Quantifying Aspiration in Scintigraphic Deglutition Testing: Tissue Attenuation Effects

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Scintigraphic studies for determining aspiration associated with swallowing have ignored error due to differential gamma attenuation in the patient by the various regions of the body. This study sought to estimate the magnitude of that error, and to assess the feasibility of providing individual attenuation corrections based on clinical data. **Methods:** Relative attenuation for the pharynx, thorax and abdomen were determined from physical measurements employing an anthropomorphic phantom and 45 adult human subjects. A small sealed radioactive source of 2.5 mCi of ^{99m}Tc was placed inside the phantom at various locations within the upper digestive tract and respiratory system, and relative count rates determined via static scans with a gamma camera. Similar data for human subjects was obtained from clinical swallowing testing using a bolus of 2.5 mCi of ^{99m}Tc in 10 cc of water. **Results:** The ratios representing relative counts were highly similar between the phantom and average human data. Test-retest replication of results was good for the abdominal reference and pharynx ratios—less so for the thorax. A procedure is described for estimating accuracy of percent aspiration calculation based on group data, using normalization coefficients derived for separate anatomical regions in the subglottic respiratory system. **Conclusions:** Error in percent aspiration calculation will depend on the amount and location of aspirate. Individual subject corrections based on the type of clinical data studied should be attempted with caution.

Key Words: scintigraphy; aspiration; tissue attenuation

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Aspiration of swallowed substances, secretions or refluxed material represents a failure of airway protection, with risk of the patient developing aspiration pneumonia. The extent of that risk depends on many factors, including the amount of material aspirated and the patient's ability to subsequently clear it (*1*).

Scintigraphy is beginning to be used for identifying aspiration and quantifying the amount of material aspirated. There are procedural differences in methodology among investigators depending on whether the issue is aspiration of oral secretions (*2–4*), reflux of gastric contents (*5*) or ingested material (*6–11*). The general approach for protocols involving ingested material is to determine aspiration from static scans immediately after the material is swallowed. Regions are identified on the images representing aspirate in the trachea, bronchi or lungs. If percent aspiration is to be quantified, radioactive counts from those regions are referenced to the total counts emitted by the patient following the swallow, including residue in the mouth and pharynx, and material in the esophagus, stomach and small bowel. Static scans may also be done at a later time to determine the rate of clearance of the aspirate from the airways.

The anatomical regions where aspirate might be detected include the proximal trachea just below the larynx and above the clavicles, the distal trachea behind the sternum, and the bronchi and lungs behind the rib cage. There is considerable variation in both the thickness and tissue composition of these regions, thus large differences in attenuation for separate regions would be expected. The reference for total gamma emissions from the body is the sum of components from regions with very different attenuation properties (e.g., mouth, pharynx, esophagus, abdomen). Adding to the complexity is the individual patient variation in body size and shape.

With the exception of two recent papers, most published reports of scintigraphic studies of swallowing and aspiration have not attempted to take into account differential gamma attenuation in the patient by the various regions of the body. In a study on gastro-pulmonary aspiration, Ruth et al. (*5*) incorporated a correction for anterior-posterior location of aspirate in the lungs by taking the geometric mean of counts from anterior and posterior images. This method does not address attenuation differences for superior and inferior locations of aspirate within the respiratory system. Hamlet et al. (*12*) utilized dynamic data during a swallow to correct for attenuation when determining oropharyngeal residues. They assumed the radioactive bolus acted as a "point source" (circumscribed volume) passing from the mouth to the stomach, so that the total-area counts when the source was at a given location could be used as a reference in determining percent residue at location. This approach is also incorporated in the methodology described in this paper.

The specific aims of the study were: (1) To provide an

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estimate of the amount of error in determining percent aspiration when relative tissue attenuation effects are ignored; and (2) to assess the degree to which data from individuals, tested with a clinical protocol, might be used to provide correction for attenuation effects.

METHODS

There are two sub-components to this study: description of clinical data and phantom measurements.

Clinical Data

Clinical studies were performed on 45 adults enrolled in a swallowing research project (ages 28–76 yr, mean 52 yr; 16 females and 29 males). They were normal controls and head and neck cancer patients, each tested on one occasion. None of the subjects aspirated when swallowing. For a sub-group of 23 subjects, data for a second clinical test done on a separate day were available for replication statistics. No physical measurements of subject physique were made, although they represented a range from small-boned and very thin to large and stocky or obese. Particular individuals representing extremes were noted.

