Radionuclide Gastric Emptying: Correlation Between the Anterior-Only and the Geometric Mean Method

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The purpose of our study was to compare the attenuation-corrected method and noncorrected method in calculating gastric emptying in patients with a clinical diagnosis of delayed emptying. Two different methods of calculating gastric emptying time were analyzed in 135 patients. Patients were given 100 ml of microwave-cooked egg whites labeled with 2.0 mCi of technetium-99m sulfur colloid and 300 ml of water. Anterior and posterior counts were obtained by a computer, interfaced to a gamma camera, with the patients in an upright position. The correlation coefficients for the 60- and 90-min data were 0.90 and 0.92, respectively. The results of the anterior-only method differed from the geometric mean method in 13% of the patients at 60 min and in 10% at 90 min. Assuming the diagnosis of delayed gastric emptying by the geometric mean method to be true, 3 of 135 patients (2.2%) at 60 min and 5 of 135 patients (3.7%) at 90 min could have been missed by the anterior method. Only 3 of 135 patients (2.2%) could have been missed by both 60- and 90-min anterior studies. The advantages of the anterior-only method may overcome the theoretical advantage of the geometric mean method in the usual clinical practice.

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Many disease states, as well as surgical procedures, can cause abnormalities in the gastric emptying rates in individuals (*1*). Currently, the method of choice for the estimation of gastric emptying is radionuclide scintigraphy. The method entails obtaining sequential counts over the stomach, usually in the anterior projection, after a radiolabeled meal is ingested.

Several investigators suggested that it is necessary to correct for attenuation due to differences in depth while measuring the gastric emptying rate (*2–6*). This is accomplished by calculating the geometric mean of the anterior and posterior counts obtained during the study.

The purpose of our study was to determine how much and how often the attenuation correction procedure affects the results of a gastric emptying study in a clinical setting. To that end, we compared the results obtained from anterior counts only with the results from the geometric mean method.

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MATERIALS AND METHODS

Data were obtained from 135 patients who were suspected of having delayed emptying and referred for radionuclide gastric emptying studies. Most patients fasted for eight hours prior to the study. They were given a meal consisting of 100 ml of microwave-cooked egg whites labeled with 2.0 mCi of technetium-99m (^{99m}Tc) sulfur colloid and 300 ml of water.

With the patient in an upright position, one-min anterior and one-min posterior images were acquired sequentially in a computer that was interfaced to a gamma camera, at 0, 10, 30, 60, and 90 min. Patients remained in an upright position between the images. Gastric retention was calculated by dividing the counts obtained in the stomach region-of-interest by the baseline counts. Baseline counts were obtained from the entire abdomen immediately following ingestion of the meal (Fig. 1).

Two methods were utilized for the calculation of gastric emptying: (1) the geometric mean method (the square root of the product of the anterior and posterior counts) and (2) the anterior-only method. Counts were corrected for physical decay. In our imaging system, there was no appreciable dead-time noted in point sources ranging from 0.25 mCi to 2.0 mCi of ^{99m}Tc.

We considered the 60- and 90-min data to be most significant clinically in diagnosing delayed gastric emptying, and only these data were analyzed.

RESULTS

The correlation coefficient between the two methods was 0.90 at 60 min (Fig. 2), and 0.92 at 90 min (Fig. 3). Normal ranges for gastric retention in our laboratory are 21%–45% at 60 min, and 8%–28% at 90 min (*2*). At 60 min, 101 patients (75%) had abnormal results using both the anterior-only and the geometric mean methods. Likewise, 16 patients (12%) had normal results by both methods (Table 1).

