Variable Tracheal Stenosis Related to Body Position*

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We demonstrated a variable extrathoracic tracheal stenosis which developed after technically adequate tracheostomy and was worsened by changes in body position. When the patient's arms were above his head, minimal airway diameter was reduced 31 percent, and maximal inspiratory flow rate 37 percent below values measured with arms down, but expiratory flow rates were preserved. Tracheostomy may disrupt the integrity of tracheal support and allow airway collapse under circumstances of increased extratracheal or decreased intratracheal pressure.

Tracheal stenosis is a well-recognized complication of both endotracheal intubation and tracheostomy. Its incidence has been reported to range from 3 percent to nearly 100 percent. Recent prospective studies suggest stenosis may occur in one-half to two-thirds of patients following tracheostomy. Some of the variability in reported incidence no doubt results from differing surgical techniques and alternative definitions of stenosis. Most reports have defined tracheal stenosis in terms of anatomic deformity or radiographic narrowing. Friman and colleagues measured inspiratory and expiratory volumes and calculated the pressure drops across tracheal stenoses in ten patients. They developed predictive equations relating flow, pressure drop, and area of stenosis in these subjects.

Changes in the degree of stenosis induced by respiration, cough, or other factors have been investigated in very few of these reports. Kirchner described a patient in whom too many tracheal rings had been incised, and suggested that expiratory phase tracheal collapse was due to the Bernoulli effect. Dane and King observed tracheal collapse (partial and complete) during cough or forced expiration at time of bronchoscopy. We describe a patient with an extrathoracic tracheal stenosis, with variability related to body position changes, a finding not previously reported to our knowledge.

Patients and Methods

A 55-year-old man was evaluated at the University of Vermont Medical Center Hospital of Vermont for progressive dyspnea and reticulonodular interstitial infiltrates. Open lung biopsy showed desquamative interstitial pneumonitis. The patient was supported postoperatively in a positive-pressure ventilator in the intermittent mandatory ventilation (IMV) mode via a nasotracheal tube with a high-volume, low-pressure cuff. Methylprednisolone sodium succinate therapy was begun on day 8 at 80 mg/day. Cyclophosphamide therapy, 150 mg/day, was begun on day 15 because of worsening respiratory status. A vertical midline tracheostomy using sharp dissection techniques was performed after 29 days of positive-pressure ventilation. There was no resection of tracheal rings and no flap was developed. A soft tracheostomy tube was placed, equipped with a low-pressure, high-volume cuff. There was no clinical evidence of stomal infection at any time during the maintenance of the tracheostomy although sputum cultures grew four different isolates of enteric bacteria. Separation from the ventilator ultimately was possible after 64 days of positive-pressure ventilation, and the tracheostomy tube was removed 16 days later. The duration of tracheostomy was 49 days, and the hospitalization 91 days.

After discharge treatment with cyclophosphamide, prednisone, and supplemental oxygen was continued. Three months later, the patient complained of increased dyspnea when his arms were raised above his head or while lying on either side. He was comfortable supine. He did not have stridor or subjective exertional dyspnea greater than usual. Because of the new complaint, he underwent bronchoscopic study, laryngotracheal tomography, and measurement of forced flow rates.

Results

Anatomic Studies

Bronchoscopy examination was performed with an Olympus fiberoptic bronchoscope to evaluate the location and character of the stenosis. At the level of the tracheostomy site, the trachea was transversely narrowed with a quadrilateral cross section. The tracheal rings appeared to be lacking the anterior segment, allowing anterolateral collapse. The left lateral wall moved more medially when the upper extremities were elevated. A tiny stellate scar was noted on the stomal site, but no granulation tissue was seen. The cuff site was unremarkable, although the examination was necessarily limited. Representative bronchoscopic photographs are shown in Figure 1.

Physiologic Studies

Maximal forced inspiratory (FIF) and expiratory flow (FEF) rates were measured with an Hewlett-Packard pneumotachograph and flow transducer (No 47304A), medium gain amplifier (HP No 8802A), and strip chart recorder (HP No 7754A, Hewlett-Packard). The apparatus was calibrated against a high-precision flowmeter. Maximal forced inspiratory and expiratory

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flows were measured with the patient's arms at his sides and with them raised above his head in both seated and supine positions. In addition, measurements were made in the symptomatic right lateral decubitus (RLD) position. Flow rates were compared using Student's t test for unpaired samples.

These data are summarized in Table 1. The maximal inspiratory flow with arms at the sides was significantly greater (p<0.01) than that with arms above his head in both the seated and supine positions. There was also reduction in inspiratory flow rate in the RLD position compared to supine. Maximal expiratory flow rates varied between 3.2 and 5.0 L/sec, and did not decrease in symptomatic positions.

**Radiologic Studies**

Standard tracheal tomograms were obtained, in the AP projection, at 0.5-cm intervals with hands at sides and overhead. The minimal airway diameter was measured directly and comparison was made between diameters at the same tomographic level, arms at side vs arms overhead. Statistical comparison was made by a paired t test.

There was easily detectable airway stenosis on films

<table>
<thead>
<tr>
<th>Posture</th>
<th>Non symptomatic</th>
<th>Sym ptomatic</th>
<th>p value†</th>
</tr>
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<tbody>
<tr>
<td>Seated</td>
<td>5.03 ± 0.15†</td>
<td>2.00 ± 0.49§</td>
<td>&lt;0.001</td>
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<td></td>
<td>(4)</td>
<td>(4)</td>
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<tr>
<td>Supine</td>
<td>4.07 ± 0.26‡</td>
<td>3.15 ± 0.34§</td>
<td>&lt;0.01</td>
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<tr>
<td></td>
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<td>(4)</td>
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<tr>
<td>Recumbent</td>
<td>4.07 ± 0.26‖</td>
<td>2.88 ± 0.50#</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td>(4)</td>
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<tr>
<td>All positions</td>
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<td>2.71 ± 0.62</td>
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<td></td>
<td>(16)</td>
<td>(12)</td>
<td></td>
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</tbody>
</table>

*Data expressed in L/sec as mean ± SD (number of tests).
†Student's t test for unpaired samples.
‡Arms at sides.
§Arms overhead.
‖Supine, arms at sides.
#Right lateral decubitus, arms at sides.
obstruction to airflow. Previous reports of variability in degree of tracheal obstruction have emphasized forced expiratory or tussive collapse. Friman et al showed that inspiratory and expiratory volumes were similar, but they did not report flow rates. They also developed means of estimating the tracheal area, but did not assess variability with inspiration, expiration, or positional changes.

Our patient demonstrated inspiratory flow limitation which worsened with elevation of the upper extremities and with the RLD position. In the absence of intact tracheal ring support, tractive forces developed from surrounding structures may be required for tracheal stability during the inspiratory phase. Elevation of the arms or the assumption of a decubitus position may relax those surrounding structures and allow inspiratory phase tracheal collapse. The maintenance of expiratory flow rates in all symptomatic vs nonsymptomatic positions suggests that positive intratracheal pressure may be important in the maintenance of expiratory phase airway patency in this patient.

In summary, a variable extrathoracic tracheal stenosis has been demonstrated by direct visualization, radiographs, and physiologic measurements. This lesion developed as a consequence of technically adequate tracheostomy free from infectious complications. This event probably represents an unusual manifestation of a common complication. It is notable that no evidence of variable impairment of expiration was seen by FEF measurement or by expiratory spirometric evaluation. These findings are consistent with the extrathoracic site of the lesion.

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REFERENCES
6 Dane TEB, King EG. A prospective study of complications after tracheostomy for assisted ventilation. Chest 1975; 67:398-404