Dysphagia 9:107–115 (1994)

Dysphagia

The Use of Scintigraphy in the Management of Patients with Pulmonary Aspiration

Kenneth H. Silver,[1] MD and Douglas Van Nostrand, MD[2]

[1]Department of Rehabilitation Medicine, the Swallowing Center, Johns Hopkins University School of Medicine, Baltimore, Maryland and Department of Nuclear Medicine, The Good Samaritan Hospital, Baltimore, Maryland, and [2]Uniformed Services University of Health Sciences, Bethesda, Maryland, USA

Abstract. Pulmonary aspiration was assessed using a scintigraphic swallowing procedure in 14 dysphagics in whom penetration of the larynx had been previously diagnosed. No patient had recent evidence of aspiration pneumonia. Imaging was performed during and following ingestion of a cupful of thin liquid admixed with between 1–2 mCi of Tc-99m sulfur colloid. Follow-up scans were obtained several hours later as needed to assess airway clearance. Five of the fourteen (36%) showed penetration distal to the trachea. Seven (50%) were indeterminate for aspiration, as isotope localized to the neck could not be clearly designated as being in either airway or foodway. Two subjects had negative studies. Of patients with subtracheal penetration, (1) fractions of the ingested material which were aspirated ranged from <1%–25%, and (2) elimination from airways was complete or near-complete by 3 hours. The presence of an immediate or delayed cough was noted but did not correlate with subtracheal aspiration. Based on the results of scintigraphy, 8 of 9 patients on some form of liquid restriction at the time of testing were allowed to ease restrictions. Five patients without prior liquid restriction were allowed to continue to drink. We propose that scintigraphy provides important data on airway penetration and clearance that is useful in the dietary management of dysphagic patients.

Key words: Pulmonary aspiration — Scintigraphy — Pulmonary disease — Liquid restriction — Deglutition — Deglutition disorders.

Aspiration is common in patients with dysphagia. For instance, it is reported that 50% of dysphagic stroke patients penetrate their airways to some extent [1]. The occurrence of aspiration is established most reliably and comprehensively by roentgenographic techniques. The video- or cine-fluorographic swallowing study remains the gold-standard for determining pathology of deglutition, assessing the presence of airway penetration by the food bolus, and formulating a dysphagia treatment plan [2]. Clinicians recognize, however, that fluorography is inadequate for determining the relative amount of material aspirated, the extent of the respiratory tree penetrated, or the rapidity of that material's removal from the airways. These factors, among others, are thought to be critical determinants in the development of pulmonary disease following aspiration, i.e. pneumonia [3,4].

Scintigraphic methods are widely used in the analysis of alimentary tract disorders. Over the last decades, standard procedures have been developed to assess gastroesophageal reflux, esophageal and pharyngeal motility, gastric emptying, and pulmonary aspiration following reflux [5–14]. The application of nuclear medicine tests to the oral and pharyngeal phases of swallowing is more recent. Scintigraphic analysis of both pharyngeal transit and retention during and following swallowing has been described by Hamlet [15,16]. Humphreys et al. [17] were the first to describe the use of isotopic techniques in the detection and measurement of aspiration at the time of ingestion in a series of head and neck cancer patients. Muz et al. [18] used scintigraphy in a larger series of

No commercial party having a direct or indirect interest in the subject matter of this article has conferred or will confer a benefit upon the authors or upon any organization with which the authors are associated.

Address offprint requests to: Kenneth Silver, M.D., Department of Rehabilitation Medicine, Good Samaritan POB, Room 303, 5601 Loch Raven Blvd., Baltimore, MD 21239, USA

patients at risk of aspiration. Their findings suggested that scintigraphic and fluorographic methods were complementary, but the former was more sensitive for detecting aspiration below the glottis. A later study by the same authors [19] showed that the nuclear medicine test was helpful in following the temporal course of a patient's dysphagia during and after treatment for head and neck cancer. Silver et al. [4] studied primarily stroke victims with documented aspiration and suggested that scintigraphy could identify patients with potentially benign aspiration. The measurement of airway clearance was considered to be an additional parameter by which to gauge the severity of aspiration.

Although scintigraphy depicts the extensiveness of aspiration below the glottis in ways not possible with standard fluorographic swallowing tests, few investigators have described using scintigraphy in formulating specific treatment for the dysphagic patient. In published abstracts of scientific proceedings, several authors reported basing clinical management of dysphagia on the scintigraphic measurement of aspiration and airway clearance, but did not describe these findings in detail [20–22]. Our goal was to assess how the results of a scintigraphic swallowing test altered the clinical management of 14 patients with known airway penetration.