Clinical scintigraphic data acquisition began with a liquid swallow. Cobalt markers were affixed to the skin at the angle of the mandible and anterior cricoid to aid in demarcation of the oral and pharyngeal regions. The patient was positioned in a right anterior oblique position (RAO) against a 38.7-cm diameter gamma camera with a low-energy all-purpose collimator. The field of view encompassed the mouth, pharynx, thorax and a portion of the upper abdomen in some shorter subjects. Then, 10 cc of water mixed with 2.5 mCi of ^{99m}Tc-sulfur colloid was given and the subject was told to hold this radioactive bolus in the mouth until instructed to swallow. Computer data acquisition was done in the dynamic mode during the swallow for 10 sec at a frame rate of 25/sec (40 msec per frame).

Time-activity curves were generated from the dynamic data (Fig. 1) representing activity from the oral, pharyngeal and distal esophageal regions, and from the total area encompassed by the field of view. Regional time-activity curves indicate where in the body the radioactive bolus was located at various points in time. The fluctuations in total-area counts when the bolus was at different known locations were caused by the effects of differential tissue attenuation on a relatively circumscribed radioactive bolus passing through the upper digestive tract. Adequate information for the abdominal region was not available from dynamic data, since some or all of the stomach lay below the field of view.

Following dynamic imaging, the subjects were asked to swallow several mouthfuls of plain water to wash down residue and they were not permitted to spit anything out. Then the protocol continued with a series of 2-min static scans with the patient in different orientations (RAO, LAO, LAT, ANT and a lower ANT abdominal view). Elapsed time from the dynamic imaging study was noted for all static scans for decay corrections.

In order to compute relative counts detected from the various regions, total counts from the ANT abdominal static scan were used as a reference, with correction for decay during the approximately 15 min of elapsed time after the dynamic study. These data encompassed activity in the entire field of view inferior to the top of the stomach and including the small bowel.

Counts for the separate oral, pharyngeal and esophageal regions were determined from the dynamic total-area time-activity curves. Total-area counts were determined for six consecutive

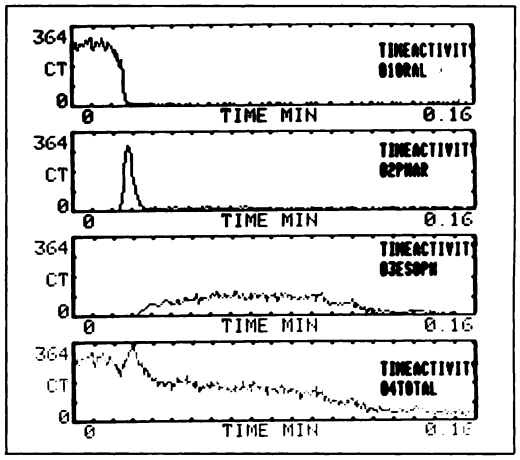

FIGURE 1. Time-activity curves for the oral, pharyngeal and distal esophageal regions, and for the total area. At the outset, the bolus was held in the mouth, so the counts for the total time-activity curve at that time are weighted for the effects of relative attenuation by the oral region. The pharyngeal region time-activity curve indicates the time when the bolus was passing through the pharynx; a corresponding peak in the total time-activity curve represents weighting for relative attenuation by the throat tissues. Relative attenuation by the chest is likewise represented in the total time-activity curve during the time the bolus is passing through the distal esophagus.

frames and then averaged when the bolus was in the mouth. Likewise, the average was determined for six consecutive frames when the bolus was in the esophagus, and over three frames centered on the pharyngeal time-activity curve maximum when the bolus was passing through the pharynx (*12*). The rapidity of bolus transit through the pharynx during a swallow limits the number of frames useful for including in an average. These averaged counts were then time-normalized to the duration of the static scan (40 msec × 3000 = 2 min.).

Corrections were made to account for the effects of retention of material in the mouth and pharynx immediately after the swallow. The proportion of oral or pharyngeal residue was determined from dynamic data, taking the residual counts (average over six consecutive frames) from the oral and pharyngeal time-activity curves immediately after the bolus had passed the region of interest, and dividing them by the average total area time-activity counts during those times when the bolus was in the mouth or pharynx, respectively (*12*). By using different portions of the total area time-activity curve for the oral and pharyngeal references, the residue computation incorporates relative attenuation by the mouth or throat.

