysis, paresis, and mobile cord, respectively) to enable the selection of which cord to operate on and to determine the timing of the operation, on the basis of objectives parameters, and
(v) Sonographic examination of the thyroid gland to detect incidental pathology.

CO_2 laser EPPTC, as described by Laccourreye *et al.* [8], was performed on all patients after obtaining their written consent. The main goal of CO_2 laser EPPTC is to achieve a clinical cure (satisfactory results). Clinical cure was defined as the distance between both vocal cords of at least 5.5 mm. However, to achieve an objective cure, the distance should be at least 7 mm [6–8].

Direct laryngoscopy and ultrasonography were performed preoperatively and 1 month postoperatively, with subsequent computer analysis of the generated

data. Patients were followed up monthly (for at least 1 year) and evaluated both subjectively and objectively (using endoscopy and ultrasound).

Results

The control group, which included 125 nonsmoker normal volunteers with a normal laryngoscope appearance, was subjected to high-resolution laryngeal ultrasound for standardization and familiarization with the normal sonographic appearance of the vocal cords. Examination of the larynx was performed through the mid portion of the thyroid cartilage to identify both vocal cords, which appeared echogenic on ultrasound. In addition, thyroid lamina, anterior commissure, vocal process of the arytenoids, and glottic chink were identified during normal quiet breathing and phonation (prolonged E). The free margins of the vocal cords were not well defined. The posterior parts of the vocal cords were also not clearly identified (as can be seen in Fig. 1).

Evaluation of the mobility of the vocal cords requires that the ultrasound probe be positioned exactly horizontal during imaging so that the range of motion of the vocal cords can be observed clearly and measured accurately. Calcification of the thyroid cartilage interfered with satisfactory ultrasonographic assessment of the vocal cords.

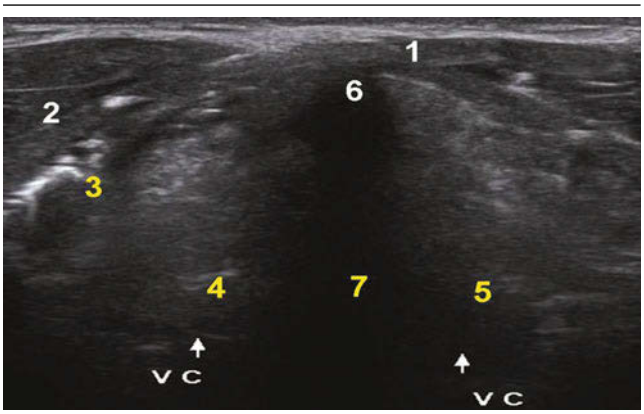
The values for anterior angle of the vocal folds measured by ultrasound and the posterior interarytenoid region as measured by ultrasound (true mm units) are summarized in Table 1.

The study group included 36 patients with bilateral immobility of the vocal cords in the adduction position (secondary to paralysis of both recurrent laryngeal nerves). The study group included 22 women and 14 men, mean age 42.7 years. The cause of bilateral recurrent laryngeal nerve paralysis and bilateral paralysis of the vocal cords was thyroid surgery in 29 patients (80%), whereas the cause in seven patients (20%) was unknown (possibly because of viral neuritis). All patients had dyspnea on exertion, dyspnea at rest, and a weak raspy voice. Twenty patients in the study group (55%) required unilateral EPPTC because the anterior angle was 12° or greater (mean 13°) by ultrasound measurement. The interarytenoid distance of the same patients measured by ultrasound was greater than 4.5 mm (mean 5.1 mm), and by laryngoscopy, the interarytenoid distance measured a mean of 2.5 pixels. Excellent airway patency (measured subjectively and objectively) was achieved in 17 patients (85%) and satisfactory patency (measured subjectively) was achieved in three patients (15%) following laser EPPTC.

Postoperative follow-up values of the anterior angle of the vocal folds measured by ultrasound and the posterior interarytenoid region as measured by ultrasound (true mm units) are summarized in Table 1.

Sixteen of the 36 patients in the study group (45%) required bilateral EPPTC [8] as the anterior angle was less than 12° by ultrasound and 24° by laryngoscopy, whereas the posterior interarytenoid distance measured by ultrasound in the same patients was 4 mm or less (range between 3.5 and 4 mm) and two pixels by laryngoscopy (Figs 2 and 3).