Materials and Methods

Subjects

Fourteen patients with either recent onset or long-standing dysphagia [7] were referred for scintigraphic swallowing evaluation to determine whether to continue or resume oral feedings of liquids. Ten subjects were inpatients on a rehabilitation unit at the time of study; the remaining were outpatients. Etiology of the dysphagia was as follows: cerebrovascular accident (n = 10); myopathy (n = 2); Arnold-Chiari malformation (n = 1); and status post cardiac valvular surgery (n = 1). Three patients had a tracheostomy. All subjects were initially evaluated by the Johns Hopkins University/Good Samaritan Hospital dysphagia service. Laryngeal penetration by liquid or solid food had been demonstrated in all subjects either by a prior videofluorographic barium swallowing study or by recovery of ingested material from the tracheostomy. The chronicity of the swallowing impairment at the time of scintigraphy was defined arbitrarily as "recent onset" if 10 weeks or less since onset of symptoms, or "chronic" if greater than 10 weeks. For the nontracheotomized subjects [11], the scintigraphic swallowing study followed the fluoroscopic test by a mean of 7.2 days in the recent onset group (6 subjects, range 3–13 days); and by 45.0 days in the chronic group (5 subjects, range 6–95 days). For patients without a tracheostomy, symptoms of dysphagia had been present a mean of 30.3 days (range 17–49) in the recent onset group and 317.4 days (range 110–515) in the chronic group prior to the most recent abnormal videofluorographic swallowing test. In those with tracheostomies, aspiration was demonstrated up to the time of scintigraphy in all cases. No patient had had recent clinical evidence of aspiration pneumonia. At the time of scintigraphy, most patients (9) were on some form of dietary modification because of the prior illustration of aspiration. Of these, 1 was allowed nothing by mouth, 2 were restricted from thin and thick liquid consistency liquids, 4 were restricted from thin consistency liquids, 1 was allowed to drink all liquids but only during assisted ventilation per tracheostomy, and 1 was limited to small volumes of liquids per drink. Five individuals had been allowed unmodified diets by the dysphagia treatment team despite the potential risk of pulmonary sequelae.

Scintigraphic Technique

All patients were studied in an upright seated position using a large-field-of-view gamma camera with an all-purpose collimator and an interfaced computer. Data were simultaneously recorded on film and saved on floppy disk for later regional analysis. While seated, each subject was asked to drink from either cup or straw 75–100 cc of fruit juice containing 1,000–2,000 μCi of Tc-99m sulfur colloid. The large volume of liquid was employed to simulate a more normal drinking circumstance, assuring multiple swallows per examination and thus maximizing the occurrence of aspiration given an underlying propensity. The radionuclide dose was selected based on our prior studies [4] which showed it to be adequate in optimizing residual activity on delayed imaging but minimizing hazardous exposure.

Most subjects were imaged both dynamically during swallowing as well as statically following completion of the swallowing. In contrast to our previous study [4], dynamic imaging was performed anteriorly with the patient facing the camera and the field of view encompassing the neck and upper chest. This position lends itself to identifying subtracheal aspiration rather than laryngotracheal aspiration for which the latreral oblique view is advantageous. Dynamic imaging began at the onset of swallowing with acquisition every 5 sec sequentially and continuously until either the contents of the cup were drained or the swallowing was otherwise stopped. Reasons for the latter included excessive coughing during swallowing or difficulty maintaining correct position. Dynamic imaging generally lasted about 30 sec. A faster frame rate of acquisition during the swallows was not necessary given the focus on the slower process of subtracheal aspiration in contrast to the more rapid events associated with the swallow itself. Care was taken to avoid spillage of oral contents during swallowing. One subject did not undergo dynamic acquisition secondary to positioning problems related to severe deficits in neuromuscular control.

All subjects underwent a subsequent static phase of imaging immediately following completion of swallowing. Each subject took several sips of untagged water, swished, and expectorated to clear the oral cavity of residual isotope. Subsequently, subjects swallowed several mouthfuls of either plain water or pudding to clear the foodway of retained and potentially obscuring isotope. Images were then acquired for 2 min in an anterior view of the chest, followed by an additional 2-min collection of the lower chest and abdomen. If isotope was noted in the neck region after clearance swallows, then lateral neck images were obtained by asking the subject to rotate the head maximally and imaging for an additional 1 min. This was done in an attempt to distinguish laryngotracheal penetration from foodway residuum. Additional posterior, lateral, or oblique images were obtained as needed to assist in localizing the isotope. Similarly, cobalt markers were affixed to the jaw angle, laryngeal prominence, sternal notch, and xyphoid when necessary.

To assess clearance of aspirated material, follow-up scans were obtained when indicated. Subjects were reimaged anterioral for 2 min if the immediate scans suggested either subtracheal or laryngotracheal penetration. These delayed scans were performed at 3 h and 6 h postingestion, as necessary, based on persistence of activity. Two patients with possible laryngotracheal-only aspiration were not able to return for the planned follow-up images.

Data Collection and Analysis

All imaging data were reviewed by both authors. Dynamic and immediate postswallow scans were classified as either (1) negative, defined as no activity noted lateral to the midline that was distinct from the esophagus and stomach on anterior views of the thorax, and in the neck region on anterior or lateral views following clearance swallows; (2) indeterminate, defined as no activity lateral to midline in the chest, yet evidence of residual isotope in the neck region; or (3) positive, defined as activity lateral to the midline in the chest.

