Original Article

Assessment of Small-bowel and Colonic Transit on Routine Gastric Emptying Scintigraphy: Establishment of Reference Values

Abstract

Purpose of the Study: The primary objective was to establish the reference values for small-bowel and colonic transit within the context of the routine standard solid meal gastric emptying scintigraphy (GES). The secondary objective was to compare the small-bowel and colonic transit between the anterior view and geometric mean methods. **Materials and Methods:** Twenty-nine healthy controls underwent routine GES, with additional imaging at 24 h if feasible. Small-bowel transit was assessed using the index of small-bowel transit (ISBT), calculated as the ratio of terminal ileal reservoir counts to total abdominal counts at 4 h. Colonic transit was evaluated using the colonic geometric center (CGC) by dividing the large bowel into four segments, with an additional fifth segment accounting for the eliminated counts. Reference values were established based on the fifth percentile or mean ± 1.96 standard deviations. Rapid small-bowel transit was visually determined. Paired Samples *t*-test or Wilcoxon signed-rank test, as applicable, was used to compare the small-bowel and colonic transit between the anterior view and geometric mean methods. For comparing small-bowel and colonic transit between females and males, the Independent samples *t*-test or Mann–Whitney *U*-test was applied, as appropriate. The correlation between age and small-bowel and colonic transit was assessed using Spearman's rank correlation analysis. **Results:** The reference value for small-bowel transit using the geometric mean method was established as ISBT >37% at 4 h, whereas rapid small-bowel transit was defined as the first visualization of activity in the cecum-ascending colon within 2 h. For colonic transit, the reference range was established as CGC 2.8–4.4 at 24 h. Comparing the anterior view and geometric mean methods, there were no significant differences in ISBT and CGC values ($P \geq 0.125$). Gender did not affect small-bowel and colonic transit in both methods ($P \geq 0.378$), and age showed no significant correlations ($P \geq 0.053$). **Conclusion:** This study determined the reference values for small-bowel and colonic transit in the Indian population using routine GES, avoiding the need for additional complex procedures. The results may be generalized to the Indian population, emphasizing the importance of assessing small-bowel and colonic transit in patients with normal gastric emptying parameters to enhance gastrointestinal transit evaluation.

Keywords: *Colonic geometric center, colonic transit, gastric emptying scintigraphy, index of small-bowel transit, normal range, reference values, small-bowel transit, whole-gut transit*

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Introduction

Functional and motility disorders affecting the upper and lower gastrointestinal tract can manifest with a wide range of symptoms, including abdominal pain, nausea, vomiting, bloating, early satiety, fullness, diarrhea, and constipation. Distinguishing between upper and lower gastrointestinal tract disorders based on symptoms alone can be challenging, as there is significant symptom overlap.[1] To aid in the evaluation of these patients, the American and European Neurogastroenterology and Motility Societies recommend specific scintigraphic techniques. Gastric emptying scintigraphy (GES) is recommended for assessing gastroparesis and dumping syndrome, whereas small-bowel transit scintigraphy is useful for evaluating diffuse gastrointestinal motility disorders. Colonic transit scintigraphy is suggested for investigating constipation or diarrhea. However, these recommendations acknowledge the lack of standardized methodologies, significant variability in normative data, and limited availability of these procedures across different centers.[2]

The consensus practice guideline by the Society of Nuclear Medicine and Molecular Imaging and the European Association of Nuclear Medicine recommends a

How to cite this article: Kumar S, Chanu AR, Jaleel J, Gupta P, Khangembam BC, Patel C, *et al.* Assessment of small-bowel and colonic transit on routine gastric emptying scintigraphy: Establishment of reference values. Indian J Nucl Med 2024;39:29-36.

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Received: 06-06-2023
Revised: 20-12-2023
Accepted: 21-12-2023
Published: 27-03-2024

Access this article online
Website: www.ijnm.in
DOI: 10.4103/ijnm.ijnm_64_23
Quick Response Code:

standard dual-tracer solid–liquid meal for whole-gut transit scintigraphy, typically using Tc-99m sulfur colloid for the solid component and In-111 diethylene triamine pentaacetic acid (DTPA) water for the liquid component. An alternative suggested in the guideline is delayed-release capsules containing In-111 DTPA charcoal particles.[1] Previous studies have predominantly assessed small-bowel and colonic transit using dual solid–liquid or liquid meals.[3] However, the influence of the solid meal on the derived values of small-bowel and colonic transit for liquid meals remains unknown. In addition, the availability of In-111 is limited, and its use results in a higher radiation burden to patients compared to Tc-99m.