Figure 1



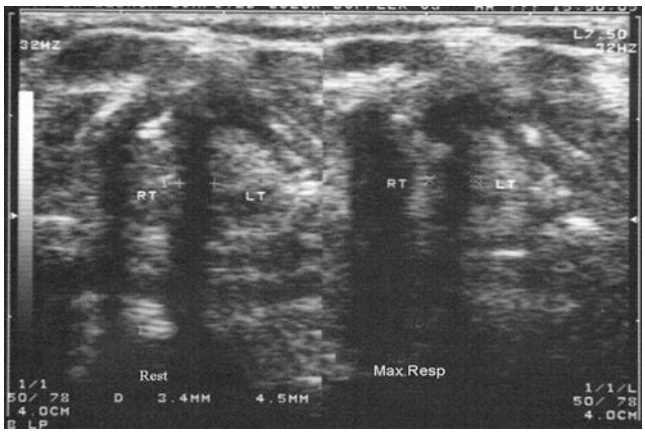
Normal anatomy of the larynx at the level of the vocal folds by ultrasound: (1 = skin and subcutaneous tissues, 2 = strap muscles of the neck, 3 = lamina of the thyroid cartilage, 4 = right vocal fold, 5 = left vocal fold, 6 = anterior commissure, 7 = glottic chink).

Table 1 The mean anterior angle of the vocal cords measured by ultrasonography and computer analysis for laryngoscopy. The posterior interarytenoid area was measured by ultrasonography and by a laryngoscope

	Anterior angle (deg.)		Posterior interarytenoid area	
	Measured by ultrasound	Computer analysis for laryngoscope	By ultrasound (mm)	By laryngoscope (pixel)
Control group (normal)	32	69	10.2	5.1
Preoperative	13	26	5.1	2.5
Unilateral laser EPPTC (postoperative)	23.7	42.6	8	4.9
Bilateral laser EPPTC (postoperative)	23.1	45	7.8	4.8

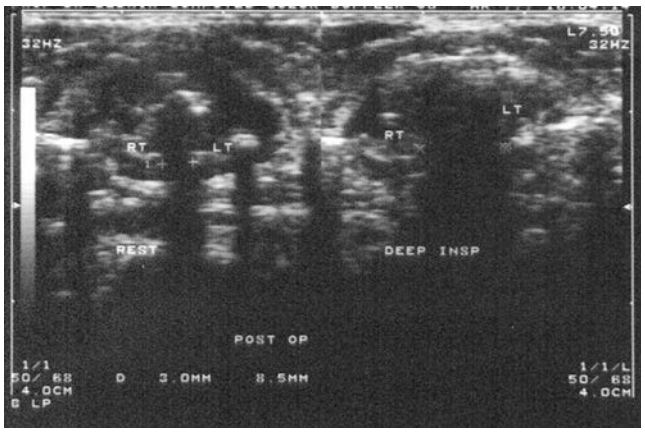
EPPTC, endoscopic partial transverse cordectomy.

Figure 2



Preoperative bilateral vocal cord paralysis in the adduction position during rest and maximum respiration.

Figure 3



Postoperative bilateral vocal cord paralysis during rest and maximum respiration.

Postoperative results of the bilateral group showed that 12 patients (75%) had excellent airways (subjectively and objectively), whereas four patients (25%) had satisfactory airways (clinical cure). In patients with excellent airways after a surgical intervention, postoperative follow-up values for the anterior angle of the vocal folds measured by ultrasound and the posterior interarytenoid region as measured by ultrasound (true mm units) are summarized in Table 1.

Patients with satisfactory airways had an anterior angle of 14° by ultrasound and 28° by laryngoscopy. The interarytenoid distance of the same patients was 5.5 mm by ultrasound and three pixels by laryngoscopy.

Discussion

Huang *et al.* [13] reported that laryngeal ultrasonography at frequencies ranging from 10 to 30 MHz was useful in the diagnosis of diseases of the vocal cords. Vats *et al.* [14] reported that ultrasound has the same diagnostic accuracy as laryngoscopy in the detection of vocal cord mobility.

Laryngeal ultrasound examination is a noninvasive, painless, and much less expensive diagnostic tool than other techniques used in the evaluation of vocal cord paralysis [15].

On evaluation of the normal ultrasonographic anatomy of the vocal folds, the free margin of the vocal folds could not be detected and well demarcated, appearing as an ill-defined margin because of the air–soft tissue interface between the glottic air and the tissues of the margin of the vocal cords. Garel *et al.* [16] reported that the air–soft tissue interface would make it impossible to delineate the margin of the vocal cords.

In addition, the calcification of the thyroid cartilage interfered with proper assessment of the vocal folds, which is supported by Youssef *et al.* [17], who reported that the laryngeal space cannot be seen clearly if the thyroid cartilage is calcified. In addition, Garel *et al.* [18] reported that complete anterior calcification of the thyroid cartilage created an acoustic shadow, which made it difficult to evaluate the larynx by ultrasound.

In 1980, Shugar *et al.* [19] reported that in patients with bilateral paralysis of the true cords, CO_2 laser endoscopic arytenoidectomy was successful in relieving the airway obstruction only if an adjacent portion of the true vocal cords was resected at the same time as endoscopic laryngoscopy [19].