Positive scans, both immediate postswallow and follow-up, were further analyzed for a relative percentage of aspiration. Counts were obtained for regions of interest drawn around areas of presumed aspiration in the chest. In some cases, a region of interest also included centrally located isotope if it appeared contiguous with activity extending off-midline. Separate regions of interest were constructed to include all other activity referrable to the esophagus and gastrointestinal tract. A percentage of material aspirated was calculated using the formula $PA = RA \times 100/RT$, where PA was the percentage of aspiration, RA was the radioactive count in the regions of presumed aspiration, and RT was the total count from all regions of interest, both pulmonary and extrapulmonary. Counts measured in analysis of 3- and 6-h postswallow data were adjusted for decay of the radioisotope using appropriate formulas.

The management of the patient's dysphagia at the time of scintigraphy, with particular reference to dietary prescription, was noted. This information was obtained by patient interview as well as review of the records. Recommendations for changes in dysphagia management were made jointly by one of the authors and the dysphagia treatment team and were based on the results of the scintigraphic test and the clinical history. Dietary recommendations were compared with both the prescintigraphic restrictions as well as the final diet agreed upon by the patient and the attending physician.

Because cough has been assumed to be an indicator of aspiration and subsequent airway clearance, its presence or absence during the swallowing of the isotope was noted. Coughs were subdivided into immediate or delayed, based on time of occurrence during the act of drinking. Statistical analysis was performed to assess correlation with the degree of positivity of the scintigraphic test.

Results

Of the 14 subjects studied, 5 (36%) had scans indicating penetration of the airway distal to the trachea, 7 (50%) had scans indeterminate for laryngotracheal-only penetration, and 2 (14%) had negative studies defined as no evidence of isotope in the airways at any level (Table 1). Figures 1, 2, and 3 are scintigrams that demonstrate the various categories of aspiration severity. Of those positive for subtracheal aspiration, 2 subjects had evidence of penetration into both lung fields. One of these individuals showed bilateral aspiration only during the dynamic phase of swallowing. The initial static scans demonstrated exclusively left lung involvement, suggesting effective and rapid clearance of the right bronchus. The other demonstrated off-midline activity in the chest on both dynamic and static imaging. All three instances of unilateral aspiration involved the right side.

The calculated fraction of material aspirated ranged from less than 1% to approximately 25% (quantification data for subject no. 5 was lost due to computer disk malfunction). Airway clearance was rapid in all cases. In 2 subjects, clearance of isotope from the subtracheal airways was complete by 3 h. The patient in whom 25% of the bolus was aspirated into bilateral airways eliminated all activity from the left side and 98% of activity from the right by 3 h. Two other aspirated sufficiently small amounts of isotope initially (less than 1%) that residual activity noted at 3 h was impossible to quantify with any degree of accuracy. In 1 case, most of the activity was gone; in the other, corrected counts suggested insignificant elimination on follow-up. More precise localization of the isotope within the subtracheal respiratory tree was more difficult. In 2 subjects, isotope could be clearly designated as residing only in the mainstem bronchus. In a third, activity, initially noted only in the mainsteam bronchus, appeared on delayed images to have migrated into more peripheral, smaller airways. The off-midline activity in 2 other subjects corresponded to more of a broncholobar pattern.

Following the completion of swallowing, activity remained in only the neck or midline upper chest regions in 7 subjects (indeterminate group). In these cases, we were unable to precisely localize isotope to either airway or foodway. In none of these subjects was activity in the neck region distinguishable as adjacent anterior and posterior channels on the lateral view, a finding that would have assisted us in identifying proximal airway inoculation. Additionally, none of these patients who returned for delayed imaging showed migration of questionable laryngotracheal material into the lungs per se.

Of 9 subjects on some form of dietary modification at the time of scintigraphy, 8 (89%) were allowed to ease restrictions. Seven subjects were instructed to liberalize diets to include all liquids without limitations. One of these used positive pressure insufflation per tracheostomy for clearing aspirated liquids. Following scintigraphy, he was advanced to drinking off the respirator. Another patient who had been placed on bolus volume restrictions was allowed to drink ad lib. The premature hospital discharge of 1 subject precluded diet liberalization being enacted. Liquid restriction was only partially lifted in the eighth subject despite complete clearance of subtracheal isotope at 3 h. This decision was based on our inability to calculate a percentage of ingested liquid aspirated (damaged disk), as well as his advanced age and physical frailty. All 5 subjects who were already drinking without restriction at the time of scintigraphy were allowed to continue as such based on either lack of definitive aspiration beyond the trachea or demonstration of prompt airway clearance. For 1 individual, continued dietary restriction was suggested because the fraction of swallowed material aspirated was high (25%), advanced age, and frailty.

