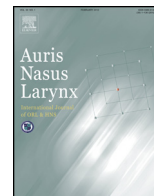




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## Vocal-fold vibration of patients with Reinke's edema observed using high-speed digital imaging

Takeshi Watanabe, Kenichi Kaneko\*, Koichi Sakaguchi, Haruo Takahashi

Department of Otolaryngology—Head and Neck Surgery, Nagasaki University Graduate School of Biomedical Sciences, 1-7-1 Sakamoto, Nagasaki 852-8501, Japan

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### ABSTRACT

**Objective:** We aimed to assess the vocal-fold vibration of patients with moderate-to-severe Reinke's edema using high-speed digital imaging (HSDI) and videostroboscopy and to confirm HSDI usefulness in examining the vocal folds with Reinke's edema.

**Methods:** We examined the vocal folds of seven patients (six severe and one moderate; six females and one male; aged 55–74 years; mean 64.7 years) with Reinke's edema using HSDI and videostroboscopy. The following characteristics were analyzed: glottic closure, mucosal-wave propagation, left–right asymmetry, phase shift, frequency difference, periodicity, and contact of the true vocal fold with the false vocal fold.

**Results:** HSDI revealed complete glottic closure, anterior–posterior phase shift, and obvious contact of at least one side of the edematous true vocal fold with the ipsilateral false vocal fold in all patients. Mucosal-wave propagation increased in six patients and decreased in one. Left–right asymmetry was observed in six patients. Left–right phase shifts and left–right frequency differences were observed in four and two patients, respectively. The vibration was periodic in four patients, quasi-periodic in three, and aperiodic in none. Anterior–posterior frequency differences were not observed for any patient. The vocal-fold vibration always synchronized with strobolights in two patients, while the vibration occasionally and never synchronized in two and three patients, respectively. In one patient whose vibration occasionally synchronized, videostroboscopy could not reveal the slight left–right frequency difference of the vibration.

**Conclusion:** It was often difficult to observe vocal-fold vibration correctly in patients with severe Reinke's edema using videostroboscopy. However, HSDI was useful for examining these patients. Our results suggest that HSDI can be very useful for examining the vocal folds of patients with severe Reinke's edema.

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## 1. Introduction

Reinke's edema is a swelling of the vocal fold in Reinke's space that is strongly related to smoking. It is associated with a characteristic hoarse voice that is rough and of low pitch, and it may present with stridor if the edema is marked. Conservative

treatments, such as smoking cessation, voice therapy, and medication, are generally effective against mild edema; however, microphonosurgery is often necessary in severe cases.

In the vocal fold with Reinke's edema the stiffness of the vocal fold cover (epithelium and Reinke's space) is decreased, whereas the mass of the cover and depth of the vibratory edge are increased [1]. These pathological changes affect the vibratory manner of the vocal folds during phonation.

Observation of vocal-fold vibration in the patients with dysphonia is crucial for accurate diagnosis and evaluation

\* Corresponding author. Tel.: +81 95 819 7349; fax: +81 95 819 7352.  
E-mail address: [kkaneko@nagasaki-u.ac.jp](mailto:kkaneko@nagasaki-u.ac.jp) (K. Kaneko).

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before and after treatment. Videostroboscopy is widely used to observe vocal-fold vibration in clinic. In particular, pre- and post-operative stroboscopic assessment of Reinke's edema is important for phonosurgery [2]. Generally, stroboscopy of the vocal folds with Reinke's edema during phonation reveals complete glottic closure with asymmetric movements of the bilateral vocal folds. Successive vibrations are often aperiodic. The amplitude of horizontal excursion is often small; however, the mucosal wave is usually marked [1,2].

However, clinical use of videostroboscopy is limited because it relies on periodic vocal-fold vibration and a stable phonation frequency to activate the strobolights; these are conditions that are not always present in disordered voices [3]. Conversely, high-speed digital imaging (HSDI) has a clear advantage over videostroboscopy because it can visualize vocal-fold vibrations irrespective of their periodicity and stability of phonation frequencies. However, little is known regarding vocal-fold vibration in patients with Reinke's edema when observed using HSDI. Thus, we assessed patients with moderate-to-severe Reinke's edema using HSDI and videostroboscopy to assess whether HSDI was useful for vocal-fold examination in such patients.