GES utilizing solid meals is a commonly employed procedure to evaluate patients with suspected gastroparesis and dumping syndrome. However, it is worth noting that a considerable number of these patients do not exhibit abnormal gastric emptying.[4,5] In such cases, it may be beneficial to conduct additional assessments of small-bowel and colonic transit during the same procedure. This comprehensive evaluation can offer valuable insights for diagnosis and management, leading to better patient outcomes. However, it is important to acknowledge that normative data for small-bowel and colonic transit are limited and vary depending on the methodology employed, with the majority of studies utilizing solid–liquid or liquid meals.

We have established the reference values for gastric emptying parameters using a readily available, standard vegetarian Indian solid meal labeled with Tc-99m sulfur colloid.[6] Building on this, the current study focused on evaluating the small-bowel and colonic transit as a minor extension of the routine GES procedure. The primary objective was to establish the reference values for small-bowel and colonic transit within the context of the routine standard solid meal GES. The secondary objective was to compare the small-bowel and colonic transit between the anterior view and geometric mean methods.

Materials and Methods

This prospective, noninterventional cross-sectional study was conducted over a period of 1 year, starting from December 2021, following the approval of the institute ethics committee (IECPG-730/25.11.2021, RT-28/23.12.2021). The study enrolled healthy controls aged 18 years and above who provided signed written informed consent. Participants with diabetes or any other conditions known to affect gastrointestinal motility, such as gastrointestinal illness or surgery, as well as neurological illnesses, were excluded from the study. Additional exclusion criteria included pregnant or lactating women, individuals taking medications (opiate analgesics, anticholinergic drugs, and prokinetic agents) that could impact gastrointestinal motility, premenopausal women >10 days of their menstrual cycle, those who refused to provide informed written consent, individuals who did not comply with the scintigraphy protocol, and participants with allergies to the meal used in the study. For the solid meal GES procedure, a standard vegetarian Indian meal containing 0.5–1 mCi of Tc-99m sulfur colloid was administered as previously described.[6]

Image acquisition

All participants underwent a minimum 6-h fasting period before the procedure. After consuming the meal, subjects were instructed to lie in a supine position on the scanner table of a dual-head GE Discovery NM/CT 670 single-photon emission computed tomography/computed tomography (SPECT/CT) system equipped with parallel-hole, low-energy high-resolution collimators. Static images of the abdominal region were acquired for 1 min each at various time points: immediately after meal ingestion ($t = 0$), as well as at 1, 2, and 4 h thereafter. The photopeak was set at 140 keV with a 20% energy window, using a zoom factor of 1 and a matrix size of 128 × 128. Subjects refrained from eating or drinking during the imaging period until the 4 h scan was completed. In addition, when feasible, another set of static images was obtained at 24 h, with a duration of 4 min. The acquisition was performed using both the anterior and posterior detectors simultaneously at each time point. Care was taken to cover the entire radioactivity distribution in the abdomen within the field of view of the gamma camera detectors.

Image analysis

The acquired images were processed and analyzed using a dedicated Xeleris 4 DR workstation with a vendor-specified whole-gut transit analysis protocol. Visual inspection of the images was conducted at each time point to ensure adequate image quality and assess the temporal movement of activity within the gastrointestinal tract. Regions of interest (ROIs) were carefully drawn to encompass the gastric activity in both the anterior and posterior images for each time point. The counts obtained from these ROIs were utilized to calculate the percent gastric retentions at 1, 2, and 4 h, as well as the half-time (T1/2) of gastric emptying after decay correction with the total gastric counts normalized to 100% at time $t = 0$ (the first image acquired immediately after meal ingestion). Only studies with normal gastric emptying parameters were included for the analysis of small-bowel and colonic transit.

For the small-bowel transit analysis, a large rectangular ROI was drawn to encompass the entire abdomen in the anterior and posterior images at each time point [Figure 1a]. The decay-corrected total abdominal counts at the 4 h image (TAC4 h) served as the input value for filling the small and large bowels. Any residual gastric activity in the 4-h image was assessed if visually evident, and its counts were subtracted from the total abdominal counts to obtain the corrected input value for filling the small bowel. An ROI was drawn meticulously

