Aspiration has been frequently noted among patients suffering from vocal-fold paralysis. The association between a defect of glottal closure and aspiration in patients with unilateral vocal paralysis appears to have been rarely reported. The current study reviews collected data consisting of videotaped flexible nasoendoscopy and stroboscopy for patients with a unilateral vocal-fold paralysis. Mean normalized glottal gap areas for patients suffering vocal paralysis with associated aspiration are significant greater than that for the non-aspiration group. Subsequent to the surgical correction of the glottal gap, all patients recovered well from their earlier aspiration.

The investigation of objectively derived data revealed that poor airway protection due to incomplete closure of the vocal fold was the major cause of aspiration for patients suffering unilateral vocal-fold paralysis. Intracordal autologous fat injection can successfully improve the breath control and eliminate aspiration in patients with vocal-fold paralysis.

Keywords aspiration glottal gap area vocal paralysis intracordal fat injection

Aspiration may produce a devastating effect upon the health and quality of life of a patient. The incidence of aspiration among patients with glottic incompetence has been reported to range from 24% to 61% depending upon the different causes.1–4 Patients with glottic incompetence resulting from a variety of conditions including vocal cord movement impairment, Parkinsonism, or old age, usually also suffer from aspiration of variable degrees. In our experience, aspiration was the second frequent symptom for patients suffering unilateral vocal-fold paralysis. It is thus clearly important to assess the swallowing function for such patients in order to attempt to prevent aspiration prior to its occurrence.

The pathogenesis of aspiration among vocal-fold paralysis patients would still appear to be unclear. In 1996, Aviv et al.5 proposed that a laryngeal sensory deficit was a predictor of aspiration. They assessed the airway protection by endoscopically administrating air pulses to the patients’ laryngeal mucosa in order to elicit the laryngeal adductor reflex. They concluded that a poor laryngopharyngeal reflex will decrease the valving effect of the glottis when swallowing and potentially induce aspiration. For patients suffering unilateral vocal-fold paralysis, the laryngeal adductor reflex cannot be elicited by performing sensory stimulation. Thus, the degree of glottic valve defect when swallowing is quite difficult to identify when using such a diagnostic method.

In the animal study of Iwanaga et al.6 a decreased glottic closing force was noted following resection of the recurrent laryngeal nerve and the glottic pressure was noted to vary widely due to differences in the position of the paralysed vocal fold and the degree of compensation provided by the unaffected vocal fold. The dimension of the glottic closing force reflects the airway protection function during swallowing. Poor airway protection is one of the major factors in aspiration. Laryngeal medialization surgery by correcting the glottal gap has been reported to be effective in eliminating acute or chronic aspiration among patients with glottic incompetence.7–9 However, to our knowledge, there has been no report objectively measuring the defect of glottal closure and its influence upon aspiration. We therefore have attempted...
to analyse the relationship between glottal gap areas and vocal paralysis-associated aspiration.

**Material and methods**

From July 2000 to June 2003, 36 consecutive patients suffering from unilateral vocal-fold movement impairment, due to recurrent laryngeal nerve palsy, were referred to our institution to undergo a swallowing function and laryngeal examination. Descriptive data were collected including age, gender, aetiological factors and the period of time that had elapsed from the commencement of dysphonia. In order objectively to evaluate the swallowing function and vocal-cord motion, videoscopic flexible nasoendoscopy and stroboscopy were performed, respectively. The normalized glottal gap area (NGGA) based on Omori et al.\(^{10}\) report was measured under videolaryngoscopy and analysed by computer software (Scope View of DR Speech\(^{2}\); Tiger DRS, Inc., Seattle, WA, USA). The traced glottal gap was calculated and expressed in square pixels. Membranous vocal-fold length was measured from the point of the anterior commissure to the point of the tip of the vocal process and was expressed in linear pixels.

\[
\text{NGGA} = \frac{\text{Glottal-gap area}}{(\text{Membranous vocal-fold length})^2} \times 100 \text{ units.}
\]

All 36 patients underwent an intracordal autologous fat injection for the attempted correction of the glottal gap. Swallowing function and voice performance were documented at 1 week posttreatment and then again during the period from 1 to 3 months posttreatment. Objective evaluation of speech and voice relied on acoustic recordings performed prior to and at a time between 1 and 3 months posttreatment. The median follow-up period was 9 months. The author and speech/swallowing therapist performed a concomitant swallowing and phonation suggestion and rehabilitation at each visit.

**Statistical analysis**

The means of the NGGA for both the aspiration and the non-aspiration group were compared using an independent t-test. The NGGA was correlated with the voice variables by a Pearson’s correlation coefficient. For all analyses, statistical significance was taken as \(P < 0.05\). Calculations were made using SPSS software (SPSS Inc., version 11.0 for Windows, Chicago, IL, USA).

**Results**

Following swallowing evaluation, 20 of the 36 patients had aspiration, while the remaining 16 patients had only a voice problem. The duration of aspiration history ranged from 4 to 30 months. Table 1 summarizes the pathogenesis of vocal paralysis for our patients. The patients’ ages ranged from 26 to 81 years (median age = 51 years). The mean NGGA value prior to and following intracordal fat injection is shown in Fig. 1. The mean preoperative NGGA value for the aspiration group was 14.3, which was significantly larger than the corresponding value for the non-aspiration group (14.3 versus 7.4; \(P = 0.007\)). Subsequent to the intracordal fat injection operation, the mean NGGA value for the aspiration and non-aspiration group decreased to 2.7 and 2.6, respectively. All the patients recovered from aspiration immediately following surgery. The acoustic variables for all 36 patients are shown in Fig. 2. All voice variables improved following surgical treatment. The preoperative glottal gap area was compared with preoperative voice parameters by application of a Pearson’s correlation coefficient method. The S/Z ratio and maximal phonation time exhibited a significant relationship with the preoperative glottal gap area (\(P < 0.01\); Table 2).

