Reaction of human small intestine to an intraluminal tube and its importance in jejunal perfusion studies

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SUMMARY A double-lumen tube with a mercury weight attached to its distal end was positioned in the small intestine of six subjects who were to undergo an elective laparotomy. The tube and the technique for its localization were exactly similar to those used in previous intestinal perfusion experiments.

Marked 'concertinaing', or gathering of the small intestine proximal to the mercury weight, was seen at laparotomy in all six subjects. The ratio between the mean intestinal length from the mercury weight to the ligament of Treitz after removal of the tube to that with the tube *in situ* was 3.0 (2.5-3.8). Mean total jejuno-ileal length was 421 (320-521) cm. In five of the six subjects the distal end of the tube was more than half way between the ligament of Treitz and the ileo-caecal valve although it was only 100-120 (mean 108) cm from the incisor teeth.

Segmental perfusion studies of the human jejunum involve a much longer length of small intestine than is generally assumed—by a factor of approximately 3. Such studies assess absorption rates over a substantial proportion of the small intestine and are not confined to a short segment of proximal jejunum. The nutritional significance of such studies in which amino acids, peptides, and carbohydrates are investigated is increased. Studies designed to measure absorption rates from the ileum should be treated with caution as part or all of the perfusion segment may be past the ileo-caecal valve.

Gathering or 'concertinaing' of the small intestine as a response to an intraluminal tube is well recognized (Hirsch, Ahrens, and Blankenhorn, 1956; Shields, 1972). Double or triple-lumen tubes are frequently used for estimating absorption rates of amino acids, peptides, carbohydrates, electrolytes, and water from the human small intestine, and

results are expressed as rate per unit length—usually 30 cm. The present investigation was undertaken to quantitate the importance of 'concertinaing' in the interpretation of intestinal perfusion studies.

Subjects and Methods

Table I summarizes the clinical details of the six subjects who were studied. They were all undergoing an elective laparotomy at the University Teaching

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Subject No.	Sex	Age (yr)	Nationality ¹	Body Weight (kg)	Clinical Diagnosis
1	M	35	Chewa	68	Left ureteric calculus
2	F	32	Kunda	46	Carcinoma of urinary bladder; <i>Schistosoma haematobium</i> infestation
3	M	44	Swaka	54	Duodenal ulcer
4	M	28	English	69	No abnormality (diagnostic laparotomy)
5	F	37	Tonga	59	Carcinoma of urinary bladder; <i>Schistosoma haematobium</i> infestation
6	M	25	Tonga	54	Duodenal ulcer; hepatosplenomegaly of unknown aetiology

Table I Clinical details of the six subjects investigated

¹Brelsford (1965)

Fig 1 Diagram of the double-lumen tube. Measurement *a* was a direct measurement of tube length, and *b* was made from the abdominal radiograph. Measurements x_1 , x_2 , and *y* were made at laparotomy (see text)

Hospital, Lusaka, and the purpose of the present investigation was explained. None was malnourished. They had not previously been investigated.

A double-lumen tube (Portex MLT/B) (external diameter 4.2 mm) was swallowed on the evening before the laparotomy (Cook, 1971a and b, 1974a) (fig 1). The mercury weight was approximately 50 g. The tube was anchored with adhesive strapping applied to the face; the distal pole of the mercury weight was 100-120 (mean 108) cm from the incisor teeth, and the infusion opening 62-82 (mean 70) cm from the incisor teeth (*a*). Sips of water were permitted overnight. Between 14 and 18 hr later the position of the tube was localized by an abdominal radiograph taken with the subject in the supine position. The distance between the proximal opening and the ligament of Treitz (cm) was measured on the radiograph with thread and reduced by a factor of 20% as an approximation for magnification; the resulting estimate was designated *b* and was 8 to 31 (mean 15) cm. The distance of the distal pole of the mercury weight from the ligament of Treitz is therefore *b* + the length of the perfusion segment of the tube (30 cm) + the distance between the distal opening of the tube and distal pole of the mercury weight (8 cm), ie, (*b* + 38) cm.

Anaesthetics were given by Dr D. M. Nagle. Atropine and morphine were given for premedication, and thiopentone sodium for induction. In cases 1 and 3 gallamine triethiodide was used for muscle paralysis and ventilation was with N_2O and oxygen; in cases 2, 4, 5, and 6 spontaneous breathing was maintained and N_2O , oxygen, and halothane were used. Immediately after the abdominal cavity was opened, the mercury weight was located and its position secured by a loose proximal suture around the small intestine. A black silk suture was tied subserosally over the distal pole of the mercury weight. By applying a length of black silk to the non-mesenteric border of the small intestine, the distance

between the suture and ligament of Treitz (x_1) was estimated in triplicate. Following withdrawal of the tube, the measurement was repeated in triplicate (x_2). By a similar technique the distance from the suture to the ileo-caecal valve (*y*) was estimated, also in triplicate. Table II summarizes results of reproducibility of the triplicate measurements.