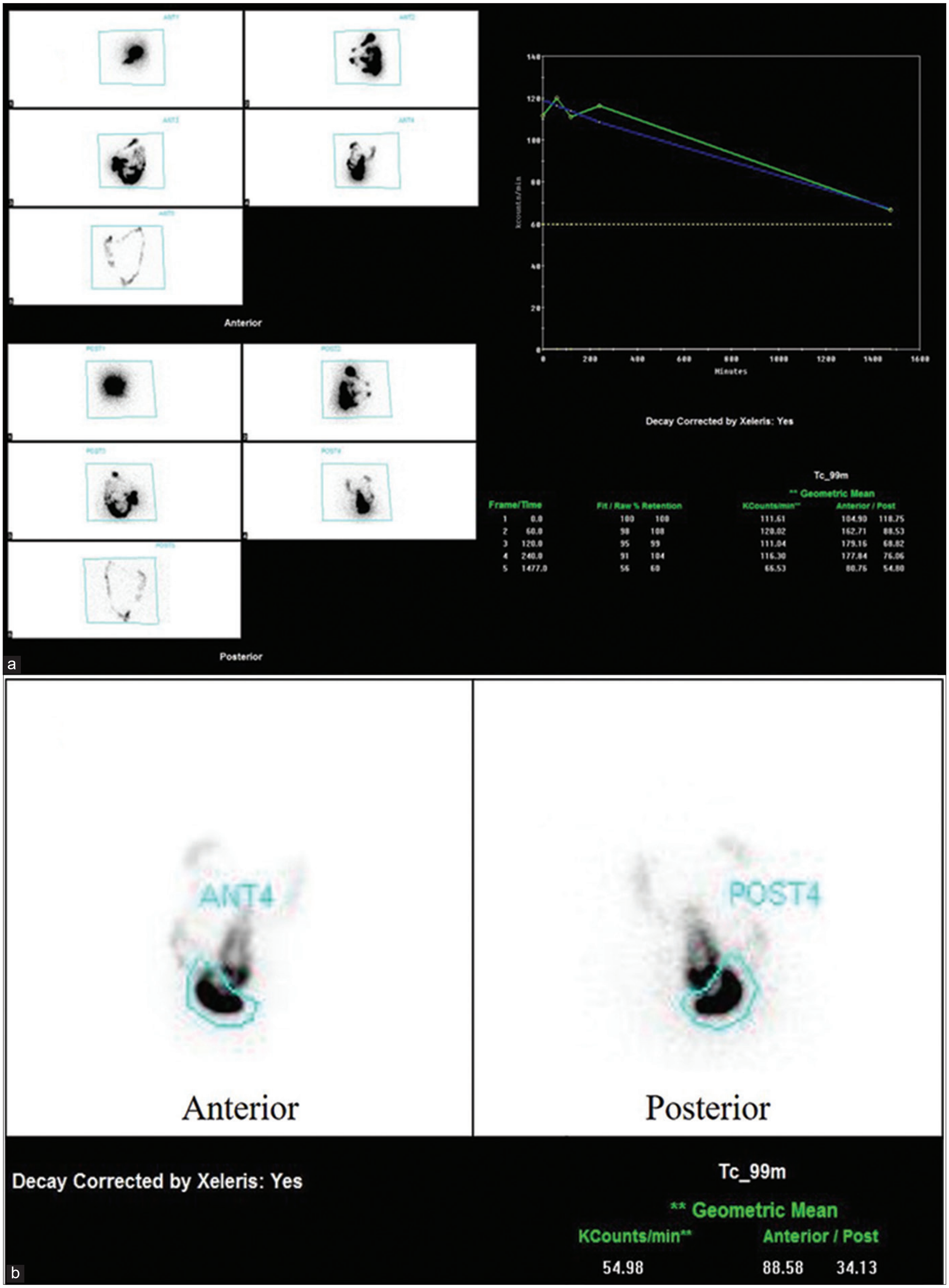

Figure 1: Assessment of small-bowel transit using geometric mean method in a 50-year-old healthy male subject. (a) A large rectangular regions of interest (ROI) was drawn in each view on each time point of imaging (0, 1, 2, 4, and 24 h) encompassing the whole radioactivity in the abdomen region. The decay-corrected total abdominal counts (kcounts/min) at 4 h was 116.30 which was used as the input activity available to fill the small bowel. (b) A ROI was meticulously drawn in the terminal ileal reservoir region in the anterior (left) and posterior (right) views at 4 h to generate the decay corrected terminal ileal reservoir counts (kcounts/min) which were found to be 54.98. The index of small-bowel transit was derived to be 47%

to encompass the terminal ileal reservoir region (and beyond, such as the cecum-ascending colon if radioactivity had passed through the terminal ileum and ileocecal junction) in the anterior and posterior images of the 4 h image [Figure 1b]. The resulting decay-corrected counts in the terminal ileal reservoir, referred to as the terminal ileal reservoir counts (TIRCs), represented the activity arrived at the terminal ileum at 4 h. The value TIRC/TAC4 h × 100 represented the percent arrival of the total abdominal counts at the terminal ileum at 4 h and was used as the index of small-bowel transit (ISBT).