## 2. Materials and methods

We examined vocal-fold vibration of seven patients with moderate-to-severe Reinke's edema (six graded as type III and one as type II under Yonekawa's classification [4], six females and one male, aged 55–74 years, mean: 64.7 years) using a HSDI system and videostroboscopy. The HSDI system comprised a high-speed digital camera (EXILIM PRO EX-F1, Casio Computer Co., Ltd., Tokyo), a 70° rigid laryngeal endoscope (STF-1, Nagashima Medical Instruments Co., Ltd., Tokyo), and a xenon 300-W light source (CLV-S40Pro, Olympus Co., Tokyo) [5]. This system enabled transoral observation of each vocal-fold vibration at a rate of 1200 frames per second (fps) with a resolution of 336 × 96 pixels. Videostroboscopy was transnasally performed with a stroboscope (LS-3A, Nagashima Medical Instruments Co., Ltd., Tokyo) straight after laryngeal observation with usual continuous light source, coupled with a flexible video endoscopy system (ENF-VH and OTV-S7Pro, Olympus Co., Tokyo). LS-3A uses a sensitive contact microphone to extract a patient's fundamental phonation frequency. The patients were asked to phonate the sustained vowel /e/ at a comfortable pitch and intensity during the examination.

HSDI and videostroboscopy images were used to analyze the vocal folds by replaying them at various speeds. In addition, kymograms were constructed from HSDI results using our original software. The vocal-fold vibration was rated per subject by three laryngologists (T.W., K.K., and K.S.) according to the following parameters: glottic closure (1: complete, 2: incomplete, 3: no closure); mucosal-wave propagation (1: decreased, 2: normal, 3: increased), left–right symmetry (1: symmetric, 2: slightly asymmetric, 3: obviously asymmetric), left–right phase shift (1: absent, 2: slight, 3: obvious), anterior–posterior phase shift (1: absent, 2: slight, 3: obvious), left–right frequency difference (1: absent, 2: slight, 3:

obvious), anterior–posterior frequency difference (1: absent, 2: slight, 3: obvious), periodicity (1: periodic, 2: quasi-periodic, 3: aperiodic), contact of the true vocal fold with the false vocal fold (1: absent, 2: slight, 3: obvious) and synchronization with strobolights (1: always, 2: occasionally, 3: never). Here *quasi-periodic* in periodicity implied that even though it was not strictly periodic in time and in amplitude, it did have some periodicity in cycles. Each rater provided ratings twice, with a 1-month interval between ratings, and inter-rater, and intra-rater reliabilities were calculated using Fleiss' Kappa. A large majority of the rating by three raters were chosen as the patients' final result for each parameter.

This study was approved by the institutional review board at Nagasaki University Hospital.

## 3. Results

The outcomes of the vocal-fold observations are shown in Table 1. The inter-rater reliability was 0.93. The intra-rater reliabilities ranged from 0.86 to 1.00.

HSDI revealed complete glottic closure in all patients. Anterior–posterior phase shift was observed in all, obviously in four and slightly in three. Obvious contact of at least one side of the edematous true vocal fold with the ipsilateral false vocal fold was observed in all, and also with the contralateral false vocal fold in two among them. Mucosal-wave propagation increased in six patients and decreased in one. Obvious and slight left–right asymmetry was observed in five and one patients with type-III edema, respectively. Left–right phase shifts and left–right frequency differences were observed in four and two patients, respectively. The vibration was periodic in four patients, quasi-periodic in three, and aperiodic in none. Anterior–posterior frequency differences were not observed for any patient. The vocal-fold vibration always synchronized with strobolights in two patients, while the vibration occasionally and never synchronized in two and three patients, respectively, even after any number of trials. In two patients whose vibration always synchronized and in one whose vibration occasionally synchronized, videostroboscopy produced similar findings as were observed for HSDI. However, in another patient whose vibration occasionally synchronized, videostroboscopy could not reveal the slight left–right frequency difference of the vibration.

Fig. 1 shows representative HSDI images of the vocal-fold vibration for Patient 1 with increased mucosal-wave propagation, obvious left–right asymmetry, obvious anterior–posterior phase shift, and contact of the true vocal fold with the ipsilateral false vocal fold.

## 4. Discussion

In the present study, HSDI revealed complete glottic closure, increased mucosal-wave propagation, left–right asymmetry, anterior–posterior phase shift, and contact of at least one side of the true vocal fold with the ipsilateral false vocal fold in most patients. Among these findings, anterior–posterior phase shift and contact between the true and false vocal fold have not been presented in the past studies. In general, irregular vibration of

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