In the early 1990s, many attempts were made to increase the phonatory results and to reduce the risk of aspiration after a CO_2 laser endoscopic arytenoidectomy. Dennis and Kashima [6]and Kashima [7] presented phonatory and respiratory findings, documenting that CO_2 laser EPPTC was effective in relieving airway obstruction without aspiration and could be performed without prophylactic tracheostomy [6,7,11]. However, data from Dennis and Kashima [6]and Lawson *et al.* [20] documented the objective restoration of good voice quality after CO_2 laser EPPTC. Lawson *et al.* [20] also compared the vocal results after both techniques (CO_2 laser endoscopic arytenoidectomy and CO_2 laser EPPTC), and they reported that there was no statistically significant difference in restoration of good voice quality between the two techniques [20].

Dennis and Kashima [6] documented that three of the six (50%) patients who had bilateral paralysis of the vocal folds who were managed with CO_2 laser EPPTC required a revision procedure to definitely relieve the airway obstruction. Laccourreye *et al.* [8] reported

similar results as initial CO_2 laser EPPTC resulted in a 68% success rate in one-step restoration of the airways. The cause of unsuccessful restoration of the airways was the development of a granuloma in two patients and an insufficient airway in six patients. In this study, preoperative assessment using ultrasound, laryngoscopy, and computer analysis of the generated data to determine the glottic width and to measure the anterior angle showed improved successful outcome from 50 [6] to 100% clinical cure and from 68 [10] to 80% objective improvement; the difference was statistically significant. In our opinion, postoperative insufficient airways may be avoided by a proper preoperative assessment. Quantification of the generated data is the most accurate method for preoperative assessment. This may explain the difference between the results of both studies. In our study, the decision to perform CO_2 laser EPPTC was not made on the basis of a subjective individual surgeon decision or experience as in similar studies [6–8], but on the basis of objective parameters, which improved the overall success rate and reduced the morbidity of one-step CO_2 laser EPPTC.

In our study, ultrasonography of the larynx was proven to be a sensitive tool in assessing the respiratory and phonatory function of patients with bilateral vocal fold paralysis. As a noninvasive technique, ultrasonography of the larynx enables dynamic evaluation of the vocal cords with less patient effort and without respiratory distress. It is a safe, short, and easily available low-cost procedure that does not require sedation. Laryngeal ultrasonography requires minimal training to interpret the images and findings [10]. Ultrasound examinations are easily documented, enabling quantification of the degree of vocal cord movement in patients with vocal cord paresis or paralysis for preoperative and postoperative comparisons. In addition, the ultrasound machine is portable and can be used at the bedside [11].

However, computer analysis using certain computer programs with laryngeal endoscopy enables documentation, data analysis, and objective assessment, independent of the surgeon's experience. However, measurement of laryngeal movement by computer analysis is indirect and susceptible to many variations. First, computer analysis depends on the frame chosen for measurement. Second, the line or the angle to be measured is liable to individual variations, unlike ultrasound measurements, which are calibrated in true millimeter units, and are accurate and devoid of individual variations. This may explain the narrow range of measurements in pixels between the different patients in computer analysis of the laryngoscopic view. We advocate the combination of ultrasonography and laryngoscopy not only for an accurate preoperative assessment in critical cases where a 1 mm difference may alter the outcome of surgery but also to achieve excellent postoperative results.

The potential value of both techniques is that they provide answers to several crucial questions. First, the decision to perform surgery or to wait depends on fixed parameters: if the posterior interarytenoid distance is greater than 5.5 mm or the anterior angle is greater than 14° by ultrasound, it is better to wait. Second, the decision to perform unilateral or bilateral CO_2 laser EPPTC depends on whether the posterior interarytenoid distance is greater than or equal to 4.5 mm or the anterior angle is greater than or equal to 12° by ultrasound; the decision should be to proceed to a unilateral procedure. Third, if unilateral EPPTC is intended, one must locate the more fixed side (vocal cord) to be operated upon as determined accurately by ultrasound. Moreover, the appropriate management on the basis of the above measurements will lead to decreased operative and postoperative costs, mortality, and morbidity as a result of the procedure.

The strengths of our prospective study were that multiple outcomes could be measured and good for measuring ultrasonography of the vocal cords compared with laryngoscopy, whereas its weaknesses were costly and time consuming with prone to bias because of loss to follow-up.

Conclusion

Ultrasonography of the vocal cords (in the hands of a well-qualified operator) is the modality of choice for the assessment of patients with bilateral vocal cord paralysis. It provides accurate preoperative data compared with laryngoscopy, which was less informative because of respiratory distress and lack of state-of-the art technology provided by ultrasonography measurements. However, both laryngeal ultrasonography and laryngoscopy should be combined to achieve optimal successful restoration of the airways by one-step CO_2 laser EPPTC.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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