Pharyngeal Aspiration in Normal Adults and Patients with Depressed Consciousness

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A sensitive technic using indium$^{111}$ chloride was devised to investigate the occurrence of pharyngeal aspiration. Twenty normal subjects and 10 patients with depressed consciousness were studied. Forty-five per cent of the normal subjects aspirated during deep sleep. Normal subjects who did not aspirate were noted to sleep poorly. Seventy per cent of the patients with depressed consciousness aspirated. Aspiration of pharyngeal secretions occurs frequently in patients with depressed sensorium and also in normal adults during deep sleep. Bacterial pneumonia may result when aspirated bacteria are not effectively cleared. This may result when clearance mechanisms are impaired or when they are overwhelmed by large volumes of aspirated secretions.

Bacterial pneumonias are thought to be due to organisms that inhabit the pharynx, and aspiration of pharyngeal contents has been suggested as the mechanism by which these bacteria reach the lower respiratory tract [1,2]. Such “silent aspiration” is presumed to occur during sleep in normal subjects [3,4] and may also occur in patients with a variety of underlying illnesses [1,5,6]. Previous studies have contained conflicting data, some of which support [7,8] and some of which refute [9] these concepts. These studies are difficult to interpret for several reasons: (1) each employed radiopaque materials which may interfere with normal clearance and protective mechanisms; (2) it is unclear what quantity of radiopaque material must be aspirated in order to be detected on chest roentgenograms; (3) the patient populations were not clearly defined.

The present study was undertaken to determine if aspiration of pharyngeal contents does indeed occur. A noninvasive technic was devised employing an inert radioactive tracer which allows detection of subtle aspiration without interfering with normal protective and clearance mechanisms. The frequency of pharyngeal aspiration was then studied in normal subjects during sleep and in patients with impaired consciousness.

MATERIALS AND METHODS

Twenty normal volunteer subjects and 10 patients with altered levels of consciousness were studied. Ages of the normal subjects ranged from 23 to 65 years. These subjects were in good health and free of acute disease. Each subject refrained from taking ethanol, sedatives and drugs affecting the autonomic nervous system for at least 72 hours prior to the study. The patients with depressed sensorium ranged in age from 19 to 65 years. The level of consciousness was determined according to the classification of Plum and Posner [10]: stupor was regarded as “a state of unresponsiveness from which the subject can be aroused only by vigorous and repeated stimuli” and...
coma was defined as "a state of unarousable unresponsiveness." Underlying illnesses in this group included cerebrovascular disease, hepatic encephalopathy, hypoxic encephalopathy and sepsis. Informed consent was obtained in every case.

The radioactive tracer was prepared by diluting 1 mCi of indium$^{111}$ chloride in 10 ml of normal saline solution. To avoid irritation of the oropharynx, this solution was buffered to a pH of 8 with sodium bicarbonate.

Preliminary studies in dogs and human volunteer subjects indicated that as little as 0.1 ml of the solution, containing 10 μCi of indium$^{111}$ chloride, could be visualized on scan after direct endobronchial instillation. In addition, the material could be detected within the thorax for at least 48 hours after instillation (Figure 1A).

Studies in normal subjects were performed between the hours of 10:00 P.M. and 7:00 A.M. in each subject a flexible plastic catheter with an outside diameter of 2.0 mm was inserted into the nasopharynx with the tip of the catheter 3 cm beyond the external nare. The catheter was connected to polyethylene tubing approximately 120 cm in length. The distal end of the tubing was fitted with a three-way stopcock and taped to an intravenous stand several feet away from the subject's head. The entire 10 ml of tracer solution was injected into the tubing and flushed with air until it just reached the subject's head. The stopcock was then closed. The catheter was secured in place and the subject was allowed to retire for the night. At 1:00 A.M. 1 ml of air was injected into the tubing via the stopcock over a 1 to 2 minute period. This maneuver delivered 1 ml of the tracer solution slowly into the subject's pharynx. An injection was repeated every 30 minutes until each subject received 10 injections. The subject's apparent depth of sleep and response to the injection were carefully observed and recorded. The subject was awakened at 7:00 A.M. and instructed to drink several glasses of water to remove the tracer from the oropharynx and esophagus. Scanning of the thorax was performed with a Pho Gamma V camera (Searle) with the window settings adjusted to include both the 0.173 MeV and 0.247 MeV photon-peaks. Each subject was scanned in the anterior view until at least 50,000 counts were collected. Every scan was performed within 4 hours after completion of the injections.

Patients with altered consciousness were studied in a similar fashion. However, those with severely depressed sensorium were studied during the daytime. Because these patients were unable to take oral liquids, the water drinking was omitted.

