Dysphagia 4:4–7 (1989)

Dysphagia
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Pharyngeal Transit Time: Assessment with Videofluoroscopic and Scintigraphic Techniques

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Abstract. The swallowing function of 31 normal and dysphagic subjects between the ages of 39 and 79 was tested with both videofluoroscopy and scintigraphy. Pharyngeal transit times for the pair of tests were compared. A statistically significant correlation of 0.66 was found. Normal pharyngeal transit time was under 1.2 s with either method, but mean values for scintigraphy were slightly longer than those for videofluoroscopy.

Key words: Pharyngeal transit – Scintigraphy – Videofluoroscopy

Timed videofluoroscopy is currently considered the preferred single technique for assessing swallowing. The physical mechanism of swallowing function is revealed and it is possible to quantify both temporal and spatial aspects of the activity. However, quantitative measurements from videofluoroscopic data are time consuming, and may involve a significant component of human judgment. Therefore, it would be useful to find alternative or adjunctive techniques that can be more easily automated.

A scintigraphic assessment of swallowing [1–3] provides a history of the concentration of swallowed radionuclide material relative to anatomical landmarks. The detailed anatomical mechanism of swallowing is not investigated. The emphasis in a scintigraphic evaluation is the dynamic transfer of the bolus material, the quantification of amount of material passed or retained, and the time required for various phases of the swallow.

Although scintigraphy has been utilized for some time in nuclear medicine for the study of bolus transit in the esophagus [1, 4–6], its application to the oral and pharyngeal phases of swallowing is quite recent [2, 3]. A new application requires comparison to established techniques for evaluation and validation, even though the new technique may rest on strong scientific principles. We report here the pharyngeal transit time measurements using two techniques applied to the same population.

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Subjects and Methods

This comparative study used data from a total of 31 subjects. Nineteen were patients with head and neck cancer between the ages of 39 and 79 (mean, 59.1 years) who had enrolled in a research protocol on swallowing effects associated with various cancer treatment strategies. This group did not include postlaryngectomy patients. Their swallowing function ranged from abnormal to severely dysphagic. Twelve additional subjects were normal healthy controls from the same research protocol, ranging in age from 40 to 70 (mean, 51.6).

All subjects underwent both a videofluoroscopic and a scintigraphic test of swallowing function. Some of the cancer patients were tested repeatedly, before and after various stages of treatment. For each testing an attempt was made to schedule the videofluoroscopic and scintigraphic tests on the same day; however, in some instances the tests were scheduled on different days (6 tests less than 1 week apart, 2 tests between 1 and 2 weeks apart, and 4 tests between 2 weeks and 30 days apart). A total of 46 comparisons were available from the 31 subjects.

Attempts were made to test 4 additional patients, but their data were not usable for this comparison. The videofluoroscopic test began with a swallow of 3 ml of liquid barium. If the patient was dysphagic and showed severe aspiration, the test was discontinued. In this study comparisons were made only between videofluoroscopic and scintigraphic data using swallows of 10 ml of liquid. In the scintigraphy protocol there was a 6 s time constraint for data acquisition. Certain dysphagic subjects who had great difficulty in the oral formation of a bolus could not complete a swallow in that amount of time.

Scintigraphy

Two cobalt markers were placed on the patient at the right angle of the mandible and at the level of the cricoid cartilage with the larynx at rest. The placements were intended to aid in demarcating the entry and exit to the pharynx. The subject

