Comparison of Left Anterior Oblique, Anterior and Geometric Mean Methods for Determining Gastric Emptying Times

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The accurate determination of gastric emptying time requires correction or compensation for tissue attenuation. The gold standard for tissue attenuation correction for gastric emptying is the geometric mean of the gastric counts from the anterior and posterior views. For reasons of efficiency, many community hospitals acquire only the anterior projection. This study addressed the hypothesis that, using the left anterior oblique view alone, one can minimize the effect of variation in attenuation as the meal moves from the fundus to the stomach to the more anterior antrum to a degree equal to that of the geometric mean technique. We studied 42 consecutive patients using a standardized 300-g meal labeled with 650 μCi of ^{99m}Tc-sulfur colloid. The patients were imaged in the anterior (ANT), posterior (POST) and left anterior oblique (LAO) views every 15 min for 90 min. Linear regressions were obtained using the ANT, LAO and GM data. Cross-correlation of the $T_{1/2}$ for 35 cases showed an R value for the GM versus LAO of 0.95 and GM versus ANT of 0.84. The p value > 0.49, for the paired two-tailed t-test of the LAO and GM methods. The p value for the ANT and GM methods is 0.0058 indicating a significant difference between these methods. The cross-correlation, F-test p and t-test p values support the hypothesis that there is no significant difference between the geometric mean and left anterior oblique gastric emptying times. It is therefore reasonable to substitute the left anterior oblique for routine GET when using a solid meal in patients with normal gastric anatomy, albeit altered physiology.

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The accurate determination of the gastric emptying time (GET) necessitates correction or compensation of tissue attenuation (*1*, *2*). The gold standard for tissue attenuation correction for gastric emptying is the geometric mean (GM) method. Gastric counts are obtained in the anterior (ANT) and posterior (POST) views from which the square root of their product is calculated (*3*):

$$\sqrt{ANT_{CNTS} * POST_{CNTS}} \qquad \text{Eq. 1}$$

(Calculated for each observation).

Obtaining both the ANT and POST images, especially in an institution without a dual-headed camera, drawing the regions of interest (ROI) and calculating the GM is a long and tedious task. For these reasons, many departments are acquiring only a single ANT view, even though this approach overestimates the half-emptying time by an average of 15% (*4*). To overcome this dilemma, other investigators have reported that a single projection, either a depth-corrected anterior view (*5*), left lateral view (*4*) or the left anterior oblique (LAO) view (*6*) can compensate for tissue attenuation, thereby permitting an accurate and precise GET from a single view.

The aim of this study was to determine if there was a significant difference in the GET measurement by the GM, LAO or ANT projection methods. The LAO approach was chosen because it places the camera closer to a plane that is parallel to the stomach in contrast to the ANT view that places the camera at an angle to the stomach plane. Advantages of a single view, compared to the GM method, include less patient movement, continuous acquisition, easier processing. Multiple ROIs may be necessary because of patient movement and variation in the gastric contour.

METHOD

We studied 42 consecutive adult patients with normal gastric anatomy using our standard protocol with the addition of a LAO view. Our standard solid test meal consisted of 149 g of beef stew, 1 g of pork pate and 150 g of water mixed with 650 μCi of ^{99m}Tc-sulfur colloid, for a total of 300 g. The patients were imaged while standing using a Searle LFOV gamma camera with a LEAP collimator in the anterior and posterior views followed by a 45-degree LAO view. The imaging sequence was chosen so that the routine GM method, used as the gold standard, was not altered. Thus, the LAO projection was done last. Images were acquired for 120 sec on an ADAC 2800 computer every 15 min for 90 min. The image matrix was 64 × 64 by 16 bits deep.