The contribution of oral residue was subtracted from the measured pharyngeal counts, and the pharyngeal counts normalized to 100% of the bolus.

$$Pc = \frac{Pm - (O \times o)}{(1.00 - o)},$$

where Pc is the corrected pharyngeal counts, Pm is pharyngeal counts based on measurements from the total area time-activity curve, O is oral counts based on measurements from the total area time-activity curve, and o is the proportion of oral residue. Similarly, average counts from the distal esophagus were corrected for both oral and pharyngeal residue.

$$Ec = \frac{Em - (O \times o) - (P \times p)}{(1.00 - o - p)},$$

where Ec is the corrected distal esophageal counts, Em is distal esophageal counts based on measurements from the total area time-activity curve, and p is the proportion of pharyngeal residue.

No correction for residue was applied to the abdominal counts determined from the static scan. The oral and pharyngeal residues present at the time of dynamic imaging were largely carried into the stomach by the water chaser and subsequent swallows during the approximately 15-min interval between dynamic and static imaging. This was verified in 29 of the subjects for whom data were available on total counts for the supragastric region in an ANT scan taken immediately before the ANT abdominal scan.

After all the adjustments for decay and residuals were done, there was a set of comparable data for each individual on counts from the oral, pharyngeal, esophageal and abdominal regions. Using the abdominal counts as a reference, relative counts (ratios) were computed for the oral, pharyngeal and esophageal regions.

Phantom Study

An anthropomorphic phantom was used for relative attenuation measurements (Alderson Rando Phantom, Alderson Research Laboratories, Inc., Stamford, CT). This phantom, which is shaped like a human male torso, is typically used for clinical dosimetry in radiation oncology. It contains materials and spaces to simulate the attenuation of muscle, bone, lung and air cavities, and is sectioned transversely into 1-inch slices. Each slice contains a number of cylindrical plugs arranged in a grid pattern. Any of these plugs can be removed and substituted with a radioactive source or dosimeter.

A sealed radioactive source was created from a 0.75-inch long piece of silastic intravenous line tubing. The tubing was plugged at one end, and approximately 2.5 mCi of ^{99m}Tc-sulfur colloid was inserted into the open end, which was then sealed. This radioactive source was placed inside the phantom at various locations within the upper digestive tract and respiratory system, either replacing a plug or against one wall of the air spaces. In order to place the source, the phantom was disassembled by removing all sections superior to the section of interest and then reassembled before scanning.

The phantom was set upright against the gamma camera in a simulation of the RAO position. Two of the neck sections were each rotated about 35° to the left around a vertical axis passing through the middle of the pharynx, and marked so that reassembly of the phantom after source insertion could be replicated. Cobalt markers were taped to the shoulders of the phantom to verify that the phantom position remained the same for all scans. After the source was scanned in the 17th section of the phantom, the gamma camera was lowered 10 inches to complete the remaining scans for sections 18–24. The cobalt markers were relocated on the phantom hips for those lower scans.

Static scans of the phantom were done with the sealed source at 48 different locations. At each location, two 1-min static scans were done in immediate succession. The total counts received during each 1-min scanning interval were recorded, and the average taken as the measurement for that source location. The elapsed time was also recorded for decay corrections.

CAT scans of the phantom were consulted for correct anatomical placement of the radioactive source. The topmost source location was horizontal on the surface of the tongue in section six. The source was then placed vertically on the posterior wall of the pharynx in several transverse sections. Starting at the level of the larynx (section 9) more than one source location per transverse section was chosen, to represent the digestive system or airways. For the digestive system, one source location per section was chosen for the esophagus, and up to three source locations per transverse section within the stomach. For the respiratory system, source locations were chosen to simulate regions of aspirate in the trachea, bronchi and inferior/medial portions of the lungs.