In 18 patients (13%), the two methods yielded conflicting results. In ten patients, the gastric emptying was abnormal (eight delayed, two rapid) only by the anterior projection method; whereas, in eight other patients, the gastric emptying was abnormal (three delayed, five rapid) only by the

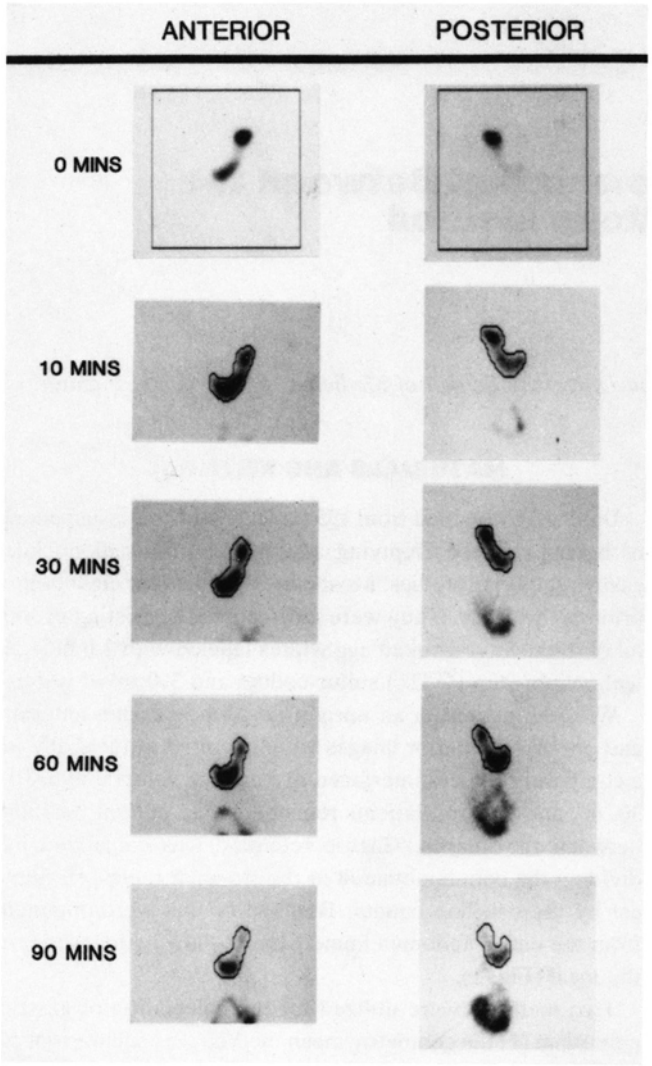

FIG. 1. In calculating meal retention, sequential one-min anterior and posterior images of the abdomen were acquired following ingestion of cooked egg whites labeled with ^{99m}Tc-sulfur colloid. At time zero, a rectangular region of interest (ROI) was used to include the entire abdomen. On subsequent images, variable ROIs were used to include the stomach activity only.

geometric mean method. The difference is not statistically significant.

At 90 min, 103 patients (76%) had abnormal results and 19 patients (14%) had normal results by both methods (Table 1). In 13 patients (10%), the two methods yielded conflicting results. Two patients had abnormal delayed gastric emptying on anterior measurements only. Eleven other patients (8%) had abnormal gastric emptying (five delayed, six rapid) only by the geometric mean method.

DISCUSSION

As ingested food moves through the stomach, it passes from the posteriorly located fundus into the antrum and pylorus which are relatively anterior. This could make the gastric emptying appear slower than it really is if the imaging