Regions of interest were manually drawn around the stomach

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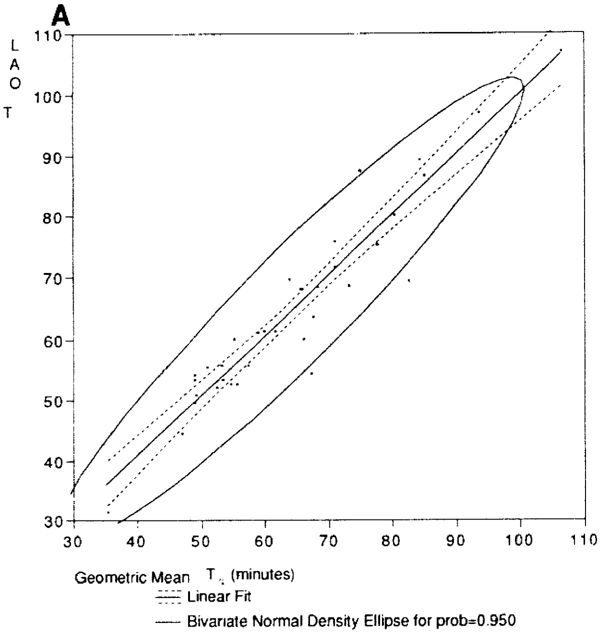
in each view and the counts recorded. Data were entered into the spreadsheet application WingZ® on a Macintosh II® computer. The counts were decay-corrected and a geometric mean was calculated in accordance with Equation 1. The statistical analysis programs StatView II® and JMP® were used to calculate a linear fit and analyze the data. If the F-test probability value for the regression exceeded 0.05, the case was excluded from further evaluation. Seven cases were considered inappropriate for use to measure the difference between imaging techniques.

The half-emptying times were calculated for the remaining 35 cases employing the GM, ANT, and LAO views using WingZ®. The half-emptying times for the ANT and LAO-projections were compared to the GM method. Regression coefficients and paired t-tests were then calculated.

RESULTS

Figure 1 shows the half-emptying times calculated from the LAO and ANT single-view method versus the GM method. The 95% confidences curve and density ellipses are included to provide a graphical exposition of the relationship of these methods. Figure 1 demonstrates the degree and form of clinical variation to be expected when employing these three methods. Furthermore, based on the assumption that the GM method represents the best estimate of the true GET parameter, it is not only graphically evident that the LAO method represents a better estimate of GET than the ANT method, but is supported by the regression analysis, which reports an R of 0.95 for LAO versus GM, and 0.84 for ANT versus GM. Figure 2 compares the distributions of these methods. The histograms and moments in Figure 2 show that the LAO and GM have a similar distribution, while the ANT data are skewed differently than the GM method data. The mean and standard deviation of the LAO method corresponds much better than that in the ANT method. A paired t-



Correlation

Correlation	Signif. Prob
.9492726	0.0000

Summary of Fit

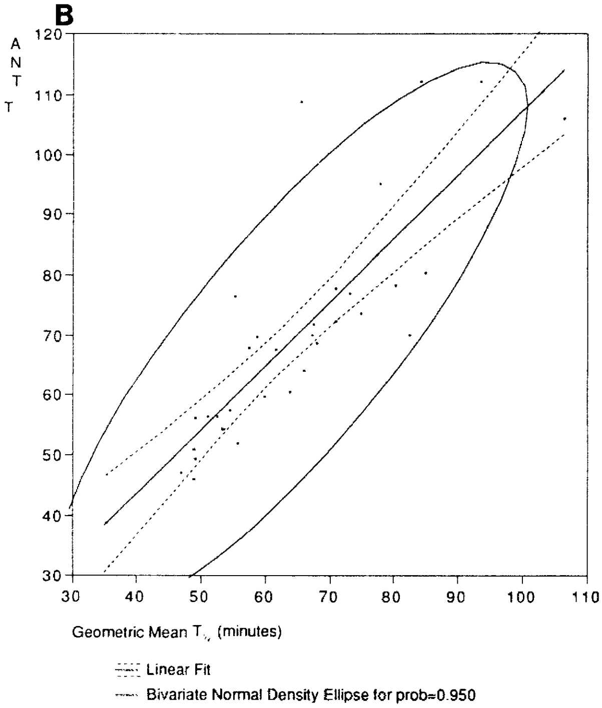
Rsquare	.9011185
Root Mean Square Error	4.997243
Mean of Response	64.57028
Observations (or Sum Wgts)	35

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	7510.0390	7510.04	300.7330
Error	33	824 0907	24.97	Prob > F
C Total	34	8334.1297		0.0000