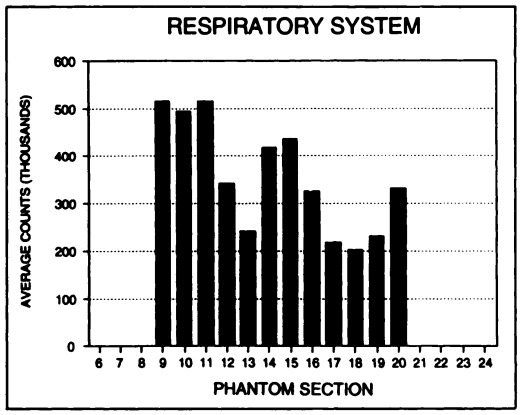

FIGURE 2. Phantom data for radioactive source locations in the respiratory system. Source locations in sections 9–11 are in the larynx and proximal trachea, 12–13 in the distal trachea and bronchi and 14–20 in the lungs.

RESULTS

Phantom Measurements

Figure 2 shows phantom data for the respiratory system. The detected counts were highest when the source was in the larynx and proximal trachea (sections 9–11), but only about half as great when the source was located in the distal trachea and bronchi (sections 12 and 13) behind the bony sternum. With the source location in the proximal medial regions of the lungs lateral to the midline (sections 14–16), the counts were nearly as high as in the larynx and proximal trachea, but reduced when the source was in the lower basilar section of the lungs (sections 17–20).

Phantom data for the digestive system are shown in Figure 3. This series of measurements showed a pattern similar to the clinical total area time-activity curve in Figure 1. For example, counts from the oropharynx (section 7) are slightly lower than from oral section 6 and hypopharyngeal sections 8–9 because the source was behind the ramus of the mandible. Counts when the source was located in the proximal esophagus (sections 10–13) were higher than from the distal esophagus (sections 14–20). For each abdominal phantom section (21–24), the counts illustrated in Figure 3 are mean values, representing midline, lateral and anterior source placements within the stomach. These abdominal counts are higher than when the source was located in the distal esophagus.

Relative counts for phantom data are represented in Table 1, expressed as ratios of measured counts from various anatomical regions relative to average abdominal counts. A ratio of less than 1.0 indicates a region of greater

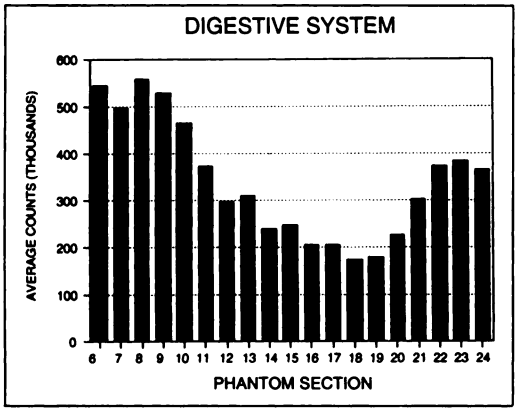

FIGURE 3. Phantom data for radioactive source locations in the upper digestive system. Source locations in sections 6–9 are in the oropharyngeal region, 10–13 in the proximal esophagus, 14–20 in the distal esophagus and 21–24 in the stomach.

attenuation than when the source was in the abdomen. Ratios were used to facilitate comparison to the clinical data.

Clinical Measurements

The clinical data were quite variable, as is characteristic of human subject data in general. We will initially present descriptive data on the magnitude of residues and variability for repeat testing.

Corrections were made to account for the effects of retention of liquid radioactive bolus material in the mouth and pharynx immediately after swallowing. Table 2 shows the magnitude of the residues. The combined oropharyngeal residue immediately after the swallow was in the range of 10%–20% for most subjects. Note that subjects with head and neck cancer had larger amounts of both oral and pharyngeal retention than normals, which would be expected. The amount of oropharyngeal residue immediately after the swallow is large enough to require corrections, particularly for patients who are likely to be clinically tested for aspiration.

TABLE 2
Descriptive Data on Residual Bolus Material Immediately After the Water Swallow (Oral and Pharyngeal Retention) and Total Supra-Gastric Residual Approximately 15 Minutes Later

Region	Percent residue: Patients mean (s.d.)	Percent residue: controls mean (s.d.)	Percent residue: All mean (s.d.)
Oral	*10.84 (7.19) n = 21	6.03 (3.09) n = 24	8.72 (5.80) n = 45
Pharyngeal	* 6.23 (4.05) n = 21	3.49 (1.55) n = 24	4.95 (3.29) n = 45
Supra-gastric	3.35 (2.43) n = 13	3.18 (1.84) n = 16	3.35 (2.09) n = 29

*Significantly different than controls, $p < 0.01$.

