Laryngeal Aerodynamics After Vocal Fold Augmentation With Autologous Fat vs Thyroplasty in the Same Patient

Dana M. Hartl, MD, PhD; Stéphane Hans, MD, PhD; Jacqueline Vaissière, PhD; Daniel F. Brasnu, MD

Objective: To analyze laryngeal aerodynamics in the same patient in 4 different circumstances: before the onset of unilateral vocal fold paralysis (UVFP), after the onset of UVFP, and after 2 types of surgical vocal fold medialization techniques to compare the results of surgery with the measurements made in that same patient when his larynx was healthy (before paralysis).

Design: Prospective self-paired study of 1 male patient. Measurements were taken before iatrogenic UVFP (of the patient’s healthy larynx), 1 week after the onset of iatrogenic UVFP (thoracic surgery), 3 days after vocal fold medialization with autologous fat, and 2 months after polytetrafluoroethylene thyroplasty.

Setting: University hospital.

Main Outcome Measure: Phonatory airflow and intraoral pressure.

Results: Airflow and intraoral pressure increased after the onset of UVFP. Airflow decreased to preparalytic values after both types of vocal fold medialization. Intraoral pressure decreased after fat injection but increased after thyroplasty, despite the favorable effects of this treatment on laryngeal resistance and vocal efficiency compared with preparalytic values.

Conclusions: Our study demonstrates the variability of intraoral pressure as an indirect measure of subglottal pressure after vocal fold medialization in UVFP, due to as yet unknown factors. Phonatory airflow, laryngeal resistance, and vocal efficiency seem to be more reliable indicators of aerodynamic results after vocal fold medialization.


Phonatory airflow and subglottic pressure are the aerodynamic forces driving laryngeal function in voice and speech. The airflow and pressure characteristics vary according to the laryngeal configuration and gesture. Laryngeal aerodynamics also vary according to age, sex, lung volume, laryngeal and tracheal sizes, and individual voice characteristics.

Unilateral vocal fold paralysis (UVFP) has been shown to cause increased phonatory airflow and pressure. Vocal fold medialization has been shown to decrease airflow by decreasing the glottal gap on phonation. However, the effect of vocal fold medialization on subglottal pressure seems to be more equivocal. Previous reports have been contradictory; some show an increase in pressure and others a decrease in pressure after medialization.

Our study was designed to maximally reduce variability by analyzing laryngeal aerodynamics in the same patient under 4 different laryngeal conditions: (1) with a normal larynx and voice, (2) after the onset of UVFP, (3) after vocal fold medialization by injection of autologous fat, and (4) after thyroplasty with polytetrafluoroethylene (PTFE). Our goal was to compare the effects of these 2 types of treatment on airflow and subglottal pressure with the measurements made in the same patient when his larynx was healthy.

METHODS

Twenty-five patients with left-sided bronchopulmonary carcinoma scheduled to undergo thoracic surgery with left mediastinal lymph node dissection were prospectively examined, their voices were recorded, and phonatory aerodynamic measurements were taken. No patients had any history of laryngeal dis-
The aerodynamic data described in the previous paragraph was thus available for the same patient in 4 different circumstances: (1) with a healthy larynx and voice, (2) after the onset of UVFP, (3) after vocal fold medialization by injection of autologous fat, and (4) after thyroplasty with PTFE. The data obtained after vocal fold medialization were compared with the data obtained before paralysis and compared with data reported in the medical literature.

The data obtained is shown in Table 1. Maximum phonation time decreased after UVFP and increased after both types of treatment, almost to preparalytic values. Despite the visual control of vocal intensity, the sound pressure level was lower than 70 dB after UVFP for the vowel sound /a/ and the syllable /pi/ in comfortable phonation, whereas the sound pressure level was slightly higher than 70 dB in the healthy condition and after both types of treatment. The MFR increased 4-fold for both phonatory tasks after UVFP but returned to preparalytic values after both types of treatment. Intraoral pressure increased after the onset of UVFP and decreased, but not to the preparalytic value, after the fat injection. After thyroplasty, Pio increased again. Laryngeal resistance decreased after UVFP and improved after both treatments, although not to preparalytic values. Finally, vocal efficiency was dramatically decreased by the advent of UVFP but improved to even better than preparalytic values after both types of vocal fold medialization.