Table 1. Study population characteristics and results

Subject	Age	Diagnosis	Onset-vfss[a] (days)	Vfss-scint[b] (days)	Scint study results	Presence of cough	Diet Restriction	
							Pre-scint	Post-scint
1	71	Cardiac/ tracheostomy	68	14	I	Yes	No	No
2	82	Cardiac valvuloplasty	243	6	P	Yes	Yes	Yes
3	60	Unilateral hemispheric CVA	24	6	I	Yes	No	No
4	41	Unilateral hemispheric CVA	17	3	P	Yes	Yes	No
5	80	Unilateral hemispheric CVA	43	5	P	Delayed	Yes	Yes*
6	63	Cerebellar CVA	412	10	P	Yes	Yes	No§
7	35	Arnold-Chiari malformation/ ventilator	575	65	I	No	Yes	No
8	72	Bilateral hemispheric CVA	49	13	I	Yes	Yes	No
9	25	Muscular dystrophy/ ventilator	133	14	N	No	No	No
10	60	Unilateral hemispheric CVA	32	11	N	Yes	No	No
11	78	Brainstem CVA	515	32	I	Delayed	Yes	No
12	33	Brainstem CVA	307	95	I	Yes	Yes	No
13	61	Brainstem CVA	17	5	P	Yes	No	No
14	68	Brainstem/ cerebellar CVA	110	82	I	No	Yes	No

I = Indeterminate result; P = positive for subtracheal aspiration; N = negative result; CVA = cerebrovascular accident.
[a]Interval between onset of dysphagia and most recent videofluoroscopic swallowing study (vfss).
[b]Interval between the videofluoroscopic and scintigraphic (scin) swallowing studies.
[c]Diet restriction lessened but not stopped.
[d]Cessation of diet restriction recommended but not followed.

The frequency of aspiration detected by scintigraphy was compared between recent onset and chronic dysphagic groups. Using two separate definitions of positive scintigrams, both of which included and excluded the indeterminate group, there was no significant difference in proportion of positive scintigrams between subjects with dysphagia less than or greater than 10 weeks (Fisher's exact test $p = 0.5$ for both definitions).

The presence of coughing during the swallowing phase of the scintigraphic study was also examined for a relationship to the degree of positivity of the test for aspiration. Separate statistical analyses using two by two contingency tables were performed for both cough with and without a delayed component and for scintigram positivity including and excluding the intermediate group. Statistical significance was only noted comparing the liberal definitions of both positive scintigram (positive plus indeterminate) and cough (immediate and late) (Fisher's exact test $p = 0.05$). The number of subjects, however, who did not cough during drinking was small among groups both positive and negative for aspiration.

Discussion

The decision to either continue or further limit liquid intake in a person who aspirates often occurs without knowledge of the fate of the material penetrating the glottis. In individuals so diagnosed, liquid may or may not migrate further into the respiratory tree. Moreover, those with penetration may or may not effectively protect themselves from the offending substances by mechanisms of airway clearance such as cough or mucociliary transport. The determination that no, or a relatively small amount of, material is aspirated below the trachea, or that airway clearance is prompt and complete should be clinically useful in the formulation of a feeding plan. The standard methods of assessing swallowing fluorographi-