Scan results were considered positive when the tracer was detected within the thorax and lateral to the midline (Figure 1A). A scan which showed the tracer within the thorax but only in the midline was considered indeterminate, since this location could represent either trachea or esophagus (Figure 1B). A scan was considered negative if it showed tracer in the pharynx or stomach but not within the thorax (Figure 1C).

Scans were interpreted independently by two physicians not involved in performance of the studies. Scans were considered either positive or negative only if both observers agreed. If there was disagreement, the scan was considered indeterminate.

RESULTS

The normal subjects consisted of 11 men and nine women with an average age of 39 years (range 23 to 66 years). Nine subjects (45 per cent), ages 27, 31, 32, 48, 49, 50, 52, 54 and 57 years, had positive scans. Six subjects (30 per cent), ages 24, 26, 29, 34, 46 and 65 years, had negative scans. Five subjects (25 per cent), ages 22, 23, 24, 25 and 61, had indeterminate scans. There was no correlation between the subject's age, sex or history of cigarette smoking and the occurrence of aspiration. Of the four normal subjects who gave a history of previous pneumonia, two had positive scans and two had negative scans. Six scans representing positive studies in normal subjects are presented in Figure 2A through 2F.

The patients with depressed sensorium consisted of five men and five women with an average age of 70 years (range 19 to 85 years). The characteristics of these patients are presented in Table I. Seven patients (70 per cent) had a positive scan, one (10 per cent) had a negative scan, and two (20 per cent) had an indeterminate scan. Six scans representing positive studies in patients with depressed sensorium are presented in Figure 3A through 3F.

COMMENTS

Bacteria may enter the lower respiratory tract by any of four routes: (1) aspiration of oropharyngeal secretions; (2) aerosol inhalation; (3) hematogenous spread from a distant site of infection; (4) direct extension from a contiguous site of infection [1]. The aspiration of oropharyngeal secretions is thought to be the most important of these mechanisms in the pathogenesis of bacterial pneumonia, but aspiration has not been demonstrated in normal subjects prior to this study. In addition, the aspiration of bacteria-laden secretions into the lower respiratory tract is thought by some investigators to play an important role in the development of pulmonary emphysema [11].

Quinn and Meyer [7] investigated the relationship between sinusitis and bronchiectasis by instilling iodized oil into the noses of sleeping patients. The administration of sedatives to some of their patients, and the rapid instillation of a large bolus of radiopaque material in other patients may have potentiated the instances of aspiration they observed. Amberson [8] reported that iodized oil introduced into the mouths of sleeping patients was aspirated into the lungs. The patients' ages, underlying diseases and levels of consciousness were not defined. The amount of iodized oil used was also not mentioned. Winfield and co-workers [9] injected small amounts of radiopaque materials into the posterior nasopharynx of hospitalized patients. Aspiration was not detected in any of those patients. All the subjects in these previous studies were hospitalized patients; the occurrence of aspiration in normal subjects was not
Figure 1. A, positive scan 48 hours after endobronchial instillation of 15 μCi of indium¹¹¹ chloride. External cobalt marker overlies sternum and right costal margin. B, indeterminate scan. C, negative scan.

Figure 2. Positive scans in six normal adults of the following ages: A, 32 year old man; B, 31 year old woman; C, 57 year old woman; D, 52 year old woman; E, 54 year old man; F, 49 year old man.

Figure 3. Positive scans in six patients with depressed consciousness. Patients are described in detail in Table 1.
examined. The techniques used in these studies may have interfered with or overwhelmed normal protective mechanisms; the results are thus difficult to interpret.

The technic used in our study appears to be ideal for investigating the occurrence of pharyngeal aspiration. This method eliminates the problems encountered with radiopaque materials. Indium

\[ \text{Indium}^{111} \]

chloride has a half-life of 2.8 days, and because of its high gamma photon yield only small amounts of tracer are required. As little as 0.1 ml of Indium

\[ \text{Indium}^{111} \]

chloride solution can be detected within the thorax thus allowing subtle aspiration to be recognized. The tracer solution may be buffered to the pH of nasal secretions to eliminate irritation of the pharynx or tracheobronchial tree. The slow administration of tracer solution ensures that protective mechanisms will not be overwhelmed. The tracer is not absorbed from the gastrointestinal tract; thus, the subsequent secretion of tracer by glands of the tracheobronchial tree yielding false positive results is not a possibility. Thus, our technic is sensitive, noninvasive and does not interfere with or overwhelm normal protective mechanisms.

We have documented the frequent occurrence of aspiration in patients with depressed consciousness and also in normal subjects. Aspiration occurred more frequently and more extensively in the patients with depressed consciousness. It is our impression that normal subjects who slept poorly or awakened during the injections had negative scans and that all subjects who slept soundly throughout the night were found to aspirate. These observations suggest that all normal people frequently aspirate secretions from their pharynx during deep sleep.