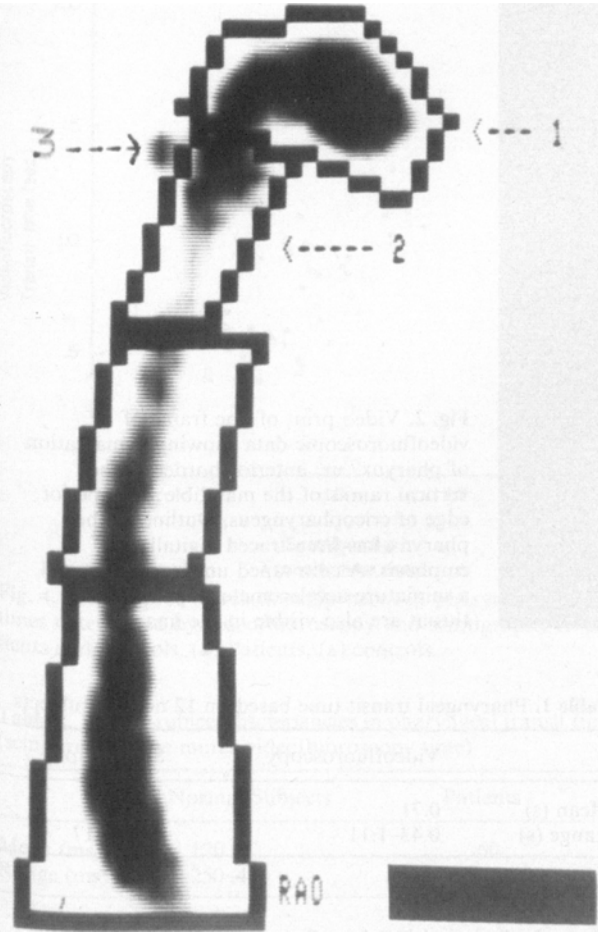

Fig. 1. Computer image generated for swallowing of radioactive tracer. Regions of interest are (1) oral cavity, (2) pharynx, and (3) marker at the angle of the mandible.

was then placed in an erect right anterior oblique position against the scintillation camera, which was interfaced to a computer. A low-energy, all-purpose collimator was used for these studies. A mixture of 0.5 ml of 2.5 mCi (92 MBq) [^{99m}Tc] sulfur colloid in 10 ml of thin barium was given to the subject to hold in the mouth and swallow on command. This concentration of sulfur colloid did not materially alter the viscosity of the barium. Simultaneously with the command to swallow, computer data acqusition was initiated and allowed to run for 6 s at 16 frames/s. Estimated total body radiation was 0.043 rads [1].

Once data acquisition was complete, the data were displayed and reviewed (Fig. 1). The pharyngeal region was identified by visual inspection and identification of natural boundaries in the scintigraphic display, which occurred in close proximity to the anatomical markers. The markers alone were used when no obvious natural boundary could be seen. A plot (time curve) was then generated by computer, representing the total radiation counts present in the pharyngeal region through time.

Videofluoroscopy

The subjects were tested in a standing position. The assessment began with a lateral view of a swallow of 3 ml of conventional liquid barium suspension (40% w/w), followed by a lateral view of the 10 ml swallow of barium. The estimated radiation exposure from the equipment used was 2.68 rads/min; most swallows can be recorded within 2 s.

Data were recorded on videotape at 30 frames/s. A digital timing signal accurate to centiseconds appeared on each frame. Pharyngeal transit times were calculated from this recorded timing information. Two frames were identified from frame-by-frame viewing of the videotape.

The first frame showed onset of pharyngeal entry, where the leading edge of the bolus had just reached the anterior border of the vertical ramus of the mandible, but had not passed beyond it (Fig. 2) and the bolus began its rapid descent into the pharynx. This criterion was modified for those subjects who held the bolus initially with a portion extending posterior to that location. In those patients the index of onset of pharyngeal entry was the first posterior movement of the leading edge of the bolus, as it began its rapid descent into the pharynx. This measurement criterion was based on similarity to scintigraphic pharyngeal demarcation, and ease of reliable judgment of bolus position and activity.

The second frame identified was the end of pharyngeal exit, where the trailing edge of the bolus had passed the superior border of the upper esophageal sphincter (Fig. 2). Identification of the frame representing pharyngeal exit at times presented a problem in patients with pharyngeal retention. In these cases an estimate was made based on perceived passage of the bulk of the bolus and completion of the swallow.

Results and Discussion

An example of a scintigraphic time curve for the pharynx is shown in Fig. 3. The curve builds from baseline to a peak as the bolus enters and accumulates in the pharynx, and then declines as the bolus begins to exit into the esophagus and further influx ends. Pharyngeal transit time can be determined directly from such a curve, if one measures from the frame just prior to the point of curve ascent to the time when the curve returns to baseline or residual value.

Normal Subjects

Table 1 provides values for pharyngeal transit time for the two measurement techniques, based only on the normal control subjects. For normal subjects the pharyngeal transit times were all under 1.2 s, but the mean time measured via videofluoroscopy was 120 ms longer than that measured via videofluoroscopy for the 10 ml bolus.