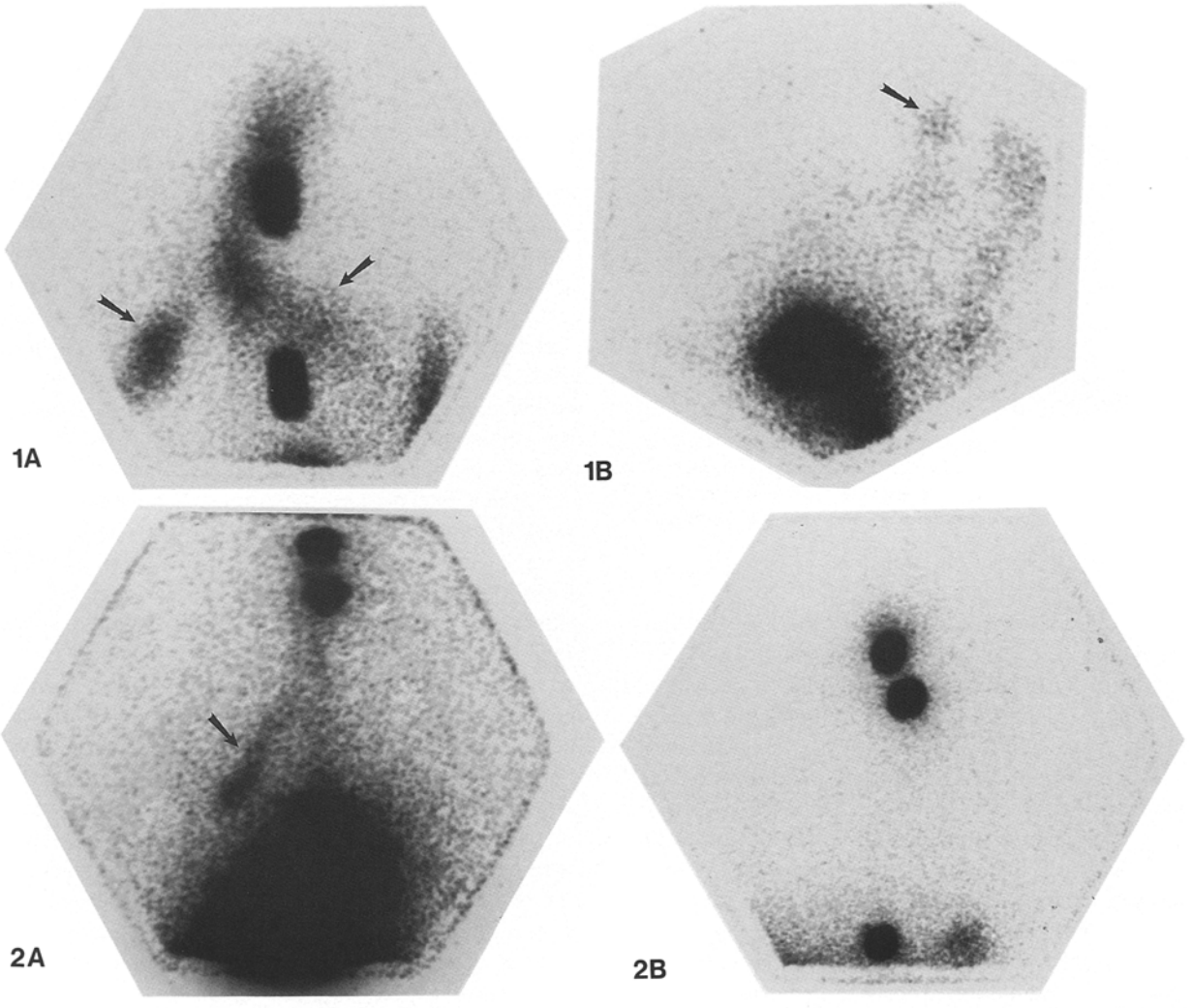

Fig. 1. Anterior thoracic images of subject 1(**A**) immediately following ingestion showing bilateral aspiration (arrows) and (**B**) 3 h later with residual isotope remaining only in the left lung field (arrow). Isotope more inferior and lateral represents the gastrointestinal tract.
Fig. 2.A Depiction of aspiration localized primarily to the right mainstem bronchus immediately after swallowing (arrow) on anterior views in subject 5. **B** Complete clearance at 3 h. Midline markers seen affixed to the laryngeal prominence, sternal notch, and xyphoid.

cally, however, do not adequately address these issues. Isotopic tests have been shown to be capable of judging the severity of aspiration, yet few studies have described their use in the clinical management of swallowing disorders. Although some [18,23] have suggested that prudence be exercised if a critical percentage of material is aspirated, no paper has been published that details the use of the scintigraphic swallowing test in making specific alterations in treatment. The experiences presented here demonstrate how information concerning severity of airway penetration beyond what is available with standard videofluorography can influence treating the patient who aspirates.

For this investigation, feeding recommendations were based on a global consideration of many factors that were believed to contribute to the development of aspiration pneumonia. These included the presence and depth of airway penetration, the estimated fraction of material aspirated, the completeness of clearance at 3 h postingestion, and historical features such as a record of recent pneumonia, age, and physical frailty. It was generally recognized that dietary recommendations based on scintigraphic data did not preclude the eventuality of respiratory disease, however, the demonstration of no or minimal deeper airway penetration and/or vigorous clearance contributed substantially to confidence in the subsequent decisions on feeding. Because the study involved exclusively liquid alimentation, alterations in the subjects' solid food diets were not considered.

We assumed subjects whose studies were nega-

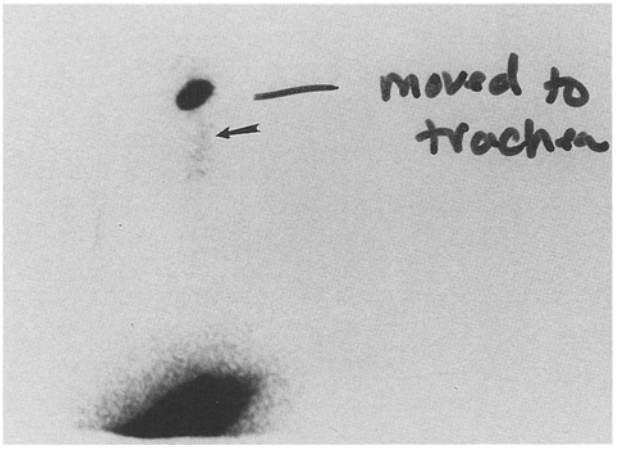

Fig. 3. An example of an indeterminate study. Following swallows of nonisotopic water to clear the foodway, activity remains just inferior to the laryngeal marker (arrow). Lateral views (not shown) were unable to identify the residual isotope as localized to either airway or foodway.

tive either did not aspirate during drinking a cup of thin liquid, or did so, but cleared the airways and foodways so rapidly that it was not detected. An alternate explanation is that isotope was present in the airways but the technique was insufficiently sensitive to detect it. The latter point is considered unlikely according to our experience and the experiences of others which demonstrate scintigraphy to be a sensitive technique for detecting extremely small amounts of isotope [4,17,18]. Although it is true that test-retest reliability was not assessed, our methodology included multiple swallows of liquid rather than single swallows, the former being a feature that enhances the chance that aspiration will occur if the potential is present. Neither subject with a negative study (subjects 9 and 10) had been restricted from liquid consistencies at the time of scintigraphy. One had intermittent coughing associated with fluorographically demonstrated subglottic penetration, and the other had small amounts of food and liquid occasionally suctioned from a tracheostomy tube. Although neither had had recent pulmonary infections, questions remained prior to the nuclear medicine study as to the relative safety of allowing continued drinking. Based on the demonstration that no isotope was detected in the airways either during or immediately following the swallowing, it was concluded that aspiration was unlikely and that liquids need not be restricted.