Table 2 and Table 3 review literature reports concerning airflow and Pio measurements, respectively. Phonatory airflow systematically decreases after medialization, be it by external thyroplasty with or without arytenoid adduction, or by injection of autologous fat, silicone, micromized acellular dermis, or hydroxylapatite. Furthermore, a recent comparison of the results of micromized acellular dermis injection com-
pared with results of thyroplasty did not reveal a significant difference in airflow between the 2 techniques.16 There does not seem to be any advantage of one technique or material over another in terms of reduction of phonatory airflow.

Our findings in measurements obtained in the same patient are in accordance with reports in the literature. Before treatment, airflow ranged from 340 to 955 mL/s in the reports cited in Table 2. The airflow rate of 547 mL/s for our patient after onset of the UVFP falls within this range. Airflow is affected by the size of the larynx (determined in part by the patient’s sex), by vocal intensity, and by the phonatory task.18-21 These variables could explain the range of results reported in the literature.

Values of less than 280 mL/s for English-speaking women and less than 320 mL/s for English-speaking men are considered to be within the reference range.13,18 The reference range measured for French-speaking men was reported to be 134±43 mL/s (in comfortable phonation).22 Our measurements and the literature reports agree with this data, with a return to healthy values of phonatory airflow after vocal fold medialization.

In contrast, our findings and the literature reports regarding Pio show varying results after vocal fold medialization. Values of 3.3 to 8.1 cm H₂O are considered to be in the reference range for English-speaking men13 and values of 4.9 to 8.8 cm H₂O for French-speaking men using the same method.22 For our patient, the Pio values before UVFP and after vocal fold medialization by fat injection fell within the reference range. In our study, the Pio increased after the onset of UVFP in accordance with previous reports1 and with the reports cited in Table 3. However, the increase in Pio after thyroplasty was unexpected, especially because the acoustic result, reported previously, was favorable with a decrease in high-frequency noise and an increase in harmonic energy and

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<th>Table 2. Previously Reported Average Mean Phonatory Airflow Rates (MFR) for the Vowel Sound /a/ Before and After Vocal Fold Medialization</th>
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<td>Source</td>
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<td>Brandenburg et al,10 1992</td>
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<td>Bielamowicz et al,‡ 1995</td>
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<td>Hirano et al,11 1995</td>
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<td>Adams et al,‡ 1996</td>
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<td>Kraus et al,‡ 1999</td>
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<td>McLean-Muse et al,‡ 2000</td>
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<td>Selber et al,‡ 2003</td>
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<td>Lundy et al,‡ 2003</td>
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<td>Rosen and Thekdi,‡ 2004</td>
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Abbreviations: AA, arytenoid adduction; CT, cricothyroid; NA, not available; thyro, thyroplasty.
*Values in boldface indicate a statistically significant change after treatment.
†Nagashima, Tokyo, Japan.
‡Kay Elemetrics, Pine Brook, NJ.

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<th>Table 3. Previously Reported Average Intraoral Pressure Before and After Vocal Fold Medialization</th>
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<td>Adams et al,‡ 1996</td>
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<td>Shin et al,‡ 2002</td>
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Abbreviations: CT, cricothyroid; Pio, intraoral pressure; thyro, thyroplasty.
*Syracuse, NY.
†P = .04.
‡Kay Elemetrics, Pine Brook, NJ.
§P < .05.
regularity. Another report in the literature also found a statistically significant increase in $P_{io}$ after thyroplasty.

