A modified radiographic method for estimating segmental colonic transit time in subjects with rapid gut transit

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In this study on Indian subjects, the single X-ray method was assessed for its reliability in measuring the transit of particulate matter through the colon, and if inaccurate a suitable and simple alternative was to be devised. Radio-opaque markers were serially followed in 20 normal male volunteers. This was done by three 12 hourly radiographs and by stool collection to determine the transit time through the colon and its segments. It was compared with similar parameters calculated from the same data using one radiograph and three combinations of two radiographs each. The mean ± SD colonic transit time determined by using three X-rays was 18.8±6.6 h which agreed well with the mean mouth-to-anus transit time of 24.2±6.8 h (mean ± SD err = -6.2 ± 2.9). When two of the three X-rays were used in various combinations, the best results were obtained with the method including radiographs at 12 and 36 h. Parameters calculated from a single radiograph done 36 h after the ingestion of markers showed lesser agreement with the results of the three radiograph method. Therefore in subjects with rapid gut transit, the simplified method for estimating the colonic and segmental transit times using a single X-ray is inaccurate. Using two radiographs enhances the accuracy.

Key words Colonic motility - colonic transit time - gastrointestinal motility - gut transit

The transit of material through the unprepared human colon and its segments has been measured by radiographic and scintigraphic methods both of which have their advantages and disadvantages. The radiographic method using radio-opaque markers is easy to perform and has been simplified to require only a single X-ray film thereby decreasing the exposure to radiation. However, these methods were developed in a population with a mean ± SD mouth-to-anus transit time (MAT) of 53.3 ± 3.7 h. Normal whole gut transit time in healthy adults from the developing world is less than half that of Caucasians. In these populations markers given at intervals of 24 h are at risk of being passed out before the subsequent X-ray is done.

Therefore in the study described below, the purpose of which was to assess the reliability of the single X-ray method in people with rapid gut transit - we shortened the interval between markers and radiographs to 12 h. It may appear irrelevant to conduct colonic transit studies in people with rapid gut transit, as the clinical situation where this test is done is slow transit constipation. However, it is imperative to standardise this method for physiological studies in people from the Indian subcontinent.

Material & Methods

Subjects: Twenty healthy adult male volunteers (age

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18 to 55 yr, mean 31 yr) who did not have symptoms or signs of gastrointestinal disease or diseases that might affect gastrointestinal function were studied. For ethical and practical reasons, women and those below 15 yr of age were excluded because of the exposure to radiation however small the dose. The study was approved by the Ethics Committee of our institution and written informed consent was obtained from all subjects.

**Design**: The subjects were admitted to a metabolic ward a day prior to the study and were on their usual diet. Eight of the subjects were vegetarian. Radio-opaque markers were administered and serial radiographs done over the next 36 h in a set sequence. Twenty markers each of three shapes (semi-circles, large rings and small rings denoted Markers 1 to 3 respectively) cut from tubes with outer diameters of 4 and 2.5 mm were used. These were easily distinguishable from one another radiographically. Each stool was collected separately in a plastic bucket, labelled with the name, date and time, and the markers counted in these samples fluoroscopically. Stool collection began with the administration of Marker 1 and continued until all markers had been excreted.

Since there are no validated methods for counting of markers in stools we assessed the accuracy of this method in a separate experiment. Morning stools were obtained in numbered containers from 15 patients, between 10 and 20 markers randomly added to each and the markers counted thrice in random order. The person counting the markers (CGP) was not aware of the total number of markers used or the numbers added to each container. Of the 225 markers added, 224, 223 and 224 were correctly identified during the separate counting giving an overall accuracy of 99.4 per cent for the fluoroscopic counting method.

**Modification introduced**: 

(i) The interval between the radiographs was shortened to half that described in studies from the West. This was necessary because of the rapid gut transit in our population. Each subject had an anteroposterior abdominal radiograph (high kilovoltage fast film technique, radiation dose=0.08 rads per film) done 12, 24 and 36 h after the ingestion of the first of the markers and they were denoted X-rays 1, 2 and 3 respectively. Ingestion of Markers 2 and 3 immediately followed the 12 and 24 h X-ray films, respectively.

(ii) Based on ethical considerations the number of X-rays were restricted to three per subject as these were normal individuals and the study was experimental. This limit on the number of X-rays was circumvented by counting the markers in stool and calculating the markers remaining in the colon at 12 hourly intervals after the third radiograph until all markers had been expelled.

**Colonic transit time (CTT) and mean colonic transit time (MCTT)**: CTT was calculated for each of the three types of markers (CTT M1, CTT M2 and CTT M3 from Markers 1 to 3 respectively) as described by Arhan et al.

\[
\text{CTT (h)} = \frac{1}{N} \times \sum n_i \left[ \frac{1}{2} (t(i+1) - t(i-1)) \right] \\
= \frac{1}{20} \times \sum n_i \left[ \frac{1}{2} (24-12) \right] \\
= 0.6 \times \sum n_i \\
= 0.6 \times (n_1 + n_2 + n_3)
\]

where \(N\) is the number of markers administered (20), \(n_i\) the number of the markers on a film taken at time \(t_i\), 1/2 [(t(i+1) - t(i-1)) the time interval between two successive radiographs and \(n_1, n_2\) and \(n_3\) the number of the Marker 1, 2 or as the case may be present in the colon at the given time 12 h apart.

