Detection of Pulmonary Aspiration in Infants and Children with Respiratory Disease: Concise Communication

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Twenty children with respiratory disease ingested 500 μCi of Tc-99m sulfur colloid orally, and scintigrams of the thorax were obtained to determine whether pulmonary aspiration of gastric contents could be detected. The children ranged in age from 1 mo to 14 yr; 13 were 8 mo of age or younger. Children were studied at 5 min and 4 hr after ingestion of Tc-99m sulfur colloid using a high-sensitivity computer oscilloscope to record 100K-count images. Additional images were obtained after the children had slept overnight. Five children (25%) showed definite pulmonary accumulation of activity; four of these also had a barium swallow and three showed either pulmonary aspiration of barium or moderately severe gastroesophageal reflux. Oral ingestion of Tc-99m sulfur colloid provides a noninvasive means for diagnosing pulmonary aspiration under physiologic conditions in infants and children.

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Chronic or recurrent pulmonary disease may be caused by pulmonary aspiration of gastric contents following gastroesophageal (G-E) reflux in infants and children (*1–5*). Recurrent respiratory infections have occurred in children with hiatus hernia (*4*), and in the presence of G-E reflux without hiatus hernia (*1–3*). A recent study (*5*) suggested that all children with recurrent pulmonary disease should have esophageal function testing to determine whether G-E reflux with aspiration could be the cause.

The tests available for diagnosing G-E reflux in infants and children include esophageal manometry, the pH probe (Tuttle) test, and barium esophagography. Manometry and the Tuttle test are more difficult to perform than barium esophagoscopy, but the latter is a relatively insensitive detector of G-E reflux (*5*). Fisher et al. (*6,7*) showed that G-E reflux can be detected with high sensitivity following oral ingestion of Tc-99m sulfur colloid (TcSC), and Reich et al. (*8*) have shown that pulmonary aspiration can be detected in adults using similar techniques. In this prospective study we have attempted to determine the feasibility of detecting pulmonary aspiration using TcSC in infants and children with recurrent pulmonary disease.

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METHODS

Twenty children (11 boys, nine girls) ranging in age from 1 mo to 14 yr (ave. 30 mo) were studied. Informed consent was obtained from the parents in each case. Thirteen of the children were 8 mo of age or younger (Table 1). Seventeen were referred because they had signs and/or symptoms of respiratory disease, two were studied in following up repair of a tracheo-esophageal (T-E) fistula, and one had tracheal stenosis, possibly due to repeated aspiration of gastric contents.

Infants were brought to the nuclear medicine laboratory at feeding time and were given 500 μCi of TcSC mixed with infant formula or milk (60–100 cc). They were usually fed by their mothers, and ingested the mixture from a baby bottle. Older children ingested the tracer (500 μCi) in approximately 120 cc of orange juice

TABLE 1. RESULTS OF PULMONARY ASPIRATION STUDIES

Patient	Age	Sex	Presenting diagnosis	Aspiration study	Site
1	7 mo	M	Viral pneumonia	NL	
2	8 mo	M	Chronic lung disease	NL	
3	4 mo	F	Pneumonitis	+	RML
4	13 mo	F	Pneumonitis	NL	
5	5 mo	M	Pneumonitis	+	RUL, LUL
6	5 mo	M	Pneumonitis	NL	
7	4 mo	F	Post TE fistula repair	NL	
8	5 mo	M	Post TE fistula repair	NL	
9	11 yr	M	Chronic pneumonitis	NL	
10	4 mo	M	Pneumonitis	NL	
11	3 mo	F	Chronic cough	+	RUL
12	5 yr	F	Recurrent bronchitis	NL	
13	3 mo	M	Pneumonitis	NL	
14	6 mo	F	Pneumonitis	NL	
15	3 yr	M	Tracheal stenosis	NL	
16	5 yr	M	Pneumonitis	NL	
17	1 mo	F	Pneumonitis	NL	
18	14 yr	F	Suspected TE fistula	+	LLL
19	6 mo	M	Pneumonitis	NL	
20	3 yr	F	Pneumonitis	+	LLL

from a plastic cup. All children ingested a small amount of nonradioactive liquid at the end of the feeding to clear the esophagus. Within 5 min children were placed supine under a gamma camera and 100,000-count images of the chest and abdomen (anterior, posterior, both laterals) were obtained to verify esophageal clearing and visualize baseline lung activity. No artificial means were used to increase abdominal pressure during the imaging procedure. No abdominal binders, no manual pressure on the abdomen, or rolling, turning, or the Trendelenburg position were used.