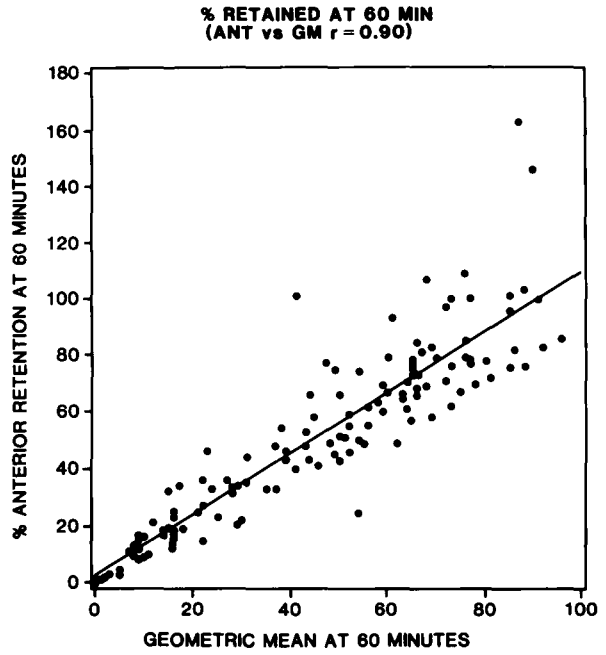

FIG. 2. Relationship between the gastric meal retention of ^{99m}Tc-labeled eggs at 60 min by the anterior-only method and the geometric mean method.

is performed in the anterior projection. This phenomenon has been discussed previously (*3–6*). However, only a small number of normal volunteer subjects were evaluated in these studies. Furthermore, the compositions and sizes of the meals were different.

Collins et al. (*5*), illustrated the effects of tissue attenuation in 24 normal subjects using the gastric emptying of ^{99m}Tc-labeled chicken liver. Their study of solid food retention

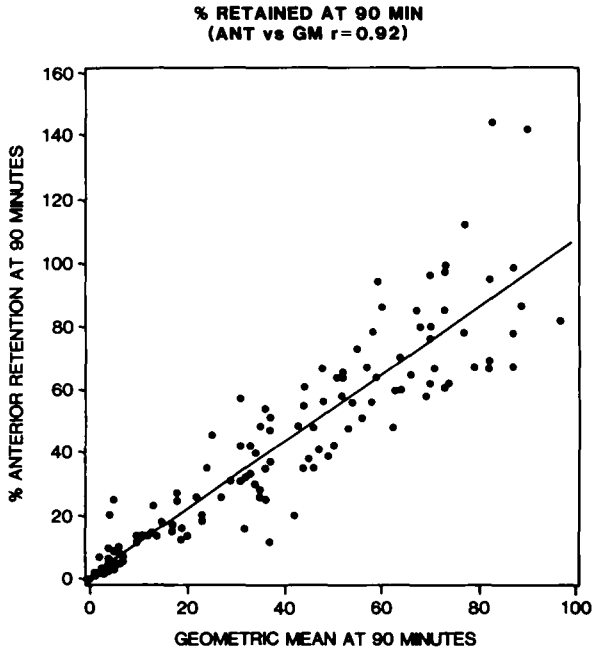

FIG. 3. Relationship between the gastric meal retention of ^{99m}Tc-labeled eggs at 90 min by the anterior-only method and the geometric mean method.

TABLE 1. Results of Gastric Emptying Study in 135 Patients

Gastric Emptying	60 Min	90 Min
Both ant. and GM abnormal	101	103
Both ant. and GM normal	16	19
Ant. abnormal, GM normal	10	2
Ant. normal, GM abnormal	8	11

Note: ant. = gastric emptying calculated from the anterior data only. GM = gastric emptying calculated from the geometric mean method.

showed a 20% variation in count rates as the food redistributed in the stomach. This was noted in the first 16 min. At 60 and 90 min, however, the count rates for the corrected and uncorrected data appeared to decrease at the same rate.

In the study by Christian et al. (*4*), the average solid-phase, half-emptying time in ten healthy male volunteers who were fed a 300-g meal was overestimated by 10.3% on anterior-only imaging.

Roland et al. (*7*) used two opposing cameras to study six normal volunteers fed with radiolabeled pancakes without additional water. Their results indicated a correlation coefficient of 0.78 for the gastric emptying rate obtained in the anterior projection compared to the geometric mean method (Table 2) (*7,15*).

In our study of 135 patients, the correlation coefficient was 0.92 and the anterior counts were not always greater than the attenuation-corrected counts. In fact, the latter was greater in 5 of 11 patients who had abnormal results by the geometric mean method at 90 min.