Since only three radiographs were done, after the third one, the number of markers remaining in the colon at a given time was calculated as:

\[
\text{Markers remaining unexcreted} = \text{Markers administered} - \text{markers excreted in stool}
\]

MCTT was calculated as:

\[
\text{MCTT} = (\text{CTT M1} + \text{CTT M2} + \text{CTT M3}) \div 3
\]

Single X-ray method (modified after Metcalf et al.):

For measurement of transit using one radiograph alone Markers 1, 2 and 3 were counted on the radiograph done at 36 h.

\[
\text{CTT (h)} = \frac{1}{20} \times \sum N_i \left[ \frac{1}{2} (t(i+1) - t(i-1)) \right] \\
= \frac{1}{20} \times \sum N_i \left[ \frac{1}{2} (24-0) \right] \\
= N_i \times 0.6
\]

where \(N_i\) is the total number of Markers 1, 2 and 3 counted on X-ray 3.

Two X-rays method - In Methods A to C X-rays 1 and 3, X-rays 1 and 2 and X-rays 2 and 3 were used respectively. The formulae used to calculate CTT and
segmental colonic transit time (SCTT) are given below:

Method A: Marker 1 counted on X-rays 1 and 3 only.

\[
\text{CTT (h)} = \frac{1}{20} \times N_c \{\frac{1}{2} (t_i + 1) - (t_i - 1)\} \\
= \frac{1}{20} \times \text{Ni1} \{\frac{1}{2} (36-0) + \text{Ni3} [\frac{1}{2} (48-12)]\} \\
= \frac{1}{20} \times \{\text{Ni1} \times 18\} + \{\text{Ni3} \times 18\} \\
= \text{Ni1} \times 0.9 + \text{Ni3} \times 0.9 \\
\]

Method B: Marker 1 counted on X-rays 1 and 2 only.

\[
\text{CTT (h)} = \frac{1}{20} \times \text{Ni1} \{\frac{1}{2} (24-0) + \text{Ni2} [\frac{1}{2} (48-12)]\} \\
= \frac{1}{20} \times [\{\text{Ni1} \times 12\} + \{\text{Ni2} \times 36\}] \\
= \text{Ni1} \times 0.6 + \text{Ni2} \times 0.9 \\
\]

Method C: Marker 1 counted on X-rays 2 and 3 only.

\[
\text{CTT (h)} = \frac{1}{20} \times \text{Ni2} \{\frac{1}{2} (36-0) + \text{Ni3} [\frac{1}{2} (48-24)]\} \\
= \frac{1}{20} \times [\{\text{Ni2} \times 18\} + \{\text{Ni3} \times 24\}] \\
= \text{Ni2} \times 0.9 + \text{Ni3} \times 0.6 \\
\]

where Ni1, Ni2 and Ni3 are the number of Marker 1 counted on the X-rays 1, 2 and 3 respectively.

Measurement of segmental colonic transit time: The large bowel segments were demarcated on the radiographs as described by Martelli et al. and the time for transit through the right colon (RCTT), left colon (LCTT) and the rectosigmoid (RSTT) were calculated. The formulae detailed above were used by substituting the number of markers in the segment of interest in place of the number of markers in the whole colon. The standard for comparing the total colonic transit was the MCTT. The standard used for comparing segmental colonic transit time by the different methods, however was estimated by Marker 1 only. This was necessitated by the Ethical Committee’s restriction on the number of radiographs per subject.

Measurement of whole gut transit time: This was done by following the excretion of the markers in the stool. The mouth-to-anus transit time (MAT) was calculated for each type of marker and the mean of the MAT obtained for the three markers gave the mean mouth-to-anus transit time (MMAT).10.

Statistical analysis: The transit times determined by the various methods were compared with those of the standard method by calculating the mean ± standard deviation of the differences (SD\text{diff}). From these values the 95 per cent limits of agreement were calculated as mean±2 (SD\text{diff}).

Results

The study group had a stool frequency of 1–3 per day (mean ± SD = 1.6±0.6). The stool collection was complete in all subjects and 1191 (99.3%) of the 1200 markers administered for the transit studies were recovered in the stools. That the shape and size of the markers did not influence their transportation through the gut was proved in a separate study on 10 normal subjects by administering 20 of each of these simultaneously. The mean±SD\text{diff} for the MAT determined by using the three different markers were 0.2±4.8, 1.3±3.7 and -1.5±5.3 respectively.

Colonic transit time: The MCTT±SD was 18.0±6.6 h and this made up three-fourths of the mean±SD mouth-to-anus transit time (24.2±6.8 h). The mean±SD\text{diff} of differences between the two parameters was -6.2±2.9h. CTT M1 agreed well with CTT M2 and CTT M3 (Table I).