After completion of the initial images children returned to their hospital ward. The parents were instructed to let the child behave naturally. Thus, many of the infants slept when returned to their hospital beds. No specific instructions regarding sleeping position (e.g., prone against supine) were given. Approximately 4 hr after tracer ingestion the child returned for another series of images. They also returned the next morning for a final set of images.

The gamma camera was fitted with a high-resolution parallel-hole collimator, and was calibrated for the 140-keV photopeak of Tc-99m using a 20% window. Cobalt-57 skin markers were placed on the shoulders during a portion of the imaging sequence to provide anatomic orientation. Multiple views of the chest (anterior, posterior, both laterals) were obtained to help locate any abnormal activity in the thorax. All images were recorded on 35-mm film and displayed on a computer output oscilloscope, which was set to maximum sensitivity and contrast. No attempt was made to quantify pulmonary deposition of activity, or to detect or quantify any gastroesophageal reflux that occurred without aspiration. To maximize detection of pulmonary activity, the computer was set to provide high-sensitivity, high-contrast images. All computer-oscilloscope images were recorded on Polaroid film.

Fifteen of the 20 children also had barium studies for gastroesophageal reflux. The barium studies were performed with 1 wk of the radionuclide study, but never on the same day. Barium was given orally with the child in the recumbent lateral position on the x-ray examining table. Uncooperative children were given barium through a nasogastric tube. A quantity of barium similar to the volume of a routine feeding (e.g., about 90 cc in infants) was administered, followed by a small amount of water to clear the esophagus. In infants, gastric air was expelled, and all children were rotated 360° on the table. Gentle manual compression of the stomach was occasionally applied during filming. Water siphonage was not used. Gastroesophageal reflux was graded as mild if contrast appeared above the G-E junction but did not reach the carina. If contrast regurgitated beyond the carina the reflux was classified as moderate; if it reached the cricopharyngeus muscle or above it was classified as severe. A single film of the G-E junction area was obtained 20–30 min after ingestion to detect possible "late reflux."

RESULTS

Five children (25%) showed pulmonary aspiration of

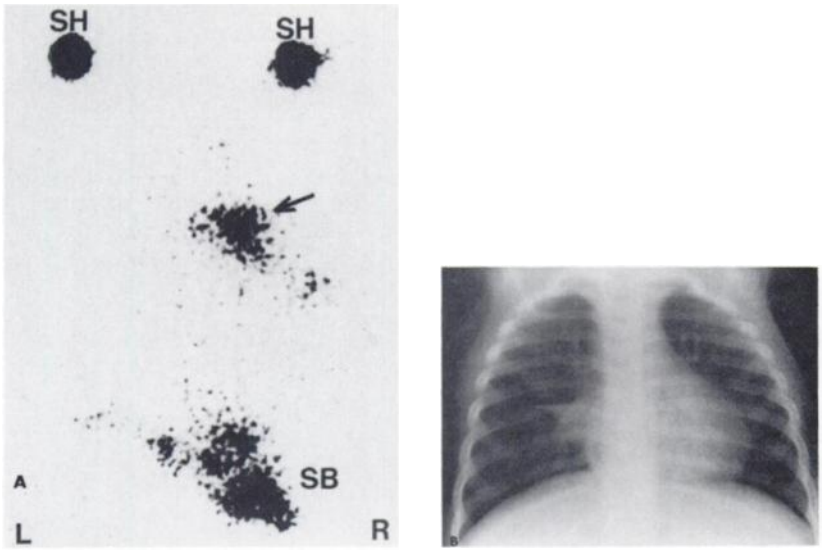

FIG. 1. (A) Posterior image of thorax obtained 4 hr after oral ingestion of Tc-99m sulfur colloid in 4-mo-old girl (Patient 3, Table 1) shows abnormal site of activity in right mid-lung field. SH = shoulder markers, SB = small-bowel activity. Activity corresponds to region of infiltration seen in radiograph (B).