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Y Intercept	1.2317030	3.74879	0.33	0.7446
Slope	.98977140	.057074	17.34	0.0000



Correlation

Correlation	Signif. Prob
8404668	0.0000

Summary of Fit

Rsquare	.7063845
Root Mean Square Error	10.43037
Mean of Response	69.13342
Observations (or Sum Wgts)	35

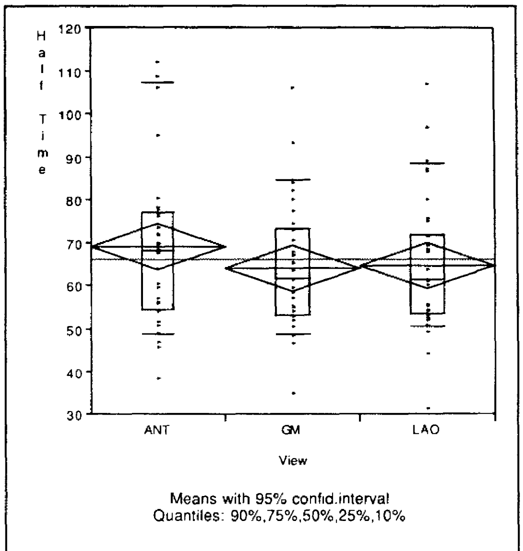
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	8637.262	8637.26	79.3919
Error	33	3590.161	108.79	Prob > F
C Total	34	12227.423		0.0000

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Y Intercept	1.2075440	7.82458	0.15	0.8783
Slope	1.0614556	.119128	8.91	0.0000

FIGURE 1. (A-B) Linear fits with their 95% confidence interval of the fit and the bivariate normal density ellipses for a probability of 0.95 for the LAO versus geometric mean and ANT versus geometric mean, respectively. The density ellipse defined the area where 95% of all values lie. The statistical summary follows each. The R^2 values and 95% density ellipses show a better fit by the LAO method than the ANT.



	ANT	Geometric Mean	LAO
Mean	69 13	63 99	64 57
Std Dev	18.96	15 02	15.66
Std Err Mean	3 21	2 54	2.65
upper 95% Mean	75 65	69 15	69.95
lower 95% Mean	62 62	58.84	59 19
N	35	35	35
Sum Wgts	35	35	35

FIGURE 2. Half-times plotted by camera position for the geometric mean, LAO and ANT methods. The mean and standard deviation for the geometric mean and LAO have a high correspondence. The ANT method has a higher mean and larger variance.

test, comparing the LAO and ANT half-times to those from the GM method (Figure 3) shows no significant difference between the half-times calculated using the GM and the LAO view, $p > 0.05$. However, the half-times calculated from the anterior view are significantly different from that of the GM method, $p < 0.05$.

DISCUSSION

The GM method is the accepted gold standard for correcting for tissue attenuation when calculating gastric emptying times. Obtaining both the anterior and posterior images involves repositioning the patient for sequential images unless a dual-headed camera is used. Image processing is tedious because separate ROIs must be drawn for each image. A single view method, on the other hand, simplifies data collection and processing and permits continuous acquisition thus allowing for evaluation of the lag phase (*4*). Many experts believe that evaluating the lag phase is important. Images obtained every 15 min, in our opinion, are inadequate for proper evaluation of the lag phase because the sampling rate is too low.

Previously, other investigators have used a single projection, either a depth-corrected anterior (*5*) or posterior (*4*) view using the left lateral view or the LAO view (*6*) to compensate for tissue attenuation. Fahey et al. (*6*) used a peak-to-scatter ratio (P/S) correction with and without small intestine activity (SI) and the LAO method to correct for tissue attenuation. In 21 solid gastric emptying studies, the percent gastric emptying at 60 min for the ANT, P/S, P/S + SI and the LAO method were compared to the GM. The R value for the ANT and LAO compared to the GM for solid gastric emptying were 0.957 and 0.956, respectively. The P/S and P/S + SI R values were 0.948 and 0.889. For the LAO and P/S + SI methods, the paired t-test p values were greater than 0.9, indicating that no statistical difference could be shown. The p value for the ANT and P/S methods were not reported, however, they were rejected because the mean difference from the GM mean underestimated the percent emptying by 7% and therefore did not compensate for attenuation.