Furthermore, for the analysis of colonic transit at 24 h, a large rectangular ROI encompassing the entire abdomen was drawn on the corresponding images. The decay-corrected total abdominal counts at 24 h (TAC24 h) were automatically adjusted for the duration of the static image acquisition (4 min) by dividing the value by 4. ROIs were then meticulously drawn on the 24 h image to divide the large bowel into four segments: cecum-ascending colon, transverse colon, descending colon, and rectosigmoid-anal canal [Figure 2]. Perminute imaging counts were automatically generated from these ROIs and assigned weighting values: cecum-ascending colon (1), transverse colon (2), descending colon (3), and rectosigmoid-anal canal (4). The counts eliminated through feces were assigned a weighting value of 5. This eliminated count

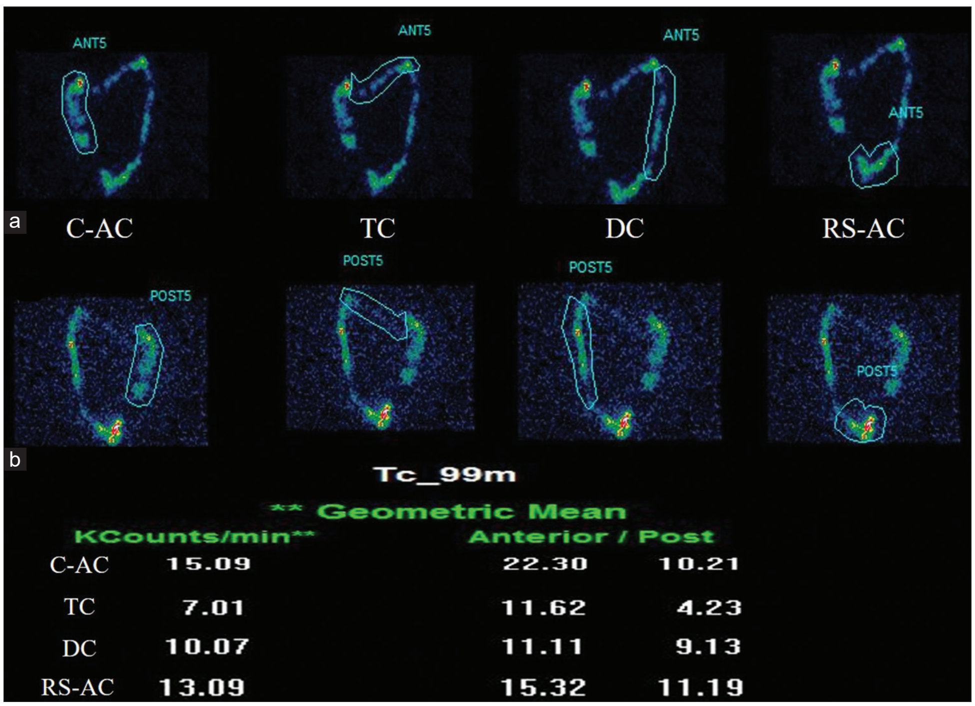

Figure 2: Assessment of colonic transit using geometric mean method in a 50-year-old healthy control. Regions of interest (ROIs) were meticulously drawn encompassing the regions of cecum-ascending colon, transverse colon, descending colon, and rectosigmoid-anal canal in the anterior (a) and posterior (b) Images at 24 h. The eliminated counts (kcounts/min) at 24 h in this patient obtained by subtracting the total abdominal counts at 24 h from that of 4 h (as shown in Figure 1) was 49.77. Using these count values, the colonic geometric center was calculated to be 3.1. C-AC: Cecum-ascending colon, TC: Transverse colon, DC: Descending colon, RS-AC: Rectosigmoid-anal canal

Table 1: Summary statistics of small-bowel and colonic transit

Parameter	Mean±SD	Median (range)	Skewness	Kurtosis	Probability of normality	2.5th percentile	5th percentile	95th percentile	97.5th percentile
Small-bowel transit									
ISBT (%)									
Anterior view method	66±15	67 (30–89)	−0.3829	−0.4734	0.4456	32	39	87	89
Geometric mean method	64±16	66 (28–84)	−0.4847	−0.6135	0.1329	30	37	83	84
Colonic transit									
CGC									
Anterior view method	3.8±0.6	3.8 (2.4–4.5)	−1.0360	1.5846	0.2497	-	2.4	4.5	-
Geometric mean method	3.6±0.4	3.5 (3.0–4.3)	0.4399	−0.9705	0.4730	-	3.0	4.3	-