Tc-99m. Each of these studies was characterized by a localized accumulation of activity in the lungs, as seen on multiple projections. Stomach activity inferiorly, and the Co-57 shoulder markers superiorly, provided orientation. One of the studies was positive on films obtained 5 min after ingestion of TcSC. This 14-year-old girl had a past history of T-E fistula that had been surgically repaired. She had recently begun to have repeated episodes of pneumonitis, and a recurrent T-E fistula was suspected. The possibility that she had directly aspirated TcSC through her larynx was considered, but a repeat feeding at 4 hr resulted in further increased lung deposition without clinically obvious aspiration. Therefore, a contrast esophagram was performed, but no T-E fistula could be found. The test was repeated 2 days later, however, and the T-E fistula was demonstrated. Three children showed evidence of pulmonary aspiration only on the images obtained 4 hr after ingestion of TcSC, and one child showed evidence of pulmonary activity only after sleeping overnight. Figure 1 shows the 4-hr posterior view of a 4-month-old female with recurrent right middle lobe pneumonia. There is an obvious accumulation of activity in the right mid-lung field. In three of the five children, the area of radionuclide accumulation corresponded to an area of radiographic infiltrate (Figs. 1 and 2). Each area of pulmonary activity in the five children with positive studies was visible on both standard films and the computer's output oscilloscope.

A comparison of results between contrast G-E reflux studies and radionuclide studies of pulmonary aspiration is shown in Table 2. Only two children had evidence of pulmonary aspiration during their contrast study; both showed aspiration during the radionuclide study. One of the two children who showed moderate gastroesophageal reflux during the barium study also showed pulmonary accumulation of TcSC (Fig. 2). The two children who showed mild barium reflux showed no evidence of aspiration. One of nine children who had normal contrast studies showed evidence of pulmonary aspiration on the radionuclide study.

The importance of obtaining a chest radiograph in children who showed thoracic TcSC activity was illustrated by the study of an 8-month-old boy who had multiple congenital anomalies and recurrent pneumonia.

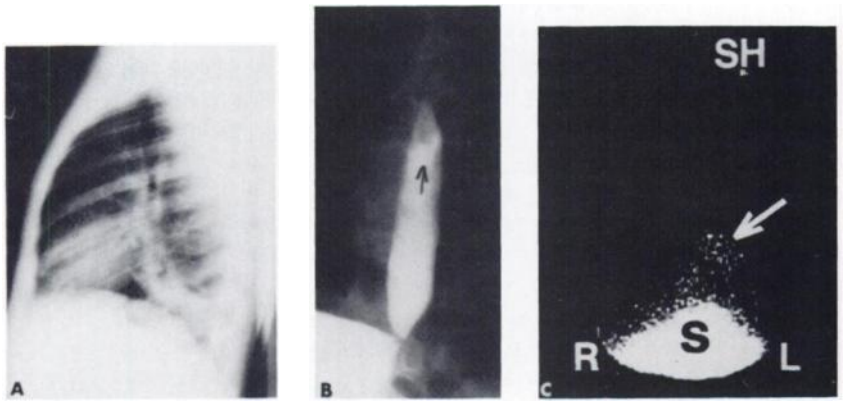

FIG. 2. Lateral chest radiograph (A) demonstrates L. lower lobe infiltrate. Barium esophagram (B) shows moderate G-E reflux. 4-hr Tc-99m sulfur colloid image (C) shows LLL activity (arrow) (S = stomach). (Patient 20, Table 1).

TABLE 2. COMPARISON OF RADIONUCLIDE ASPIRATION STUDIES AND BARIUM ESOPHAGRAMS

Esophagram	Radionuclide	
	Normal	Aspiration
Normal	8	1
Reflux, mild	2	0
Reflux, moderate	1	1
Aspiration	0	2

His radionuclide aspiration study showed a focal accumulation of activity in the left lower thorax. However, his chest radiograph revealed a loop of bowel protruding into the thorax through a diaphragmatic hernia. A contrast upper G.I. series confirmed that this structure was bowel. The activity visualized on the radionuclide study was normal small-bowel activity, not pulmonary aspiration. Correlation of the radionuclide results with the chest radiograph prevented a false-positive interpretation.