Pulmonary infections are uncommon in normal subjects despite the repeated aspiration of bacteria during sleep. It appears that the aspirated bacteria are usually cleared efficiently by pulmonary defense mechanisms. A variety of external factors may alter those protective mechanisms and contribute to the development of bacterial pneumonia. Ethanol ingestion may produce infection by impairing leukocyte function and depressing mucociliary transport. In addition, ethanol may depress the level of consciousness and result in the aspiration of large volumes of bacteria-laden secretions. Viral infections may also predispose to bacterial superinfection by impairing mucociliary clearance and by increasing the volume of pharyngeal secretions. Thus, normal adults are constantly contaminating their lower respiratory tract with bacteria; however, infection only develops when normal pulmonary defense mechanisms are either impaired or overwhelmed and the aspirated bacteria can rapidly multiply.

## REFERENCES


## TABLE I Characteristics of Patients with Depressed Consciousness

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (yr) and Sex</th>
<th>Diagnosis</th>
<th>Level of Consciousness</th>
<th>Gas Reflex</th>
<th>Nasogastric Tube</th>
<th>Position</th>
<th>Scan Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71,F</td>
<td>Pancreatic carcinoma</td>
<td>Coma</td>
<td>Absent</td>
<td>No</td>
<td>Supine</td>
<td>Positive (Figure 2A)</td>
</tr>
<tr>
<td>2</td>
<td>19,F</td>
<td>Hepatic encephalopathy</td>
<td>Stupor</td>
<td>Diminished</td>
<td>Yes</td>
<td>Supine</td>
<td>Positive (Figure 2B)</td>
</tr>
<tr>
<td>3</td>
<td>65,M</td>
<td>Cerebrovascular accident</td>
<td>Stupor</td>
<td>Diminished</td>
<td>Yes</td>
<td>Supine</td>
<td>Positive (Figure 2C)</td>
</tr>
<tr>
<td>4</td>
<td>80,M</td>
<td>Cerebrovascular accident</td>
<td>Stupor</td>
<td>Diminished</td>
<td>Yes</td>
<td>Supine</td>
<td>Positive (Figure 2D)</td>
</tr>
<tr>
<td>5</td>
<td>70,M</td>
<td>Cerebrovascular accident, pneumonia</td>
<td>Stupor</td>
<td>Diminished</td>
<td>No</td>
<td>Right lateral decubitus</td>
<td>Positive (Figure 2E)</td>
</tr>
<tr>
<td>6</td>
<td>80,F</td>
<td>Cerebrovascular accident, hypotension</td>
<td>Stupor</td>
<td>Diminished</td>
<td>No</td>
<td>Left lateral decubitus</td>
<td>Positive (Figure 2F)</td>
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<td>7</td>
<td>85,M</td>
<td>Hypoxic encephalopathy</td>
<td>Stupor</td>
<td>Absent</td>
<td>Yes</td>
<td>Supine</td>
<td>Positive</td>
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<td>8</td>
<td>79,F</td>
<td>Cerebrovascular accident</td>
<td>Stupor</td>
<td>Normal</td>
<td>No</td>
<td>Left lateral decubitus</td>
<td>Indeterminate</td>
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<tr>
<td>9</td>
<td>71,F</td>
<td>Cerebrovascular accident</td>
<td>Stupor</td>
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<td>Yes</td>
<td>Supine</td>
<td>Indeterminate</td>
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<td>10</td>
<td>75,M</td>
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<td>Stupor</td>
<td>Absent</td>
<td>No</td>
<td>Supine</td>
<td>Negative</td>
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</table>
vascular leukocyte sequestration: a potential mechanism 
12. Buhrmeister CC: A study of the hydrogen-ion concentration, 
nitrogen content and viscosity of nasal secretions. Ann Otol 
Rhinol Laryngol 42: 1041, 1933
of the role of stomach emptying using Indium-113 and a 
10-crystal rectilinear scanner. Can Med Assoc J 108: 180, 
14. Green GM, Kass EH: Factors influencing the clearance of 
15. Laurenzi GA, Guarneri JJ: A study of the mechanisms of pul-
monary resistance to infection: the relationship of bacterial 
clearance to ciliary and alveolar macrophage function. Am 
16. Hers JFPH: Disturbances of the ciliated epithelium due to in-
fluenza virus. Am Rev Resp Dis 93 (suppl 3): 182, 
1966
17. Camner P, Jarstrand C, Phillipson K: Tracheobronchial 
clearance in patients with influenza. Am Rev Resp Dis 
18. Wright GW: Structure and function of respiratory tract in 