A study such as this, using only a dozen normal subjects with one swallow per volume of liquid in each test, can only give an indication of the range of normal values. A true normative study should systematically study different bolus volumes and consistencies. This is especially important for scintigraphy, which is only beginning to be used for assessing the pharyngeal phase of swallowing. Procedures for evaluating swallowing are

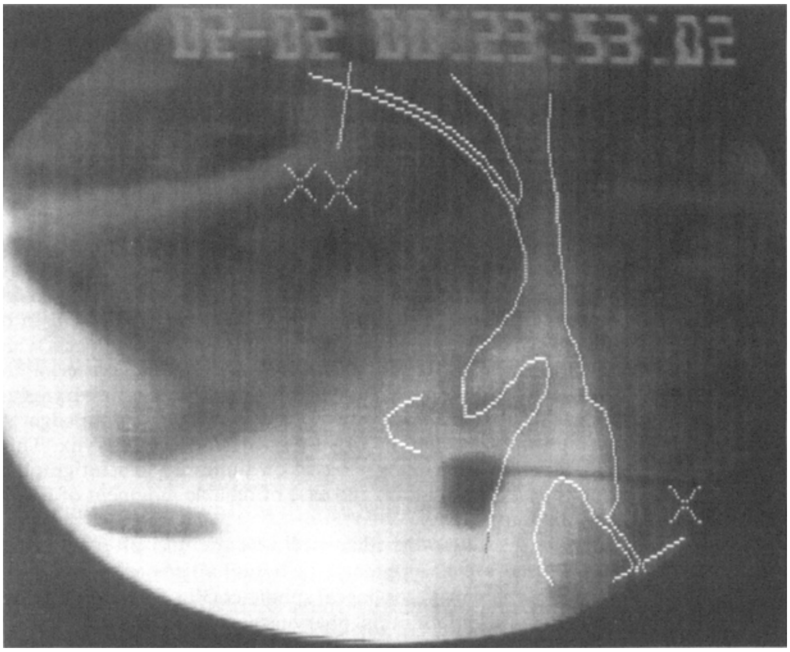

Fig. 2. Video print of one frame of videofluoroscopic data showing demarcation of pharynx. *xx*, anterior border of the vertical ramus of the mandible; *x*, superior edge of cricopharyngeus. Outline of the pharynx has been traced digitally for emphasis. A coin taped under the chin and a miniature accelerometer taped to the throat are also visible in the image.

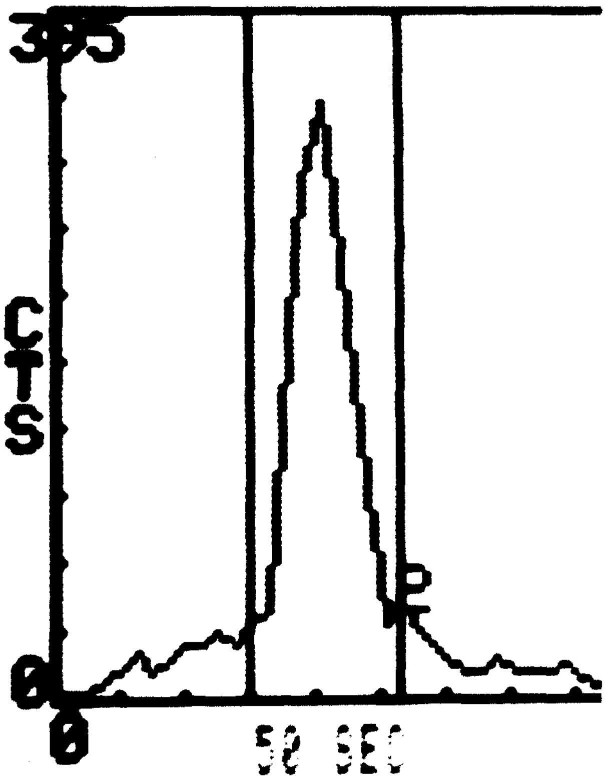

Fig. 3. Pharyngeal transit time (0.5 s) delineated by two vertical lines on the pharyngeal transit curve.

not standardized, and it has yet to be determined what combinations of bolus volumes, consistencies, and sequences would give the best indications of habitual swallowing function.

Table 1. Pharyngeal transit time based on 12 normal subjects

	Videofluoroscopy	Scintigraphy
Mean (s)	0.71	0.83
Range (s)	0.43–1.11	0.74–1.17

Correlation and Within-Subject Differences

A scatter plot of the data is shown in Fig. 4. It can be seen that correspondence exists for pharyngeal transit times measured by the two techniques. With computation based on normal subjects and patients combined the correlation coefficient (Pearson r) is 0.66, which indicates a statistically significant ($p<0.001$) but still only moderately strong relationship.