Roland et al. (*5*) used a depth-correction method for the anterior view on a study population consisting of six

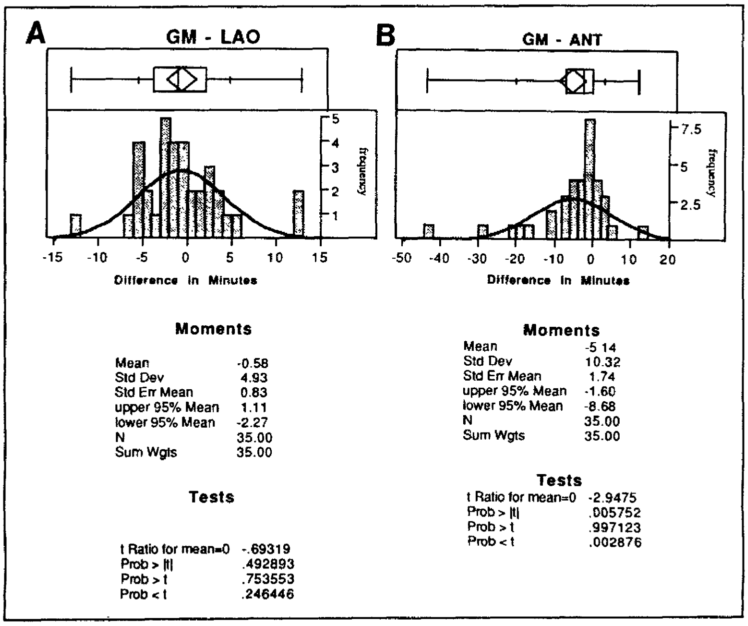


FIGURE 3. A paired two-tailed t-test was performed by subtracting the LAO and ANT half-lives from the geometric mean half-life. The histogram plots of the difference, moments and t-Test results are shown. A p value less than 0.05 is used as the criteria to reject the difference as being due to chance. Because the LAO method has a p value much greater than 0.05 ($p > 0.49$) no statistical difference can be shown between the LAO and geometric mean methods. The p value for the ANT method is 0.0058, meeting the criteria to reject the variation from the geometric mean method as being due to chance.

young adult males. This involved continuous acquisition for 90 min after the subjects ingested a solid meal of a pancake labeled with 10 MBq (270 μCi) of ^{99m}Tc-sulfur colloid. At the termination of the study, and additional 10 MBq (270 μCi) of ^{99m}Tc-sulfur colloid in 150 ml of water were given. A 1-min left lateral view was then acquired for depth correction of the proximal and distal halves of the stomach. Their results showed an uncorrected R value for the residual activity at 60 min of 0.87 and a corrected value of 0.96. No other statistical evaluations were performed.

Collins et al. (*4*) used a depth-corrected posterior view to correct for tissue attenuation in a study population consisting of five adults, four males and one female. The subjects ate a solid meal consisting of 30 MBq (810 μCi) on "in vivo" ^{99m}Tc-labeled chicken liver mixed with 100 g of ground beef and then drank 150 ml of water. Data were collected for 2 hr, at which point the subjects ingested an additional 3.7 MBq (100 μCi) of ^{99m}Tc pertechnetate mixed with 150 ml of water just prior to the acquisition of the left lateral view. As with Roland et al. (*5*), a left lateral view was done at the end of the study for depth measurement correction. Expressing the results as a percentage of the GM value, the depth-corrected percent emptying value corresponded better to the GM method than the uncorrected posterior view alone.

In our study, we showed no statistical difference between the half-times determined by the GM method and the LAO view (paired two-tailed t-test p value of 0.49). The anterior view overestimated the half-time by 8% and has a greater variance; indicating it is less accurate and precise. The t-test p value of the ANT versus the GM method was less than 0.05, $p < 0.0058$, indicating a significant statistical difference between these methods (Fig. 3). These results support those reported by Fahley et al. (*6*). We therefore conclude that since the LAO method closely approximates the GM method it can therefore be used for routine GET when using a solid meal in a patient with normal gastric anatomy, albeit altered physiology.

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