DISCUSSION

Fisher et al. (*6,7*) first demonstrated the utility of oral ingestion of Tc-99m sulfur colloid for evaluating and quantitating G-E reflux in adults. Similar techniques have now been used to study children with suspected G-E reflux. In the combined series of Heyman (*9*), Rudd (*10*), Thirunavukkarasu (*11*), and Devos (*12*), 68 of 102 children with suspected G-E reflux had positive radionuclide reflux studies. The administered TcSC doses and imaging techniques in these series were similar, but some groups (*10,11*) used either manual or mechanical pressure to augment reflux, while others (*9*) used no abdominal pressure. The low level of radiation exposure involved in the technique was documented by Heyman et al. (*9*). With a TcSC dose of 150 μCi to 1 mCi, the stomach receives 300–500 mrad exposure, the gonads 17–36 mrad, and the total body 33–65 mrad. If 5 ml of gastric contents are aspirated into the lungs and removed only by physical decay, the lung receives 110–130 mrad.

Reich et al. (*8*) first reported radionuclide detection of pulmonary aspiration. They administered 3–5 mCi of TcSC orally to seven adults who had pulmonary fibrosis in association with hiatal hernia or neurologic disease. The radionuclide was ingested just before the patients went to sleep (10 p.m.), and the patients were imaged the following morning. Two of the seven patients (28%) showed definite pulmonary activity, indicating aspiration. No digital image enhancement was used to improve detection efficiency. Heyman et al. (*9*) obtained a 2-hr thorax image in each of 39 children, and saw evidence of pulmonary aspiration in two (5%). The lung activity was faint in both cases, making digital image enhancement necessary for its detection. Thirunavukkarasu (*11*) obtained thoracic images of 30 of their children at 4 and 24 hr, but failed to detect pulmonary activity.

In the current study, five of 20 children (25%) showed definite lung activity. These results support the initial observations of Reich et al. (*8*), and suggest that radionuclide detection of pulmonary aspiration is feasible in children. There are several possible explanations for the higher rate of positive aspiration studies in the current series than in the studies of Heyman (*9*) and Thirunavukkarasu (*11*). The most likely explanation is patient selection. Our children were studied because they had pulmonary disease. Children with signs of simple G-E reflux (e.g., esophagitis, failure to thrive, or episodic vomiting) were excluded from this series. Second, the 13 infants we evaluated usually slept after their TcSC feeding, so the conditions for infants closely paralleled those in Reich's study (*8*). In the study of Thirunavukkarasu et al. (*11*) there was no close temporal relation between colloid ingestion and sleep.

All five patients with positive images in the current study were detected using both film and digital images. However, use of the computer oscilloscope during the study seemed to enhance the chances of detecting aspiration. The highly sensitive computer oscilloscope provided immediate feedback to the technologist and physician about positioning and possibile sites of aspiration. Standard film images were acquired only after optimum positioning was achieved. Film technique (e.g., the exposure setting) was often changed depending on the oscilloscope findings. We initially attempted to use a standard persistence scope to provide this same information, but its poor resolution compared with the computer oscilloscope made it less useful. High-contrast Polaroid film could be used to acquire images at frequent intervals during the study, and might serve as an alternative approach in laboratories without computers.

The sensitivity and specificity of this technique for detecting pulmonary aspiration have not been determined. Each of our 20 patients had suspected aspiration, but the actual frequency of aspiration in our population is unknown. Only one of nine children (11%) with a negative barium reflux study showed pulmonary activity, but barium reflux studies are known to be insensitive for reflux (*5,9,11*), so this child might have had reflux and aspiration. Thirunavukkarasu (*11*) and Devos (*12*) studied a total of 20 "controls" and found no TcSC reflux. Normal adults, during deep sleep, may aspirate pharyngeal secretions labeled with In-111 chloride (*13*), but there is no evidence to indicate that pulmonary aspiration of gastric contents occurs in normal individuals. However, gastroesophageal reflux does occur in normal infants (*14,15*). This "benign regurgitation" usually resolves spontaneously by age 7–8 mo. Thus, selection

of patients is important to avoid inappropriately "positive" G-E reflux studies, especially in infants. For these reasons, we selected patients with histories strongly indicating recurrent pneumonitis, and then concentrated on detecting aspiration rather than reflux. Our results indicate that pulmonary aspiration can be detected in infants and children using physiologic methods. Further experience will be required to determine the sensitivity and specificity of these studies, and their clinical utility.

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