Further insight was sought into the nature of discrepancies between measures of pharyngeal transit time for the two methods. The time measured via videofluoroscopy was subtracted from that measured via scintigraphy for each data pair, thus, positive numbers indicate longer times for scintigraphy. Table 2 gives these values. Normal controls showed a within-subject mean difference of 120 ms, and patients a within-subject mean difference of 60 ms, which are both in the direction of longer values for scintigraphy. Wide ranges in discrepancy values were present for both normal subject and patient groups.

Recall that the frame rate for scintigraphy was 16/s whereas the frame rate for videofluoroscopy was 30/s. This difference in frame rate would effec-

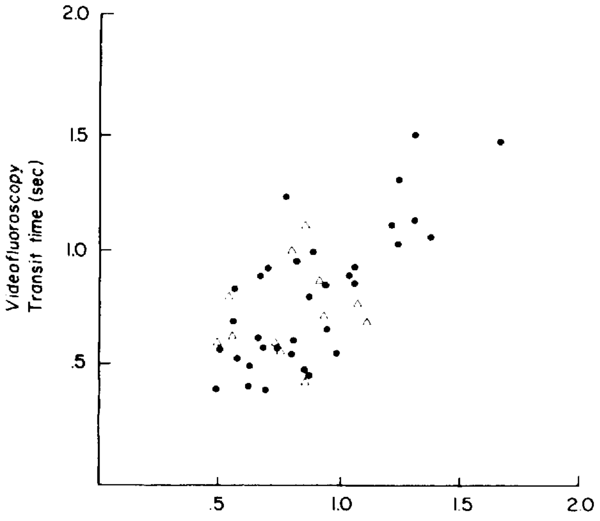

Fig. 4. Scatter plot of relationship between pharyngeal transit times determined by videofluoroscopy and scintigraphy in patients and controls. (●) Patients, (△) controls.

Table 2. Within-subject discrepancies in pharyngeal transit time (scintigraphy time minus videofluoroscopy time)

	Normal Subjects	Patients
Mean (ms)	120	60
Range (ms)	−250–430	−560–430

tively increase the error of temporal measurement by approximately 30 ms at either end of the pharyngeal transit. Thus scintigraphic measures of pharyngeal transit time could be 60 ms longer owing to that factor alone. Modifications are currently being undertaken at our scintigraphic facility to permit frame rates of 30/s.

A second factor predisposing to slightly longer mean transit times with scintigraphy is the method of determining the location of the pharyngeal exit. A marker was placed at the level of the cricoid with the larynx at rest, and was used when there was no natural boundary seen in the scintigraphic data. However, the larynx is raised during a swallow and the cricopharyngeus may have been slightly superior to that location at the end of pharyngeal bolus transit.

It should be kept in mind that videofluoroscopic and scintigraphic data were, of necessity, taken from different swallows, so that swallow-to-swallow variability enters into the potential correlation between pharyngeal transit times measured by the two techniques. Data on multiple swallows for the same volume were not available, but it was possible to compare the 3 ml and 10 ml barium swallows done with videofluoroscopy. The correlation coefficient (Pearson r) between 3 ml and 10 ml transit times was 0.59 ($p < 0.001$). This is comparable to the correlation coefficient between videofluoroscopic and scintigraphic 10 ml data sets, which suggests that differences between swallows may have been more important in the discrepancies than differences between techniques. If the two measures had been made on the same swallow, the correlation would likely have been considerably higher.

Conclusions

Both videofluoroscopy and scintigraphy yielded values of pharyngeal transit time in the same range (under 1.2 s for normal controls in an aging population swallowing 10 ml liquid boli).

Average pharyngeal transit times as measured by scintigraphy were slightly longer than for comparable swallows evaluated by videofluoroscopy. The slower frame rate for scintigraphy (16/s) and details of methods for determining boundaries of the pharynx contributed to this difference.

There was a statistically significant but only moderately strong correlation between pharyngeal transit time values measured with the two techniques in the same subjects. The fact that different swallows were tested, so that swallow-to-swallow variability enters into the comparison, appears to explain the lack of a stronger correlation.

Acknowledgement. This work was supported by Grant No. CA 43838 from the National Cancer Institute.

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