**Discussion**

Aspiration caused by glottic incompetence may vary from minimal occasional aspiration of saliva with a somewhat annoying cough to severe and life threatening aspiration.\(^{11}\) The underline mechanism for such aspiration appears to relate...
to premature spillage, abnormal coordination, abnormal glottic movement, ineffective bolus transport or a combination thereof. The sensory deficit may also be a possible causative factor of aspiration for patients with laryngeal incompetence. But Bastian questioned the role of laryngeal sensation in airway protection. In their study, most patients did not aspirate after anaesthetizing the larynx. As the onset of vocal-fold adduction has been reported to be the first recordable event in the process of normal swallowing, a point with which we concur, it would appear likely that vocal-fold closure movement is the primary protective process that prevents aspiration during deglutition. In our study, we found all patients demonstrated a similar vocal-fold movement disorder but displayed different swallowing results due to the relative position of the vocal fold.

The width of the preoperative NGGA was found to be a potential warning sign for aspiration in our study. In our series of data, patients suffering from an NGGA wider than 10 units all experienced aspiration. Among the patients with unilateral vocal-fold paralysis, the NGGA value for the aspiration group was significantly wider than was the corresponding value of the non-aspiration group. Although other airway protection mechanisms (such as laryngeal elevation and epiglottis tilting) appeared to be intact, they were not able to compensate the consequences caused by the wide glottal gap. According to the result, we conclude that in patients with a unilateral vocal-fold paralysis, the probability of aspiration increased when the glottal gap was wide.

Those patients experiencing a high-level laryngeal nerve paralysis may also suffer additional disruption to their pharyngeal innervation. In such a group of patients, instead of glottic incompetence, laryngeal sensation, pharyngeal protective response and contraction force are also reduced. Poor food bolus management with premature spillage of materials contributes to the aspiration in such patient group. We postulate that the dimension of the NGGA have a poor predictive value for patients suffering high-level laryngeal nerve paralysis.

Several previous reports have suggested that combining laryngeal framework surgery and cricopharyngeal myotomy, instead of medialization surgery alone, is appropriate for treating glottic incompetence-related aspiration. Hetmiller et al. claim that aspiration results primarily from the impairment of airway protection, not from oesophageal obstruction with laryngeal ‘spill over’, myotomy typically being reserved for patients who are continuously experiencing this problem subsequent to conservative management and medialization procedures having failed. In 1998, Heller et al. reported that an intracordal Teflon injection appeared to relieve aspiration for high vagal paralysis following intracranial surgery. However, Teflon injections, complicated with foreign body inflammation and granuloma, have not often been performed in recent years. Such disadvantages led to the use of injectable fat as a substitute material. In our study, we have demonstrated that the closure of the glottal gap by intracordal fat augmentation is an appropriate method to relieve aspiration.

The main drawback of autologous fat injection is the relative unpredictability of the degree of its resorption. In previous reports, the results of injection of fat lasted for from 2 months to 4 years. However, most studies evaluated the voice outcome but not the swallowing function. In the context of swallowing, the compensation mechanism may save some central palsy patients from experiencing aspiration. We suggest that some compensation for vocal incompetence is possible subsequent to gradual onset of the resorption of fat and muscle atrophy, and, as a consequence, aspiration is not likely to recur.

Surgery to close an existing glottal gap improves not only airway protection but also breath control, which is also helpful in swallowing rehabilitation. In our experience, the Valsalva manoeuvre, the most important part of supraglottic swallowing, cannot be maintained for a period of more than 3 s prior to intracordal fat augmentation surgery. Prior to surgery, we have noted that air always leaks out from the glottal gap when forceful exhalation is performed. An intracordal fat injection will help to enforce adequate glottic closure and make the rehabilitation process easier.

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<th>Table 2. The correlation of glottal gap area and the voice parameters</th>
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<td>$S/Z$ ratio</td>
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<td>Pearson’s correlation</td>
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H/Z ratio, harmonic to noise; MPT, maximal phonation time.
We thus propose three distinct mechanisms for this treatment modality. First, intracordal fat injection increases the bulk and stiffness of the vocal cord with medialization, and provides an effective buttress, and, as a result, the glottic closure force is increased. Secondly, subglottic pressure is increased when deglutition occurs following complete closure of the larynx. Thirdly, subsequent to closure of the glottal gap, patients should be able to breath hold subsequent to a full inhale/exhale manoeuvre. This further helps patients to conduct supraglottic swallowing in order to reduce the likelihood of aspiration.

This preliminary study has provided compelling evidence to suggest that patient’s experience aspiration improvements as a consequence of the correction of an existing inappropriate glottal gap. However, these results are not conclusive because of several weaknesses. First, the sample size is somewhat modest and thus, the impact of variables should have been controlled for. Although the study group was limited to those patients suffering from similar lower laryngeal disease, variables that were not controlled for included potential effects of gastroesophageal reflux, pulmonary vital capacity, duration of vocal paralysis and the extent of pharyngolaryngeal fibrosis. Nevertheless, we believe that our results have generated several interesting hypotheses for future investigation. We propose that age- and disease-specific patients would constitute a reasonable group to study the effects of the variation in glottal gap upon aspiration in a prospective manner.

Conclusions

A wide NGGA is a warning sign of aspiration for patients suffering from unilateral vocal paralysis. The correction of wide NGGA by intracordal autologous fat injection can successfully eliminate aspiration for patients suffering from unilateral vocal paralysis by lower laryngeal nerve or endolaryngeal damage. For patients who require swallowing rehabilitation, breath control can be assisted by correction of the existing aberrant NGGA.

References