ACKNOWLEDGMENT: Dr. Susan Miner provided excellent pathological assistance and advice, and Cathy Harrell gave secretarial assistance.

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Tracheal Sounds in Upper Airway Obstruction

Hans Rusterkamp, M.D.; and Ignacio Sanchez, M.D.†

A boy with subglottic narrowing secondary to laryngotracheitis presented with noisy breathing. Acoustic measurements of tracheal sounds at standardized air flows correlated well with the clinical course and with spirometric assessments. This indicates the potential value of respiratory sound characterization in patients with upper airway obstruction. (Chest 1992; 102:963-65)

A cute upper airway obstruction commonly presents with abnormal respiratory sounds. Inspiratory stridor is a well recognized clinical sign, but stenosis of the upper airways may also lead to greater respiratory noise that lacks the musical quality of stridor. We report measurements of tracheal sounds in a boy with noisy breathing because of acute laryngotracheitis and subglottic stenosis. We found the sound spectral characteristics at given airflows to correlate well with changes in maximum inspiratory and expiratory flows during the course of the illness. Objective characterization of tracheal sounds may provide a noninvasive and effort-independent method to assess therapeutic effects in upper airway obstruction.

CASE REPORT

This 8½-year-old boy who was previously well had acute onset of hoarseness and respiratory distress without cough or fever. There was no history of trauma or choking, and other family members were not ill at the time. The past history was negative for asthma, atopy, or croup. Two days later, the boy was admitted to the community hospital because of stridor. He responded temporarily to treatment with inhaled racemic epinephrine but remained symptomatic. Four days later, he was transferred to the Children's Hospital Winnipeg. On admission, he was afebrile and in moderate respiratory distress. The throat was erythematous. Noisy breathing without stridor, use of accessory muscles, and chest retractions were noticed. The lungs were clear on auscultation. The white blood cell count was normal (14.6 x 10³/L) with high normal neutrophil count (85 percent), no left shift, and relative lymphopenia (22 percent). Fluoroscopy showed narrowing of the subglottic trachea. Spirometry indicated extrathoracic airway obstruction with reduced inspiratory flows. Viral studies of tracheal secreotions were negative, but bacterial cultures later returned positive for Staphylococcus aureus. The patient was treated with prednisone, 2 mg/kg/day for three days. On the next day, he was already much better, and on discharge three days later, the only remaining symptom was hoarseness. Spirometry was clearly improved, but fluoroscopy remained unchanged. The patient was again admitted one week later because of persisting hoarseness. Two episodes of stridor and respiratory distress had been observed in the interim. He was still afebrile, and the white blood cell count was normal. Spirometry showed some worsening of inspiratory flow obstruction. Bronchoscopy revealed swelling of the vocal cords, subglottic edema extending 2 cm below the cords, and thick, purulent secretions which grew Staphylococcus aureus and nonhemolytic streptococci. Treatment with oral administration of cefoxitin, 500 mg qid for two weeks, was begun, and the patient was sent home. Three months later, there had been no recurrence of symptoms. The boy was healthy, and spirometry was normal.

On four occasions, we recorded tracheal sounds at the suprasternal notch with a contact sensor. The recording site was kept the same for all tests. With a nose clip in place, the patient sat and breathed through a calibrated pneumotachograph. Sound and air

<table>
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<tr>
<th>Variable</th>
<th>Predicted</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
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<tr>
<td>FEV₁, L</td>
<td>1.78</td>
<td>1.75</td>
<td>1.95</td>
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<td>1.79</td>
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<td>FEV₁/FVC, %</td>
<td>90</td>
<td>88</td>
<td>78</td>
<td>86</td>
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<td>PEF, L/s</td>
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<td>2.28</td>
<td>2.82</td>
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<tr>
<td>PIF, L/s</td>
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<td>0.86</td>
<td>1.85</td>
<td>1.40</td>
<td>2.38</td>
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<tr>
<td>FIFₚ/FEFₚ</td>
<td>&gt;1</td>
<td>0.52</td>
<td>0.85</td>
<td>0.72</td>
<td>1.05</td>
</tr>
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</table>

*FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow; PIF, peak inspiratory flow; FIFₚ/FEFₚ, forced inspiratory flow at 50% of vital capacity and FEFₚ, forced expiratory flow at 50% of vital capacity.

Table 1 — Changes in Median Frequency

<table>
<thead>
<tr>
<th></th>
<th>Inspiration</th>
<th></th>
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<th></th>
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<tr>
<td>0.2 L/s</td>
<td>N</td>
<td>Fmed</td>
<td>N</td>
<td>Fmed</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>11</td>
<td>571±25</td>
<td>n/a</td>
<td></td>
<td></td>
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<tr>
<td>b</td>
<td>16</td>
<td>256±22†</td>
<td>6</td>
<td>323±25</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>n/a</td>
<td></td>
<td>8</td>
<td>574±70†</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>9</td>
<td>80±10†</td>
<td>7</td>
<td>136±8†</td>
<td></td>
</tr>
</tbody>
</table>

Mean±SEM

*Fmed, median frequency in the band from 50 to 2,400 Hz; N, number of averaged spectra; n/a, not available (less than five samples within flow gate).