Based on the 5th percentile value of ISBT in the geometric mean method, the proposed reference value of small-bowel transit at 4 h is >37%, based on mean±1.96 SD of CGC in the geometric mean method, the proposed reference range of colonic transit at 24 h is 2.8–4.4. SD: Standard deviation, ISBT: Index of small-bowel transit, CGC: Colonic geometric center

Table 2: Comparison of raw counts and small-bowel and colonic transit between anterior view and geometric mean methods

Data	Anterior view method		Geometric mean method		*P*
	Mean±SD	Median (range)	Mean±SD	Median (range)	
TAC4h (KCounts/min)	187.4±88.8	177.8 (57.1–429.3)	121.5±57.3	114.5 (45.7–294.2)	<0.001#
TIRC (KCounts/min)	125.3±72.9	116.6 (28.0–367.6)	79.2±47.3	78.5 (24.7–240.7)	<0.001#
TAC24h (KCounts/min)	71.2±26.9	65.2 (27.6–118.9)	62.9±20.9	60.0 (26.3–99.2)	0.004*
C-AC (KCounts/min)	14.1±9.0	10.2 (2.2–25.9)	11.4±7.0	8.5 (2.0–20.9)	0.010*
TC (KCounts/min)	19.0±19.4	8.8 (2.4–55.1)	12.7±11.3	7.1 (2.6–32.7)	0.020#
DC (KCounts/min)	8.9±9.0	5.1 (1.3–30.0)	7.8±7.3	4.6 (1.3–23.1)	0.098#
RS-AC (KCounts/min)	11.0±5.7	11.6 (2.0–21.5)	11.5±4.9	12.6 (2.0–18.0)	0.611*
EC (KCounts/min)	151.0±97.6	117.7 (17.2–359.8)	88.3±54.6	74.9 (42.2–232.8)	0.020#
ISBT (%)	66±15	67 (30–89)	64±16	66 (28–84)	0.125*
CGC	3.8±0.6	3.8 (2.4–4.5)	3.6±0.4	3.5 (3.0–4.3)	0.160*

**P* value based on paired samples *t*-test, #*P* value based on Wilcoxon signed-rank test. TAC4h: Total abdominal counts at 4 h, TIRC: Terminal ileal reservoir counts at 4 h, TAC24h: Total abdominal counts at 24 h, C-AC: Counts of cecum-ascending colon at 24 h, TC: Counts of transverse colon at 24 h, DC: Counts of descending colon at 24 h, RS-AC: Counts of rectosigmoid-anal canal at 24 h, EC: Eliminated counts at 24 h, ISBT, Index of small-bowel transit, CGC: Colonic geometric center, SD: Standard deviation

Table 3: Comparison of raw counts and small-bowel and colonic transit between females and males

Data	Females		Males		*P*
	Mean±SD	Median (range)	Mean±SD	Median (range)	
Anterior view method					
TAC4h (KCounts/min)	180.4±99.0	157.4 (57.1–429.3)	200.6±68.2	211.2 (100.3–324.7)	0.570*
TIRC4h (KCounts/min)	120.5±79.7	105.1 (28.0–367.6)	134.6±60.9	161.8 (51.3–215.5)	0.353#
TAC24h (KCounts/min)	77.6±26.2	69.5 (43.9–118.9)	56.2±26.9	60.4 (27.6–80.8)	0.274*
C-AC (KCounts/min)	14.5±9.9	9.4 (2.2–25.9)	13.0±8.5	11.1 (5.8–22.3)	0.829*
TC (KCounts/min)	24.4±21.1	23.8 (4.5–55.1)	6.6±4.7	5.6 (2.4–11.6)	0.198*
DC (KCounts/min)	9.1±10.6	4.6 (1.3–30.0)	8.5±5.4	11.1 (2.4–12.1)	0.833#
RS-AC (KCounts/min)	11.2±5.5	10.7 (3.9–21.5)	10.5±7.4	14.1 (2.0–15.3)	0.868*
EC (KCounts/min)	151.2±116.5	100.7 (17.2–359.8)	150.4±46.4	172.4 (97.1–181.6)	0.991*
ISBT (%)	66±16	67 (30–89)	65±15	67 (39–84)	0.854*
CGC	3.7±0.7	3.6 (2.4–4.5)	4.1±0.5	4.2 (3.5–4.5)	0.378*
Geometric mean method					
TAC 4 h	118.7±61.8	110.9 (45.7–294.2)	127.0±50.1	120.3 (54.0–197.3)	0.717*
TIRC 4 h	78.3±50.8	75.2 (25.1–240.7)	80.9±42.4	89.2 (24.7–144.0)	0.636#
TAC24h (KCounts/min)	69.0±19.3	61.5 (43.7–99.2)	48.7±20.5	53.4 (26.3–66.5)	0.172*
C-AC (KCounts/min)	12.2±7.9	7.6 (2.0–20.9)	9.7±5.2	9.5 (4.6–15.1)	0.642*
TC (KCounts/min)	16.3±11.9	15.9 (3.3–32.7)	4.4±2.3	3.6 (2.6–7.0)	0.136*
DC (KCounts/min)	8.0±8.5	4.0 (1.3–23.1)	7.3±4.3	9.6 (2.4–10.1)	0.833#
RS-AC (KCounts/min)	12.6±4.3	14.3 (5.4–18.0)	9.1±6.1	12.2 (2.0–13.1)	0.327*
EC (KCounts/min)	92.1±64.6	64.6 (42.2–232.8)	79.6±27.4	85.2 (49.8–103.7)	1.000#
ISBT (%)	65±16	68 (28–84)	61±15	62 (37–82)	0.494*
CGC	3.5±0.4	3.4 (3.0–4.3)	3.7±0.5	3.9 (3.1–4.0)	0.561*