Table 2 also shows the amount of supra-gastric residue about 15 min following the swallow, after drinking additional water. These data are from only 29 subjects, using counts for the total supra-gastric field of view in the ANT scan, so the values cannot be directly compared to the dynamic data for oral and pharyngeal regions immediately after the swallow. They can, however, be used to verify the assumption that supra-gastric residue would be negligible at that time. It is apparent that the great majority of radioactive material had been washed down into the stomach by the time of the reference ANT abdominal scan. No corrections were made for any small amount of residue present at the time of the ANT abdominal scan.

The total counts from a 2-min ANT abdominal scan were chosen as a reference, rather than a time-normalized value from inherently less accurate dynamic data for the oral, pharyngeal or esophageal regions. Table 3 provides information on the variability of counts from repeated ANT abdominal scans, done on different days. The mean ANT abdominal counts for test and retest were not significantly different. In addition, linear correlations were computed

TABLE 1
Relative Counts Detected When the Radioactive Source Was Located in Various Anatomical Regions*

Region	Phantom	Males (n = 29) mean (s.d.)	Females (n = 16) mean (s.d.)	All (n = 45) mean (s.d.)
Oral	1.47	1.43 (0.40)‡	1.63 (0.63)¶	1.50 (0.50)‡
Pharynx	1.53	1.58 (0.46)**‡	1.59 (0.63)**‡	1.58 (0.52)**‡
Distal esophagus	0.59	0.63 (0.18)‡	0.75 (0.25)†§	0.67 (0.21)†‡
Abdomen	1.00	1.00 —	1.00 —	1.00 —
Larynx and proximal trachea	1.43			
Distal trachea and bronchi	0.77			
Medial lungs	1.06			
Basal lungs	0.69			

*The reference for the ratios is the average of 10 abdominal measurements (sections 21–24) from phantom data, and the total counts from the ANT abdominal static scan for clinical data.

†Significantly different than phantom, $p < 0.05$.

Significantly different than abdomen: ‡ = $p < 0.001$, ¶ = $p < 0.01$, § = $p < 0.05$.

**Significantly different than distal esophagus, $p < 0.001$.

TABLE 3
Comparison of Group Data (n = 23) for Repeat Clinical Testing. Total Counts From the Abdomen Were Used as the Reference for the Oral, Pharyngeal and Esophageal Ratios

Region	Swallow 1 mean (s.d.)	Swallow 2 mean (s.d.)	Correlation Pearson's r
Abdomen, total counts	561,272 (168,001)	545,299 (131,985)	0.74*
Oral, ratio	1.54 (0.51)	1.39† (0.47)	0.77*
Pharyngeal, ratio	1.66 (0.46)	1.65 (0.48)	0.82*
Esophageal, ratio	0.69 (0.22)	1.00‡ (0.49)	0.75*

*Significant correlation, $p < 0.001$.
†Significant difference between swallows, $p < 0.05$.
‡Significant difference between swallows, $p < 0.001$.

(Pearson r) for the test and retest distributions. The correlation coefficients were highly statistically significant.

For each subject, relative attenuation for an anatomical region (oral, pharyngeal, esophageal) was expressed as a ratio of time-normalized total counts from that region, based on dynamic data, divided by the ANT abdominal reference. Ratios for each subject were computed and statistics done on group data (Table 1). Regardless of anatomical region, there was no statistically significant difference in mean ratios for males and females permitting the data for males and females to be grouped together.

A direct comparison can be made between phantom measurements and clinical data for regions in the digestive system. Average clinical data ratios were very similar to phantom measurements (except for females) and all subjects as a group when the source was located in the distal esophagus (the phantom utilized was modeled on male anatomy). The difference between phantom and female clinical data for the distal esophageal region might be anticipated given that the average female thoracic skeleton is smaller (i.e., causing less attenuation) relative to her abdominal mass.

There was a strikingly consistent pattern (Table 1) shown by almost all subjects; esophageal region attenuation was greater than abdominal (42/45 subjects), abdominal attenuation was greater than oral (40/45 subjects) or pharyngeal (44/45 subjects). There was no statistically significant difference in mean ratios for the oral and pharyngeal regions.

It was informally noted that subjects who had pharyngeal and esophageal ratios more than 1 s.d. above the mean were of a stocky, large-boned build, although not necessarily obese. Conversely, those with pharyngeal and esophageal ratios more than 1 s.d. below the mean were slightly built, thin individuals.