All subjects designated as indeterminate for laryngotracheal-only aspiration were also allowed to either advance to less restrictive diets or to continue without restrictions. In this group, it was unclear if isotope noted in the neck region was truly in the supracarinal airways. In the worse-case scenario, if liquids were aspirated to the laryngotracheal level without immediate or delayed innoculation of more distal airways, we believed this represented a more benign pattern of aspiration that was unlikely to result in respiratory infection.

The decision of whether to liberalize drinking in the presence of subtracheal aspiration was more complex. In 2 of the cases the estimated percentage aspirated was less than 1% of the ingested liquid. Although small amounts of residual isotope were noted at 3 h in each case, the fraction cleared was difficult to measure because the number of counts was low. For subject 4 the isotope remained confined to the mainstem bronchus. In contrast, delayed imaging showed the activity having migrated to more distal airways for subject no. 6. In these cases, although isotope entered the subtracheal airways, the material aspirated represented such a small volume that contamination was believed to be of low consequence, given other clinical factors.

In 2 other subjects the estimated amount aspirated was probably greater. Clearance, however, was complete at 3 h in each case. In subject no. 13, a maximum of 6% of the ingested isotope was noted in a left broncholobar pattern, and in subject no. 5 the regional count analysis could not be done because of technical problems. In the latter, isotope was noted only in the right mainstem bronchus and appeared to be more than just a trace amount. Subject no. 13, who had not had dietary restrictions at the time of the study, was allowed to continue to drink all consistencies, based in part on a negative recent history for pulmonary infection. Subject no. 5, however, was more conservatively managed because of his advanced age (80 years), a generally frail medical condition, and uncertainty as to the fraction of material aspirated. Accordingly, he was allowed thick liquids per mouth but thinner consistencies continued to be restricted. For subject no. 2 it was thought that the 25% aspiration was significant and represented a risk to health, despite the demonstration that he was able to entirely clear the left broncholobar activity and approximately 98% of right bronchial activity by 3 h. Other factors considered in this decision were his advanced age (82) and general frailty. Interestingly, according to his medical record, he did not subsequently develop pulmonary infections in spite of not following dietary restrictions.

The relationship of cough to airway penetration is inconstant. Some individuals who aspirate material into the airways cough vigorously and immediately. In others, due to sensory or motor impairments, the cough reflex is weak, delayed, or absent [24]. Studies of bedside dysphagia evaluation [25] have not shown the presence of cough to be a reliable predictor of aspiration. In this study we attempted to assess if coughing during or following ingestion was positively correlated with the severity of aspiration. We were unable to establish a strong relationship between the presence of cough, either immediate or delayed, with the positivity or negativity of

the scintigram for aspiration. Immediate coughing was present in 9 subjects (64%) and delayed coughing in an additional 2 (14%). Of these 11 patients, 5 (45%) had isotope imaged below the trachea, and 5 (45%) had equivocal studies. If in fact coughing signifies airway penetration, its presence or timing did not serve to distinguish tracheal from subtracheal aspiration as depicted scintigraphically.

Our prior study [4] was criticized for not having strictly minimized the interval between the radiographic demonstration of glottic penetration and the scintigraphic test. It was suggested that scintigraphy, in contrast to fluorography, had not revealed definitive aspiration because the patient's dysphagia had improved in the interim. Although the interval between studies may still explain some of the negative or indeterminate results in the study presented here, our purpose was less to compare fluorography with scintigraphy than to demonstrate the latter's usefulness in clinical management of already documented aspiration. However, to better place the scintigraphic study in a temporal context, we related the interval between swallowing studies to the duration of dysphagia symptoms by retrospectively dividing the subjects into recent onset and chronic dysphagia groups. The scintigram followed fluorographically demonstrated aspiration by an average of only 7 days in the former, and 45 days in the latter. Based on the short interval between studies, we presumed that those with dysphagia of more recent onset were still likely to be aspirating at the time scintigraphy was performed. Similarly, it was assumed that individuals in the chronic group, with fluorographically demonstrated aspiration at a mean of 317 days from dysphagia onset, were likely to still have airway penetration despite the greater delay between their radiographic and scintigraphic studies. There were no significant differences between the two groups in their respective proportions of positive or equivocal studies.