**P* value based on independent samples *t*-test, #*P* value based on Mann–Whitney *U*-test. TAC4h: Total abdominal counts at 4 h, TIRC: Terminal ileal reservoir counts at 4 h, TAC24h: Total abdominal counts at 24 h, C-AC: Counts of cecum-ascending colon at 24 h, TC: Counts of transverse colon at 24 h, DC: Counts of descending colon at 24 h, RS-AC: Counts of rectosigmoid-anal canal at 24 h, EC: Eliminated counts at 24 h, ISBT: Index of small-bowel transit, CGC: Colonic geometric center, SD: Standard deviation

was obtained by subtracting TAC24 h from TAC4 h. The colonic geometric center (CGC), an index of colonic transit at 24 h, was derived by summing the decay-corrected counts from each segment (normalized to acquisition time) as a fraction of the decay-corrected total abdominal counts available for filling the large bowel. The weighting values corresponding to each segment were used in the calculation to represent the progression of radioactivity through the colon as described below:

$$CGC = \sum_{i=1}^{5} \frac{Ai}{\text{TAC4 h}} X\, i$$

Table 4: Correlation analysis between age and small-bowel and colonic transit

	Anterior view method		Geometric mean method	
	ISBT	CGC	ISBT	CGC
Spearman's ρ	0.171	−0.626	0.290	−0.486
P	0.376	0.053	0.128	0.154

ISBT: Index of small-bowel transit, CGC: Colonic geometric center

Ai = Decay-corrected counts in the particular large bowel segment, *i*, at 24 h normalized to acquisition time.

TAC4 h = Decay-corrected total abdominal counts at 4 h.

i = Large bowel segment numbers/weighting values (1 = Cecum-ascending colon, 2 = Transverse colon, 3 = Descending colon, 4 = Rectosigmoid-anal canal, and 5 = Eliminated counts through feces).

Statistical analysis

Descriptive statistics were employed to summarize the various variables, including frequency (percentage), mean ± standard deviation, median (minimum–maximum), and percentiles (2.5th, 5th, 95th, and 97.5th percentiles). Continuous variables were tested for normality with Shapiro–Wilk test. To compare small-bowel and colonic transit between different camera view methods, the Paired samples *t*-test or Wilcoxon signed-rank test was utilized as appropriate. For comparing small-bowel and colonic transit between females and males, the Independent Samples *t*-test or Mann–Whitney *U*-test was applied. The correlation between age and small-bowel and colonic transit was assessed using Spearman's rank correlation analysis. The reference value for the ISBT was established based on the fifth percentile value, assuming that 95% of the normal population falls above this value. Rapid small-bowel transit was determined by visually inspecting the static images at multiple time points to identify the first visualization of activity in the cecum-ascending colon. The reference range for the CGC was derived using the mean ± 1.96 standard deviations, assuming that 95% of the normal population falls within this range. A two-tailed $P < 0.05$ was considered statically significant. Statistical packages IBM SPSS 26.0.0.0 (IBM Corp., Somers, New York, USA) and MedCalc 19.6.4 (MedCalc Software, Ostend, Belgium) were used for the statistical analyses.