Christian et al. have demonstrated the importance of meal size in the estimation of the gastric emptying rate (*4*). Their data imply that relatively accurate estimates of the gastric emptying rate can be determined by anterior-only imaging for lighter meals (300 g), but not for larger meals (900 g).

In our study, we utilized a meal of approximately 400 g, including 300 ml of water. It has been shown that the labeling efficiency of ^{99m}Tc-sulfur colloid-labeled eggs is excellent and stable for the study period of 90 min. The initial binding was 96% and at 3 hr it was 82% ± 6% (*8*).

Meyers et al. compared the geometric mean method and the peak-to-scatter ratio method (*9*). Their results indicated that errors from septal penetration or scatter were more significant than errors from a change in the depth.

The total discrepant results in our study were less at 90 min (10%) than at 60 min (13%). Although Gelfand et al.'s

TABLE 2. Correlation of Gastric Emptying Rates Obtained from Anterior-Only Method and Geometric Mean Method

Study	No. of Subjects	Study Length	Correlation Coefficient
Roland (*7*)	6	90 min	0.78
Tothill (*15*)	70	120 min	0.89
Kelley	135	90 min	0.92

TABLE 3. Average Percent Stomach Retention Using Two Counting Methods

Method	60 Min	90 Min
Anterior-Only	52	40
Geometric Mean	46	37

study was in the pediatric population, they concluded that the 1-hr data were of less clinical importance than the 2-hr results (*10*).

Our clinical study from 135 patients agrees with the findings from the normal volunteer studies (*11–13*) that there are variations between the anterior-only and the geometric mean method. However, we agree with Rattner (*14*) that the variation is minimal and not significant in clinical applications using small size meals. In our study, only 3 of 135 patients (2.2%) at 60 min and 5 of 135 patients (3.7%) at 90 min could have been missed by the anterior method.

Among the three patients with delayed results by the geometric mean method at 60 min, two had delayed results by the 90-min anterior data. Among the five patients with delayed results by the geometric mean method at 90 min, three had delayed results by the 60-min anterior data. Thus, if the diagnosis of delayed emptying had been based on finding delayed results at either 60 or 90 min, 3 of 135 patients (2.2%) would have been missed completely by using anterior counts only.

In our study, six patients at 60 min, and three of the same six patients at 90 min, showed greater than 100% meal retention only by the anterior method. In four of them, it was less than 109% retention. In two patients, it was 146% and 163%. This unusual finding presumably resulted from anterior movement of the ingested food from the posteriorly located fundus into the anterior sections of the stomach during the course of the study, causing there to be a greater number of counts at 60 and 90 min than at time zero. These six patients also had markedly delayed emptying by the geometric mean method.

The average stomach activity calculated from the anterior projection was slightly more than that calculated by the geometric mean method (Table 3). At 60 min, the gastric retention was 52% by the anterior method and 46% by the geometric mean method. This suggests that the anterior method may slightly overestimate delayed gastric emptying. We feel it is acceptable since the gastric emptying study is generally used to rule out delayed emptying.

Although the geometric mean method has the advantage of being more precise, whether the precision has a significant clinical advantage over the anterior method is not known. There are several advantages to performing anterior acquisition only. There is less time involved in performing the study; the patient will have to stand in front of the gamma camera for only five min, compared to more than ten min when acquiring both anterior and posterior counts. This is an important factor when considering patient comfort. It reduces the technologist's time and efforts in repositioning the

patient for the anterior and posterior images. The anterior-only method also reduces the cost of film used and computer time as well.

CONCLUSION

The geometric mean method has a theoretical advantage over the anterior-only method in estimating the gastric emptying rate. For research purposes, where it is essential to measure precise rates of gastric emptying, attenuation correction using the geometric mean method should still be utilized. In the usual clinical setting, however, the anterior-only method, as used in our study, may suffice for the recognition of delayed gastric emptying and follow-up of such patients.

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