Variability for repeat testing was also examined for oral, pharyngeal and esophageal ratios (Table 3). Except for the pharyngeal ratio, the results were not as favorable as for the abdominal reference. The mean ratios corresponded between test and retest only for the pharyngeal ratio, although there were highly significant correlations between test and retest values for all regions. This means that for oral and esophageal regions, high (or low) ratios on the first test will also be high (or low) on the second test, but the actual numerical values will not necessarily correspond that closely.

There are no direct comparisons available between phantom and clinical data for the subglottic respiratory system, which is most relevant to aspiration measurements. However, respiratory system ratios for human subjects can be estimated using an adjustment based on a comparison of within-phantom data for the digestive and respiratory systems. The pharynx ratio was used as a reference for within-phantom comparisons, because this would then be applied as an adjustment to pharynx ratios in clinical data, which were the most stable. For example (Table 1), in phantom data the ratio for the larynx is 1.43 and for the pharynx 1.53, so the adjustment would be 1.43/1.53 = 0.93. This adjustment would be applied to the pharyngeal region ratio from the clinical data by multiplying the clinical ratio by 0.93. The result yields a normalization coefficient, which might be used to correct percent aspiration measurements for the effects of tissue attenuation.

Table 4 lists some representative normalization coefficients for clinical data based on 45 subjects. Data from Table 1 were used for the clinical ratios, using mean values and values representing ±1 s.d. from the mean. Normalization coefficients could be computed for individuals also using the adjustments from within-phantom data.

DISCUSSION

With long scanning times, extremely small concentrations of radioactive aspirate can be detected. Theoretically, scintigraphy would seem to offer great accuracy in quantifying aspiration. However, in practice, the measurement precision is limited by multiple factors including the stochastic nature of radioactive emissions, the exact specification of the anatomical regions containing aspirate, replicability of data processing of the images and differential tissue attenuation.

Prior approaches to determining percent aspiration have assumed the tissue attenuation effects to be insignificant, or at least too complex to account for in a routine clinical environment. Attenuation effects in the human body are in fact highly complex, but the clinical problem is not intractable when approached as an empirical task using physical measurements rather than purely theoretical modeling. The empirical data are also useful for checking the validity of theoretical models.

The data presented provide a way to assess the expected amount of error in determining percent aspiration, when relative tissue attenuation effects are ignored. Let us use an

TABLE 4
Respiratory System Normalization Coefficients for Human Subjects Extrapolated from Clinical Data Using Adjustments Based on Within-Phantom Measurements*

Phantom ratio adjustment		Normalization coefficients			
			Coefficient		
Comparison	Adjustment	Region	−1 s.d.	mean	+1 s.d.
Larynx and proximal trachea re pharynx	0.93	Larynx, proximal trachea	0.99	1.47	1.95
Distal trachea and bronchi re pharynx	0.50	Distal trachea, bronchi	0.53	0.79	1.05
Medial lungs re pharynx	0.69	Lungs, medial	0.73	1.09	1.45
Basal lungs re pharynx	0.45	Lungs, basal	0.48	0.71	0.95

*The reference for within-phantom measurements is the pharynx region ratio.

example of a moderately large amount of aspiration. The range of percent aspiration we have encountered in clinical testing of head and neck cancer patients is from less than 1% to massive aspiration of 20% immediately after ingesting a 10-cc liquid bolus (*11*). Most frank aspiration is on the order of 5%–10%.

Assume that an aspirating patient was found to have a total of 8% aspiration (1% of the aspirate in the proximal trachea, 3% in the distal trachea and bronchi and 4% in the medial portion of the lungs). Dividing each percentage by the appropriate normalization coefficient for that region, and adding the quotients, will yield a corrected value of percent aspiration. Using normalization coefficients based on mean relative count ratios (Table 4), the total aspiration for this example would change from 8% to 8.2%. Using normalization coefficients for relative count ratios +1 s.d. from the mean would yield 6.1% aspiration, and count ratios −1 s.d. from the mean would yield 12.2% aspiration. It can be seen that when clinical ratios are high, this means that the uncorrected aspiration value would be spuriously high and the correction will lower it, and vice versa. For the above example, the tolerances could be estimated between −2% and +4% of the total radioactivity emitted by the body. The tolerances will depend strongly on the amount and location of aspiration.