Results

A total of 34 healthy controls underwent GES. Data of 29 healthy controls with a mean age of 41 ± 12 years (10 males, 19 females) were included for the final analysis. The remaining five were excluded due to the presence of rapid gastric emptying (percent gastric retention <20% at 1 h). The median percent gastric retentions of the enrolled subjects were 36% (20%–77%), 13% (2%–35%), and 1% (0%–3%) at 1, 2, and 4 h, respectively, with a median T1/2 of 44 min (22–91 min). Ten healthy controls underwent imaging at 24 h, and hence, colonic transit was assessed in these patients. Summary statistics of small-bowel and colonic transit are depicted in Table 1.

Assessment of small-bowel transit

The TAC4 h and TIRC in the anterior view method were significantly higher compared to the geometric mean methods ($P < 0.001$), whereas no statistically significant difference was observed in the ISBT between the two camera view methods ($P = 0.125$) [Table 2]. Furthermore, no significant variations were found in these parameters between females and males using both the anterior view and geometric mean methods ($P \geq 0.353$) [Table 3]. In addition, there was no noteworthy correlation between age and ISBT in either the anterior view or geometric mean methods ($P \geq 0.128$) [Table 4].

Assessment of colonic transit

In our study, we observed that the TAC24 h and the counts of the cecum-ascending colon, transverse colon, and eliminated counts at 24 h were significantly higher when using the anterior camera view method compared to the geometric mean method ($P \leq 0.020$). However, there were no significant differences in the respective counts of the descending colon, rectosigmoid-anal canal, and CGC between the two camera view methods ($P \geq 0.098$) [Table 2]. Furthermore, when comparing females and males using both camera view methods, there were no statistically significant differences observed in these parameters ($P \geq 0.136$) [Table 3]. In addition, no significant correlation was found between age and colonic transit in either the anterior camera view method or the geometric mean method ($P \geq 0.053$) [Table 4].

Reference values of small-bowel and colonic transit

Considering the advantages of attenuation and depth correction in the geometric mean method, we chose to establish the reference values for small-bowel and colonic transit using this method. For small-bowel transit, the reference value was set at an ISBT >37% at 4 h. Upon visual inspection of static images, it was observed that in five subjects, the first visualization of activity in the cecum-ascending colon occurred at 4 h, whereas in one subject, it occurred at 2 h, and the remaining subjects did not show any visualization even up to 4 h. However, by the 24 h mark, activity in the large bowel was visible in all subjects. This indicates that the first visualization of activity in the cecum-ascending colon at 2 h was noted in only 3.4% (1/29) of the subjects. Considering that 96.6% (28/29) of the subjects exhibited the first visualization of activity in the cecum-ascending colon by ≥4 h, it was proposed to define the presence of rapid small-bowel transit as the first visualization of activity in the cecum-ascending colon at ≤2 h. For colonic transit, the reference range was established as CGC ranging from 2.8 to 4.4 at 24 h.

Discussion

In this study, we derived the ISBT at 4 h and CGC at 24 h as representative small-bowel and colonic transit parameters, respectively. To achieve this, we utilized TAC4 h as the input activity available to fill the small-bowel and colon. Although the current guideline suggests deriving the input activity from the average of the total abdominal counts at multiple time points (namely, 2, 3, 4, and 5 h), Maurer *et al.* discovered in their study that there was negligible variability in the total abdominal counts during imaging of the initial 6 h of bowel transit studies. They proposed that a simplified analysis using the total abdominal counts from a single time point could be feasible.[1,7] Therefore, in our study, we opted to use TAC4 h as the input value available to fill the small bowel and colon. This approach not only simplified the analysis but also reduced the overall time required for the assessment.

In our study, we established a reference cutoff value for small-bowel transit, represented by ISBT, of >37% at 4 h. It is worth noting that Bonapace *et al.* suggested a reference cutoff value of >40% at 6 h, which was also highlighted in the practice guideline for small-bowel and colon transit studies.[1,8] However, it is important to consider the variations in methodology between our study and Bonapace *et al.*'s study. They employed a dual isotope technique using Tc-99m egg sandwich with In-111 DTPA in water as the meal, whereas we used Tc-99m sulfur colloid bound to a standard Indian vegetarian solid meal. In our study, we proposed the first visualization of activity in the cecum-ascending colon within 2 h on visual inspection of the static images as an indicator of rapid small-bowel transit. Bonapace *et al.* suggested a threshold of <90 min for the same.[8] It is worth noting that their study involved frequent imaging every 30 min, whereas we assessed small-bowel transit using routine GES with standard imaging time points (0, 1, 2, and 4 h). Despite the differences in methodology and types of meals employed, the results can be considered fairly similar.