†p<0.05 (unpaired student's t-test).
flow were simultaneously recorded, using pulse code modulation and a video tape recorder. On playback, the tracheal sound was low-pass filtered (6th order Butterworth, cut-off at 2,400 Hz) to avoid aliasing. The filtered sound and air flow signals were digitized at a sampling rate of 10 kHz. The signals were processed on a personal computer with customized software. A 2,048 point fast Fourier transformation was applied to successive 100 ms intervals, using a Hanning data window. Each spectrum was normalized to a reference power of 0.1 (mV)/10 Hz. A gating algorithm was applied to extract only sounds at specified flows and during the acceleration phase of the flow signal. The flow gates were 0.2 and 0.4 L/s ± 10 percent tolerance. Average power spectra were computed from the collected samples for inspiration and expiration. The results of the acoustic measurements (Fig 1 and 2, and Table 1) and of spirometry (Table 2) are shown for admission (a), initial discharge (b), readmission (c), and follow-up after three months (d).

**DISCUSSION**

This boy had a protracted episode of laryngotracheitis which caused transient subglottic stenosis. Hoarseness indicated the involvement of the vocal cords, and inspiratory stridor was noted during the first days of illness. Later, however, it was predominantly the noise level of the harsh and nonmusical respiratory sounds that reflected the degree of extrathoracic airway obstruction.

Respiratory sounds originate from turbulent flow within the airways. Sounds over the trachea present typically with broad frequency spectra that show a sharp drop in power at cut-off frequencies between 850 and 1600 Hz. In normal subjects, air flow determines the tracheal sound level. It has been reported that the mean frequency of tracheal sound spectra increases linearly with increased air flow, but remains about the same at flows above 0.75 L/s. We found that tracheal sounds at given air flows reflected the degree of airway obstruction. This was not unexpected since turbulence will increase in a tube with smaller diameter. While others have shown possible distortion of tracheal sounds at flow rates above 1.6 L/s if subjects breathe through a pneumotachograph, this was not of concern in the present case since air flows were low and the recording technique remained unchanged on all occasions. As a numerical index, the median frequency in the range from 50 to 2400 Hz reflected the change in tracheal sound spectra, increasing with more severe inspiratory flow obstruction and decreasing as the obstruction resolved. Very low frequency sounds below 50 Hz remained unchanged, likely because of the major contribution of cardiovascular and muscle noises in this band.

To our knowledge, the measurement of flow standardized

**FIGURE 1.** Average power spectra for inspiration (upper half) and expiration (lower half) at flows of 0.2 L/s ± 10 percent tolerance. At the same air flow, tracheal sounds during both respiratory phases show significantly less intensity after three days of treatment (b) compared to admission (a). There is still further reduction in sound intensity on follow-up three months later (d).

**FIGURE 2.** Average power spectra for inspiration at 0.4 L/s ± 10 percent (the patient could not generate these flows on the first admission). The number of expiratory samples was insufficient within this flow gate. On the second admission (c), the average power spectrum contains more energy in the range from 1,200 to 2,300 Hz, compared to the average spectrum on hospital discharge a week prior (b). On follow-up three months later, tracheal sounds are much reduced in intensity (d).
tracheal sounds has not been previously described in upper airway obstruction. Spectral analysis of tracheal sounds has been used to detect partial occlusion of tracheostomy tubes,\(^6\) however, sound spectra in that study were not compared to air flow. Other acoustic imaging techniques for the study of upper airway obstruction include the measurement of airway area by acoustic reflection\(^7\) and the detection of laryngeal narrowing by transmission of low-frequency sound.\(^8\) The acoustic reflection technique requires patients to breathe helium-oxygen through customized mouthpieces while keeping their glottis open. For measurement of laryngeal sound transmission, two microphones are placed above and below the glottis while low-frequency sound is introduced via loudspeaker at the mouth. Obviously, those methods can only be used with cooperative subjects.

Nonacoustic imaging and measurement of upper airway obstruction can be achieved with roentgenography and endoscopy,\(^9\) with cine computer tomography,\(^10\) and with simple spirometry.\(^11,18\) Endoscopy provided the definitive pathologic and anatomic diagnosis in our patient. Functional changes over time were documented by spirometry, but fluoroscopic imaging lacked sensitivity. We found the measurement of flow-standardized tracheal sounds to be as useful as spirometry in the case presented here. Further studies are required to determine the role of respiration acoustic measurements as a noninvasive method to assess the effects of therapy in upper airway obstruction in patients who cannot cooperate with forced respiratory maneuvers.

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**Dangerous Pencils and a New Technique for Removal of Foreign Bodies**

Tahir Yüksel, M.D.; Hasan Solak, M.D., F.C.C.P.; Dursun Odabas, M.D.; Mehmet Yenterzi, M.D.; Cesat Ospinar, M.D.; and Ufuk Özer, M.D.

Aspirated foreign bodies are important causes of childhood. Some instances may be fatal. Most of the foreign bodies are removed with use of classic instruments like rigid bronchoscopes and foreign body forceps. But sometimes we fail to remove them, particularly aspirated beads and spherical objects. In this case, a Fogarty catheter is helpful. Although we have had many experiences recently we failed to remove one aspirated foreign body which was a pencil cap. We succeeded in removing this pencil cap with a new technique that is explained in this article. We used a Storz transbronchial aspiration biopsy needle and a cotton-carrier stylet to remove the pencil cap.

*Chest 1992; 102:965-67*

**Figure 1. The colored pencils and their caps.**

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