The means of differences of the modified methods compared to MCTT were small (Table II). However, the scatter was least for method A thereby giving the best 95 per cent limits of agreement with this method.

| Table I. Colonic transit time measured using different markers over 36 h |
|-----------------|---------------|-----------------|
| CTT, h          | Mean±SD       | Mean±SD\text{diff} |
| CTT M1          | 18.8±7.7      | —                |
| CTT M2          | 16.5±8.9      | -2.3±3.9         |
| CTT M3          | 18.6±7.1      | -0.2±4.4         |

| Table II. Colonic transit time measured by the different methods and their agreement with MCCT |
|---------------------------------|-----------------|-----------------|
| Colonic transit time (h)        | Mean±SD         | 95% limits of agreement |
| Mean±SD                        |                 |                  |
| MCTT                           | 18.0±6.6        |                  |
| Single X-ray method            | 18.2±8.0        | 0.2±7.1          | -6.9 to +7.3 |
| 2 X-ray methods                |                 |                  |
| Method A                       | 19.8±8.4        | 1.8±3.1          | -1.3 to +4.9 |
| Method B                       | 19.7±8.4        | 1.7±3.2          | 1.5 to +4.9  |
| Method C                       | 10.8±8.3        | -7.2±3.3         | -3.2 to -10.5|
Segmental colonic transit times: The values for SCTT obtained by the standard method and the other methods are shown in Tables III to V. The means of the differences from the standard method were variable but the smallest means with least scatter were seen with the results of Method A. While the means of the differences were not high for the single X-ray method, the SD\text{diff} was high giving a large range for the 95 per cent limits of agreement. Method C underestimated the CTT and SCTT considerably.

Of the 20 subjects 17 (85%) excreted all of Marker 1 within 48 h of ingestion suggesting thereby that a fourth radiograph would have been unnecessary in them. Two others had only 1 marker left in the colon which was already in the rectum by the time X-ray 3 was done. The remaining subject obviously was an outlier who still retained 16 markers in the large bowel (15 of them in the rectum) at the time of the last radiograph.

| Table V. Rectosigmoid transit time measured by the different methods compared with the standard method |
|-------------------------------------------------|----------------|----------------|
| | RSTT | Mean±SD | 95% limits of agreement |
| Standard method | 6.1±5.7 | - | - |
| Single X-ray method | 5.1±4.7 | -1.0±6.7 | -7.7 to +5.7 |
| 2 X-ray methods | | | |
| Method A | 6.5±7.4 | 0.4±3.1 | -2.7 to +3.5 |
| Method B | 8.3±8.0 | 2.2±4.1 | -1.9 to +6.3 |
| Method C | 7.3±7.3 | 1.2±3.8 | -2.6 to -5.0 |

Discussion

Radiographic methods hitherto developed for measuring CTT have an inherent limitation - they can be used only when the transit times are within a given limit. Unduly slow transit has been shown to underestimate CTT measured by the method of Metcalf et al. Very little is known however about the effect of rapid gut transit on CTT measured by this method. This paper describes a simple and reliable radiological method of measuring colonic transit time in people with rapid whole gut transit. It includes two modifications on previously published methods. First a shortened interval between X-rays obviated the chances of the markers passing out before any X-rays were taken. Others have used short intervals between radiographs but have not validated their method. Second, two radiographs were used to estimate the CTT and SCTT. This was found to be superior to the single X-ray method. In subjects with rapid transit the latter is inadequate in measuring the SCTT as well as CTT. Unlike the previous studies on Indian subjects we measured the MMAT to assess its agreement with the CTT, used multiple radiographs to arrive at the best combination thereof and counter-checked the number of markers excreted in stool so as to account for all the markers remaining unexcreted. While the fluoroscopic method of counting markers has not been validated before we found the method accurate in a separate experiment. However, routine use of this is not necessary for estimating the CTT and SCTT since the radiographs alone suffice.
We could estimate the CTT by using all three markers and hence derive the MCTT because we could calculate the number of markers remaining in the colon at any given time after day 2 of the study despite the restriction on ethical grounds, to three radiographs per subject. However, the same could not be done for the segmental colonic transit times. Therefore SCTT as determined by Marker 1 was used as the standard. As we had found good agreement between the various CTTs (i.e., CTT M1, CTT M2 and CTT M3) it seems reasonable to assume that segmental transit time assessed by using Marker 1 would closely resemble the mean SCTTs had we determined them.

Which two X-rays give the best results? For the total colonic transit time, both methods A and B are good. For SCTT, however, method A would be the one of choice. Method C underestimated the transit times considerably, and clearly is unsuitable.

It has been suggested that scintigraphy is better than the radiographic methods for transit measurements in the presence of ‘intestinal hurry’ albeit without evidence’. We offer evidence that the 2 radiograph method is a cheap and reliable alternative. The radiopaque marker method is also simpler, easier and does not require special expertise or equipment. While using the radiographic method further reductions in the interval between the radiographs could be carried out if necessary in patients and subjects with gut transit that is faster than in our population to achieve an optimal estimate of CTT and SCTT. This would be important in the study of colonic transit in diarrhoeal diseases.

References


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