In our study, we determined the reference range for colonic transit using CGC at 24 h, which fell within the range of 2.8–4.4. This range is quite similar to the one proposed by Bonapace *et al.* and endorsed in the current practice guidelines (2.0–7.0).[1,8] The slight discrepancy observed could be attributed to the variations in methodology and meals utilized, as mentioned earlier. The CGC serves as an important indicator in assessing colonic transit. A low CGC suggests that the radiotracer is primarily localized in the right colon or that colonic transit is delayed. On the other hand, a high CGC signifies rapid movement or elimination of the radiotracer from the large bowel. By evaluating the CGC, researchers can gain insights into the efficiency and speed of food passage through the colon. This information is valuable in understanding the overall functionality and performance of the digestive system. Given the short half-life of Tc-99m, our study primarily focused on assessing colonic transit at the 24 h mark. Deiteren *et al.* suggested that scintigraphy-based assessment of colonic transit is highly reproducible, and CGC at 24 h should remain the primary endpoint for evaluating colonic transit in clinical trials. This is because it is easier to detect rapid colonic transit using CGC at 24 h compared to later time points.[9] These findings imply that our approach of assessing colonic transit at 24 h may have practical clinical utility in the majority of cases.

In our study, we compared two methods for assessing small-bowel and colonic transit: the anterior view method and the geometric mean method. While the raw counts obtained from the anterior view method were generally higher compared to the geometric mean method, there was no statistically significant difference in the small-bowel and colonic transit [Table 2]. In addition, the values of the derived transit parameters based on percentiles or mean ± 1.96 standard deviation did not differ significantly [Table 1]. Based on these findings, we recommend the geometric mean method as the preferred methodology as it accounts for attenuation and depth correction. However, we acknowledge that in centers with high patient throughput and limited resources where a single-head gamma camera is used for multiple studies, the anterior view method may be an acceptable alternative.

Regarding gender differences, our study did not find any statistically significant difference in raw counts, small bowel, or colonic transit between females and males. This aligns with previously reported findings by Bennink *et al.*[10] Furthermore, we observed no correlation between age and small-bowel or colonic transit. Hence, the derived small-bowel and colonic transit parameters may be applicable to both sexes and all age groups of individuals aged 18 years and above. However, it is worth noting that Table 4 shows a nonsignificant trend toward a negative correlation between age and colonic transit parameters. Our study lacks sufficient power to confirm this correlation, and we recommend larger prospective studies to address this finding adequately.

The current study possesses its own commendable attributes. It implemented the assessment of small-bowel transit within the routine GES study protocol, whereas colonic transit was evaluated with a single-time point extension of the same protocol. This approach is noteworthy, considering that many patients referred for GES due to gastrointestinal symptoms often exhibit normal gastric emptying parameters.[4,5] For such patients, incorporating additional image analysis for small-bowel or colonic transit assessment with no or minimal extension of the routine GES protocol is an impressive strategy. Moreover, this approach effectively addresses the challenges associated with the limited availability of In-111, particularly within the Indian context, by utilizing Tc-99m, a universally available radioisotope with improved radiation profile and image characteristics. Assessing small-bowel and colonic transit on routine GES protocol, with only a single-time point extension for colonic transit, offers a more patient-friendly alternative compared to the lengthy and frequent imaging protocols described in the majority of the literature.

However, despite its merits, the study is not without limitations. The main limitation pertains to the small sample size and the fact that not all subjects underwent imaging session at 24 h, resulting in colonic transit assessment being possible only in a smaller subset of the enrolled subjects. An additional constraint within the study might arise from the subjective process involved in identifying bowel segments for placing ROIs posing potential difficulty, particularly in the case of the TIRC. Approaches to address this issue could involve positioning a radioactive marker in the right iliac crest during static image acquisitions and conducting SPECT/CT acquisition at 4 h. In addition, due to the short half-life of Tc-99m, imaging beyond 24 h was not feasible, limiting the assessment of colonic inertia or functional rectosigmoid obstruction as suggested by Krevsky *et al.*[11] However, from a practical standpoint, assessing colonic transit at 24 h may be sufficient in the majority of the cases, as emphasized by Deiteren *et al.*[9] Larger prospective studies are needed to further explore these slightly differing perspectives and their impact on patient management and outcomes.

Conclusion

The study established the reference values for small-bowel and colonic transit using routine GES in the Indian population without additional complex procedures. The results may be generalized to the Indian population, emphasizing the importance of assessing small-bowel and colonic transit in patients with normal gastric emptying parameters to enhance gastrointestinal transit evaluation.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

Sonu Kumar, Asem Rangita Chanu, Jasim Jaleel, Priyanka Gupta, Bangkim Chandra Khangembam, Chetan Patel, and Rakesh Kumar declare that they have no conflicts of interest.

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