Measurement	Mean length (cm)	SD ¹	Coefficient of Variation (%)
Distal end of mercury weight to ligament of Treitz (x_1)	81.8	6.4	7.8
Distal end of mercury weight to ligament of Treitz (x_2)	242.7	17.5	7.2
Distal end of mercury weight to ileo-caecal valve (<i>y</i>)	179.4	18.3	10.2

Table II Reproducibility of three measurements of intestinal length made at laparotomy in the six subjects

¹The SD values are calculated as described by Cook (1971a; 1972)

Results

In all subjects marked concertinaing of the small intestine was noted. Figure 2 shows the appearance in subject no. 6. In two subjects (nos. 1 and 4) multiple small intussusceptions were noted immediately after withdrawal of the tube. In all of them the mercury weight seemed to be in the ileum, although biopsy specimens were not obtained.

Figure 3 summarizes the results of the mean intestinal measurements. The mean ratio x_2/x_1 is 3.0 (2.5-3.8), and the mean ratio $x_2/(b + 38)$ is 4.6 (3.3-6.4). The differences between the means for x_2 and x_1 ($t = 8.72$; $df = 5$; $P < 0.001$), and x_2 and ($b + 38$) ($t = 8.46$; $df = 5$; $P < 0.001$) are significant by the paired *t* test. The mean values for x_1 , x_2 , and *y* in the English subject (no. 4) were 84, 322, and 163 cm respectively.

Fig 2 Marked concertinaing of the small intestine proximal to the mercury weight shown at laparotomy in subject no. 6

Fig 3 Summary of results for $(b + 38)$, x_1 and x_2 (cm) in the six subjects. The means ± 1 SEM are shown.

The mean distance between the distal end of the mercury weight and the ileo-caecal valve (y) was 179 (75-276) cm. The mean total length of small intestine after removal of the tube ($x_2 + y$) was 421 (320-521) cm.

Discussion

The study clearly shows that with a small intestinal perfusion tube with a fixed proximal end marked concertinaing (or gathering) of intestine over the tube takes place. The extent of the concertinaing seems to be best expressed as the ratio x_2/x_1 in which

both measurements were made at laparotomy over a short space of time, approximately 15 min, with the subject under the same anaesthetic; the mean length of intestine which would have been perfused is then three times the length of the perfusion segment of the tube, ie, 30 cm. It is impossible to estimate the actual mucosal area perfused and also the extent to which the perfusing fluid penetrates the crevices of the tightly concertinaed intestine. Results of previous perfusion studies in the same subject using an exactly similar tube suggest that alteration in the perfused mucosal area is minimal over a perfusion period of three to four hr (Cook, 1971b, 1973a, 1974a and b). There is probably greater intersubject variation in the perfused mucosal area but in practice that also seems to be very limited (Cook, 1971a, 1973b, 1974a).

Previous studies have indicated a significant correlation between D-xylose excretion after an oral load and the small intestinal absorption rate of glucose (Cook 1971a, unpublished observation) and D-xylose (Corcino, Maldonado, and Klipstein, 1973). The present finding explains that observation as the length perfused represents a substantial proportion of the small intestinal mucosal surface area and not merely a 30-cm segment. The present finding therefore increases the nutritional importance of small-intestinal absorption studies of amino acids, peptides, and carbohydrates which were previously believed to apply to a short segment, eg, 30 cm, of proximal jejunum. Studies in which K_t and V_{max} values have been calculated for a 30-cm segment of proximal jejunum should be re-evaluated; a much larger absorptive area has in fact been studied. Previous studies of absorption rates in the ileum should also be re-evaluated as it seems likely that in some cases part or all of the perfused segment was in fact in the colon.

The site of intestinal biopsy with a small intestinal biopsy capsule, when the proximal end of the tube is fixed, must be critically evaluated in the light of the present finding. It seems possible that some biopsy specimens which have been assumed to be from the proximal jejunum have in fact been taken from the distal jejunum or even the ileum.

The effect of altering the size of the weight on the extent of concertinaing has not been evaluated in the present study; it seems possible that that may have some importance.

The mean estimate of small intestinal length in the present study is greater than that reported by Hirsch, Ahrens, and Blankenhorn (1956). Using a technique with a 2.1 mm diameter tube which was not fixed, they estimated that in 10 subjects *in vivo* the mean jejuno-ileal length was 261 (206-318) cm; they claimed that concertinaing or gathering was negligible or nonexistent.

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