The described techniques for measuring the fraction of material aspirated are inexact. The present methodologies for comparing total counts ingested to counts aspirated disregards differing attenuation of body tissues and variable distances between the underlying radioactivity and the gamma camera. For example, two similar doses of isotope may have quite different counts if one is situated more posteriorly in the thorax than the other. Additionally, accuracy is lost in failing to calculate the precise dose administered orally and to account for material expectorated or retained in the mouth. However, the present technique does allow a gross calculation of the amount of subglottic penetration, and thus has use in estimating the general severity of the swallowing disorder. For greater accuracy, it will be necessary to develop methodologies that account for attenuation of the thorax and distance from the underlying activity to the camera, as well as determine more precisely the dosage prior to ingestion.

Accuracy in detecting isotope in the laryngotracheal region is also limited with the present technique. In not 1 of the 14 subjects was isotope localized to the larynx or trachea as distinct from the adjacent foodway. This difficulty is probably due to our inability to obtain a true lateral image of the neck because of camera configuation, poor resolution inherent in scintigraphy, and positioning limitations imposed by physical impairments. Moreover, patients referred for scintigraphy commonly have associated abnormalities in pharyngeal and esophageal clearance. Such retention of isotope in the neck complicates identification of activity in the airway. In these cases, we are presently assessing inhaled radioactive xenon-133 as an internal laryngotracheal marker that would more clearly distinguish airway from foodway.

Much remains unknown regarding the true risks of aspiration, even if the volume penetrated is small and elimination prompt. The group of subjects studied here may not have been truly representative of all patients who aspirate, as they were not randomly selected, were generally healthy without significant cognitive impairment, and had not had recent pneumonia despite, in most cases, continuing to eat and drink. For those individuals deemed at increased risk to develop respiratory infection following aspiration, i.e., those with severe dementia, immunocompromise, significant concurrent medical illness, or alternation in level of consciousness, the consequence of laryngeal penetration, even in small amounts and transiently, may be more serious. For these reasons it is important to place the findings of swallowing tests, either scintigraphic or fluorographic, in a global clinical context. For our study population, we are not aware of the subsequent development of respiratory disease in any of the subjects, although approximately half have been lost to follow-up by our service. The intent of our investigation was not to correlate aspiration severity, as measured by the scintigraphic swallowing test, with the risk of developing pulmonary disease. Rather, we have shown how decisions on feeding management were altered with a measure of aspiration that was otherwise unavailable with conventional techniques. It must also be kept in mind that, as with radiographic methods, a patient's performance on the isotopic test in not necessarily representative of his or her swallowing behavior in other circumstances.

Some clinicians will allow patients to continue to drink despite laboratory demonstration of airway penetration. In these cases it is usually assumed that the degree of aspiration is mild and, because the patient is in generally good health and has not to date developed pneumonia in spite of drinking liquids, of little consequence. Conversely, others may opt for prescribing

restricted diets solely due to ambiguity regarding the significance of the aspiration documented videofluorographically. Our impression is that both practioners and patients are often uncomfortable with the risks of permitting ongoing aspiration, particularly where there is uncertainty about the patient's ability to tolerate it. The utility of the scintigraphic test lies primarily in its provision of additional data concerning the severity of airway penetration. We believe the most beneficial use of this test is identifying the absence of persisting subtracheal aspiration (negative or indeterminate categories) in the face of a positive radiographic study. Subtracheal aspiration needs to be interpreted more cautiously. Although the findings of aspiration limited to small volumes and subject to rapid airway clearance theoretically suggests a lower risk of disease sequalae, and led to dietary liberalization in some of our study group, the correlation has not been rigorously proven. Future research needs to examine the relationship between the magnitude of subtracheal aspiration and the subsequent development of pulmonary illness.

The morbidity associated with imposing fluid-restricted diets or performing pharyngeal or airway bypass surgery on individuals who penetrate the airway with food or liquid, however, is not insignificant [26]. For instance, dehydration as a consequence of limiting liquid intake is a real concern in the elderly in whom self-regulation of fluid balance has been shown to be impaired [27]. For others, the quality of life may be diminished by prolonged prohibition of fluids. The practitioner at times requires clinical data that assists him/her in balancing the risks of continued aspiration with those of prolonged dietary restriction or surgical intervention. In this regard, it is desirable to more adequately define the relative severity of aspiration. Not all patients in whom aspiration has been demonstrated will be candidates for the scintigraphic swallowing test. We believe that for selected individuals with documented aspiration in whom the prescribed dysphagia treatment is not accepted or otherwise possible, isotopic swallowing studies, by identifying airway penetration that is limited or vigorously cleared, can assist in the decision as to whether to restrict liquid ingestion.

Conclusion

Scintigraphic techniques are able to define the severity of aspiration based on measurement of the relative amount of material aspirated, the depth of airway penetration, and the rapidity and efficiency of airway clearance. In this study we have demonstrated the application of a nuclear medicine swallowing study to prescribing treatment for patients prone to aspiration of liquids. Although the place of scintigraphy in the management of dysphagia is not clearly defined at this time, we believe it is presently useful for selected patients with known aspiration in whom further understanding of the extensiveness of aspiration would be critical to the decision of whether to allow liquids by mouth.