Identifying separate anatomical regions of aspirate is meaningful for reasons other than numerical corrections. The location of aspirate is to some extent correlated with the amount; very small trace aspiration will be in the proximal trachea, and only larger aspiration will immediately reach the lungs after a single swallow. Also, the success in clearing aspirate probably depends in part on its location, with material in the trachea more easily removed by coughing than that located in the lungs proper. Evaluating the medical significance of aspiration may be enhanced by specifying the percent aspiration for different anatomical regions.

Limitation in Determining Normalization Coefficients

The normalization coefficients provided in Table 4 are based upon group data. It is possible to determine normalization coefficients for each individual patient, but with limitations.

Protocol Adherence. The dynamic data upon which normalization coefficients are based, in part, require adherence to a particular clinical testing protocol. A different procedure for ingesting the material (e.g., multiple swallows of a larger volume in a different patient orientation against the gamma camera) or a procedural error such as a premature swallow before computer data acquisition is initiated, would not yield the necessary individual data.

Variable Data. The clinical data on total counts for the pharynx and distal esophagus are taken from dynamic data, which are not highly accurate owing to the low number of radioactive counts and the rapidly changing physiological situation. There is not high test-retest reliability for individual computed ratios for the distal esophagus, although this is good for the pharyngeal region ratio.

Single-Swallow Data. Normalization coefficients were based on a single swallow. The accuracy of individual normalization coefficient determinations might be improved by averaging over multiple swallows, although in practice this may be difficult to achieve. Each swallow would require an additional dose of radionuclide, and the source of oropharyngeal residual after subsequent swallows would be hard to identify. Also, in a patient with major aspiration it is advisable to limit the amount of material ingested. A clinical test is sometimes terminated because of the amount of aspiration seen on the first swallow.

Method Variations

In preliminary investigations we tried some other procedures on a limited scale. A major challenge is to obtain good measurements in the rapidly changing dynamic situation during the swallow. It is not like a gastric emptying study where the physiological process happens slowly

enough that multiple static scans can be taken. We tried placing a radioactive bolus inside the tip of a nasogastic tube, to be passed to various locations in the pharynx, esophagus and stomach, and static scans taken. The procedure was very unpleasant for the subjects (some could not tolerate it at all), and it was felt that complicating a clinical testing procedure by harrowing calibration maneuvers was not warranted. We also tried having a few normal subjects swallow the radionuclide in a capsule, to provide a swallowed bolus that would more closely represent a point source. In most normal individuals, swallowing a capsule is not difficult, but dysphagic individuals (who are the ones likely to be assessed for aspiration) can have extreme difficulty swallowing anything solid. We decided to try to work with the type of data that could be readily obtained clinically.

Other Methods of Identifying Aspiration

Identification of aspiration can be accomplished by multiple means: bedside clinical evaluation (*13*), videofluoroscopic-modified barium swallow (*14*) and fiberoptic endoscopy (*15–17*), as well as scintigraphy. Each has its own advantages and disadvantages, including the range of types of patients which can be realistically tested, the degree of success in identifying aspiration, the ability to determine when during or after the swallow aspiration occurred. Only scintigraphy offers the ability to quantify the amount of aspirate (other than by gross visual estimation), and to repeat the assessment to determine clearing of aspirate without exposing the patient to additional radiation.

In many busy clinical nuclear medicine facilities, additional procedures and calculations to improve accuracy are not cost-effective, or medically indicated. It may be sufficient for clinical purposes to simply interpret the calculated values as accurate only to within certain tolerances. We have provided a basis for estimating those tolerances.

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EDITORIAL

Quantification of Aspiration: Methodological and Clinical Perspectives

The photon energies of the radionuclides most commonly used in nuclear medicine and the structure and composition of the human body are such that there is significant photon absorption and scatter of the emitted photons. This attenuation is not uniform, especially in the thorax, because of the low attenuation of the lungs relative to the other structures. For most routine clinical nuclear medicine procedures, no attempt is made to correct for attenuation. In many instances, a qualitative or semiquantitative impression suffices for clinical diagnosis. However, quantification may be a helpful supplement to the interpretation of data in the image. When seeking to quantify tracer biodistribution in a nuclear medicine procedure, consideration must be given to attenuation correction. Nevertheless, even when quantitative time-activity rela-

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