There are several explanations for these discrepancies. First, the Aerophone II allows for the direct measurement of airflow, but measurement of the subglottic phonatory pressure is indirect. According to the phona-
tory model proposed by Smitheran and Hixon,\textsuperscript{23} the $P_{io}$ during the unvoiced stop $/p/$ equalsizes with the subglottic pressure, due to the open glottis and the closed lips during the unvoiced stop. Measuring the $P_{io}$ during the occlusion of the $/p/$ of the syllable $/pi/$, repeated at a rate of approximately 1.5 syllables per second, permits an in-
direct measure of the phonatory subglottic pressure. This indirect method may lead to erroneous results in UVFP as a result of the abnormal laryngeal function. During voicing of the consonant $/p/$, the vocal folds cease to vibrate (devoicing) and are ab ducted. Active devoicing is the result of an active, abrupt, and voluntary abduction of the vocal folds.\textsuperscript{24} Passive devoicing is the result of the pro-
gressive increase in pressure in the vocal tract caused by the occlusion during the consonant. If this pressure is such that transglottic pressure is insufficient for vocal fold vibration, voicing ceases.\textsuperscript{25} In UVFP, voicing is of poor quality and may be more sensitive to passive devoicing than in the case of a healthy larynx. Then, when produc-
ing the $/p/$, the vocal folds will not necessarily be ab-
ducted, and the $P_{io}$ will not necessarily be equivalent to the subglottal pressure. On the other hand, active devoicing is also, in theory, compromised in UVFP as a re-
sult of the immobility of 1 of the vocal folds. The lack of rapid and complete abduction may also compromise the equilibration of pressures in the vocal tract. The glottal gap in UVFP may create turbulences in the vocal tract that could interfere with the $P_{io}$ transducer's measure-
ments. Finally, vocal fold medialization places the para-
lryngeal resistance was not increased after PTFE thyro-
plasty compared with fat injection (Table 1). It is gen-
erally believed that previous injection of autologous fat does not compromise the results of subsequent thyro-
plasty. It is possible, however, that vocal fold scarring af-
er inflammation occurred in our study's patient and is at the origin of the difference in subglottal pressure be-
tween the 2 surgical techniques. Finally, the fat injec-
tion was performed early, within the first 10 days fol-
d paralyysis. Thyroplasty was performed 10 months later. Vocal fold denervation atrophy and fibrosis prob-
ably occurred during this time-lapse and may have al-
ter ted the aerodynamic properties of the paralyzed lar-
ynx, leading to the increased $P_{io}$ after thyroplasty.

In conclusion, our study confirms the variability of $P_{io}$ after vocal fold medialization in UVFP owing to as yet unknown factors. Aerodynamic studies should stan-
dardize vocal intensity to have comparable $P_{io}$ results. Intraoral pressure as an indirect measure of the subglottal pressure may not be reliable in UVFP. Phonatory air-
flow, laryngeal resistance, and vocal efficiency seem to be more reliable indicators of aerodynamic laryngeal func-
tion after vocal fold medialization than $P_{io}$.

**REFERENCES**

3. Shin JE, Nam SY, Yoo SJ, Kim SY. Analysis of voice and quantitative measure-

**Announcement**

**Trial Registration Required**

As a member of the International Committee of Medical Journal Editors (ICMJE), *Archives of Otolaryngology–Head & Neck Surgery* will require, as a condition of consideration for publication, registration of all trials in a public trials registry (such as [ClinicalTrials.gov](https://clinicaltrials.gov)). Trials must be registered at or before the onset of patient enrollment. This policy applies to any clinical trial starting enrollment after July 1, 2005. For trials that began enrollment before this date, registration will be required by September 13, 2005, before considering the trial for publication. The trial registration number should be supplied at the time of submission.

For details about this new policy, and for information on how the ICMJE defines a clinical trial, see the editorial by DeAngelis et al in the June issue of *Archives of Otolaryngology–Head & Neck Surgery* (2005;131:479-480). Also see the Instructions to Authors on our Web site: [www.archoto.com](http://www.archoto.com).