Acknowledgment. This research was supported in part by Clinical Investigator Development Award #DC00055.

References

1. Horner J, Massey MD, Riski JE, Lathrop DL, Chase KN: Aspiration following stroke: clinical correlates and outcome. *Neurology 38:*1359–1362, 1988
2. Logemann JA: Evaluation and treatment of swallowing disorders. San Diego: College-Hill Press, 1983
3. Verghese A, Berk SL: Bacterial pneumonia in the elderly. *Medicine 62:*271–285, 1983
4. Silver KH, Van Nostrand D, Kuhlemeier KV, Siebens AA: Scintigraphy for the detection and quantification of subglottic aspiration: preliminary observations. *Arch Phys Med Rehabil 72:*902–910, 1991
5. Griffith GH, Owen GM, Kirkman S, Shields R: Measurement of rate of gastric emptying using chromium-51. *Lancet 1:*1244–1245, 1966
6. Kazem I: A new scintigraphic technique for the study of the esophagus. *Am J Roentgenol 115:*681–688, 1972
7. Tolin RD, Malmud LS, Reilley J, Fisher RS: Esophageal scintigraphy to quantitate esophageal transit (quantitation of esophageal transit). *Gastroenterology 76:*1402–1408, 1979
8. Malmud LS, Fisher RS: Radionuclide studies of esophageal transit and gastroesophageal reflux. *Semin Nucl Med 12:*104–115, 1982
9. Russell COH, Hill LD, Holmes ER III, Hull DA, Gannon R, Pope CE II. Radionuclide transit: a sensitive screening test for esophageal dysfunction. *Gastroenterology 80:*887–892, 1981
10. Menin RA, Malmud LS, Petersen RP, Maier WP, Fisher RS: Gastroesophageal scintigraphy to assess the severity of gastroesophageal reflux disease. *Ann Surg 191:*66–71, 1980
11. Boonyaprapa S, Alderson PO, Garfinkel DJ, Chipps BE, Wagner HN Jr: Detection of pulmonary aspiration in infants and children with respiratory disease: concise communication. *J Nucl Med 21:*314–318, 1980
12. Horsley JR, Sproule BJ: Radio-isotope evaluation of nocturnal aspiration in patients with chronic obstructive pulmonary disease. *Postgrad Med J 62*(Suppl 2):69–70, 1986
13. Valat C, Demont F, Pegat MA, Saliba E, Bloc D, Besnard JC, Laugier J: Radionuclide study of bronchial aspiration in intensive care newborn children. *Nucl Med Commun 7:*593–598, 1986
14. Malfroot A, Vandenplas Y, Verlinden M, Piepsz A, Dab I: Gastroesophageal reflux and unexplained chronic respiratory disease in infants and children. *Pediatr Pulmonol 3:*208–213, 1987
15. Hamlet SL, Muz J, Patterson R, Jones L: Pharyngeal transit time: assessment with videofluoroscopic and scintigraphic techniques. *Dysphagia 4:*4–7, 1989
16. Hamlet SL, Muz J, Farris R, Kumpuris T, Jones L: Scinti-

graphic quantification of pharyngeal retention following deglutition. *Dysphagia 7:*12–16, 1992
17. Humphreys B, Mathog R, Rosen R, Miller P, Muz J, Nelson R: Videofluoroscopic and scintigraphic analysis of dysphagia in the head and neck cancer patient. *Laryngoscope 97:*25–32, 1987
18. Muz J, Mathog RH, Miller PR, Rosen R, Borrero G: Detection and quantification of laryngotracheopulmonary aspiration with scintigraphy. *Laryngoscope 97:*1180–1185, 1987
19. Muz J, Mathog RH, Hamlet SL, Davis LP, Kling GA: Objective assessment of swallowing function in head and neck cancer patients. *Head Neck 13:*33–39, 1991
20. Muz J, Flemming S, Hamlet S: Bolus consistency and aspiration: quantification with scintigraphy. *Dysphagia 5:*111, 1990
21. Flemming S, Nelson R: Scintigraphy in the dysphagic patient. *ASHA 31:*112, 1989
22. Fleming S, Muz J, Hamlet S: Practical scintigraphic application for the dysphagic patient. *ASHA 32:*72, 1990
23. Muz J, Mathog RH, Nelson R, Jones LA: Aspiration in patients with head and neck cancer and tracheostomy. *Am J Otoloaryngol 10:*282–286, 1989
24. Pontoppidan H, Beecher HK: Progressive loss of protective reflexes in the airway with the advance of age. *JAMA 174:*2209–2213, 1960
25. Linden P, Siebens AA: Dysphagia: predicting laryngeal penetration. *Arch Phys Med Rehabil 64:*281–284, 1983
26. Feinberg M, Knebl J, Tully J, Segall L: Aspiration and the elderly. *Dysphagia 5:*61–71, 1990
27. Phillips PA, Rolls BJ, Ledigham JG, Forsling ML, Morton JJ, Crowe MJ, Wollner L: Reduced thirst after water deprivation in healthy elderly men. *N Engl J Med 311:*753–759, 1984