ANNALS OF SURGERY
Vol. 226, No. 6, 746–752

Ileocecal Segment Transposition Does Not Alter Whole Gut Transit in Humans

Lukas P. Degen, M.D.,* Markus O. von Flüe, M.D.,† Anette Collet, M.D.,* Christian Hamel, M.D.,† Christoph Beglinger, M.D.,* and Felix Harder, M.D.†

From the Division of Gastroenterology and the Department of Surgery,† University Hospital, Basel, Switzerland*

Objectives
We have recently described a reservoir for rectal replacement after total mesorectal excision for rectal carcinoma. The ileocecal segment with its intact extrinsic nerve and blood supply is placed between the ascending colon and the anal canal. This reconstruction has been shown to provide good defecation quality and anorectal function. Whether gastric emptying and small as well as large bowel transit are affected by this transposition remains unclear. Our aim was to quantify whole gut transit in such patients and compare it with that of a matched group of controls.

Methods
Gastric emptying rates and small intestinal and colonic transit times were assessed scintigraphically in 12 patients aged 46 to 87 years with ileocecal reservoir reconstruction after total mesorectal excision and compared to a sex-matched group of asymptomatic healthy volunteers of similar age. Gastric emptying rates and small intestinal and colonic transit times were calculated as described previously. Data were compared using Wilcoxon's signed rank test for gastric emptying rates and small bowel transit or by analysis of variance for colonic transit; $p < 0.05$ was considered significant.

Results
Gastric time for half of the meal (T_{50}) was 161 ± 16 minutes for patients and 201 ± 22 for the controls. Small bowel transit time was 150 ± 15 minutes for patients and 177 ± 22 for the controls. Geometric center at 6 hours was 1.53 ± 0.13 for patients and 1.27 ± 0.16 for the controls. Geometric center at 24 hours was 2.96 ± 0.23 for patients and 2.57 ± 0.25 for the controls. Data are mean ± SEM.

Summary
Gastric emptying rates and small bowel transit and colonic transit times (expressed as geometric center at 6 and 24 hours) were similar in patients with ileocecal reservoir reconstruction and in a sex- and age-matched group of healthy controls. We conclude that the transposition of an ileocecal segment with intact extrinsic neurovascular supply between the sigmoid colon and the anal canal does not alter whole gut transit, not even in any of the presumably key regions.

Table 1. PATIENT CHARACTERISTICS

	Patients with Ileocecal Reservoir (n = 12)	Controls (n = 12)
Gender (male/female)	8/4	8/4
Age (yr) (range)	62 (46–87)	57 (43–71)
Time since operation (mo)	7 (4–18)	—

Surgical options after proctectomy for low rectal cancer include different forms of reconstruction. Various degrees of anal incontinence, including imperative urge and increased stool frequency, occur with the classic types of reconstruction.[1] Based on these observations, we have described an alternative technique for coloanal reservoir reconstruction using an ileocecal segment with intact extrinsic nerve and blood supply.[1] This reservoir provides a neorectum with very satisfactory defecation quality and nearly normal anorectal function.[2] Whether this ileocecal transposition would affect gastrointestinal transit in any way needed to be clarified.

Feedback signals initiated by the distal ileum that act on the proximal gastrointestinal tract have been proposed to act as physiologic mechanisms (the "ileal brake").[3] By transposing the ileocecal region in the rectal region, these feedback mechanisms could be interrupted. However, evidence from patients with right hemicolectomy indicates that the ileocolonic sphincter in humans appears to play a minor role at most, because gastric emptying and small bowel and segmental colonic transit were comparable to controls in the hemicolectomized patients.[4] Our aim was therefore to quantify whole gut transit prospectively in patients with ileocecal reservoir reconstruction and to compare them to a matched group of healthy volunteers using a noninvasive scintigraphic method.[5,6]

METHOD

Experimental Subjects

Twelve patients with rectal cancer between 2 and 12 cm above the anal verge were prospectively enrolled in the study and underwent total mesorectal excision and reconstruction with an ileocecal interpositional reservoir.[1] Seven months (range, 4–18 months) after the surgical intervention, scintigraphic gastrointestinal transit was assessed. The results were compared with a group of healthy age- and sex-matched volunteers. Demographic details of both groups are given in Table 1. After informing the patients in detail about the experimental procedure, written consent was obtained for the protocol, which had previously been approved by the ethical committee of the Department of Surgery, University Hospital of Basel, Switzerland.

Supported by a grant from the Swiss National Science Foundation 32-42568.94.

Address reprint requests to Dr. Lukas P. Degen, Division of Gastroenterology, University Hospital, Petersgraben 4, CH-4031 Basel, Switzerland.

Accepted for publication May 5, 1997.

Operative Technique

Total mesorectal excision without mobilization of the left colonic flexure was performed for rectal cancer.[7] Details are given in Figure 1. The proximal anal canal was closed at the level of the puborectal sling with a linear stapler. The ileocolon was isolated with 7 cm of ileum, 17 cm of cecum, and adjacent ascending colon, rotated 180° counterclockwise, and placed ascending colon first on the pelvic floor, thus filling the presacral space. Any twisting of the vascular pedicle was carefully avoided. The anvil of the circular stapler (31 mm) already placed within the reservoir was engaged into the central shaft of

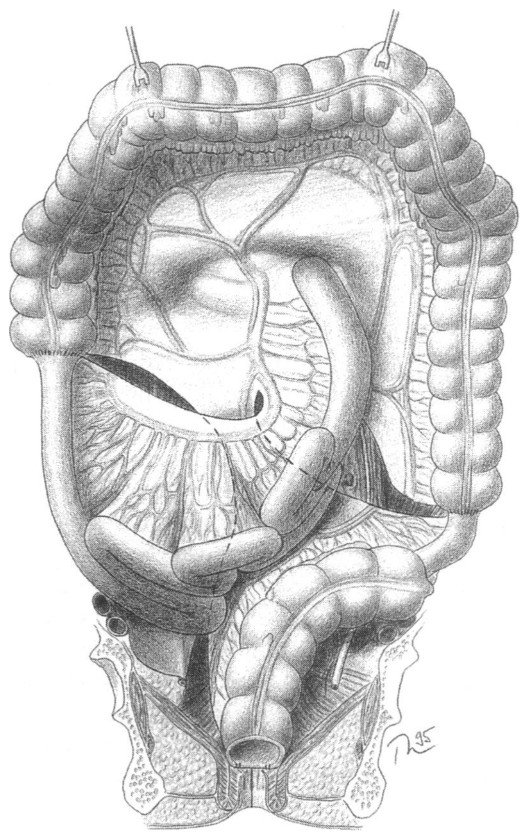

Figure 1. Schematic description of the operative procedure. (Modified from von Flüe M, Harder F, eds. Rektumchirurgie; Sphinktererhaltung und Rektumersatz. Berlin, Heidelberg: Springer Verlag, 1997, with permission.)

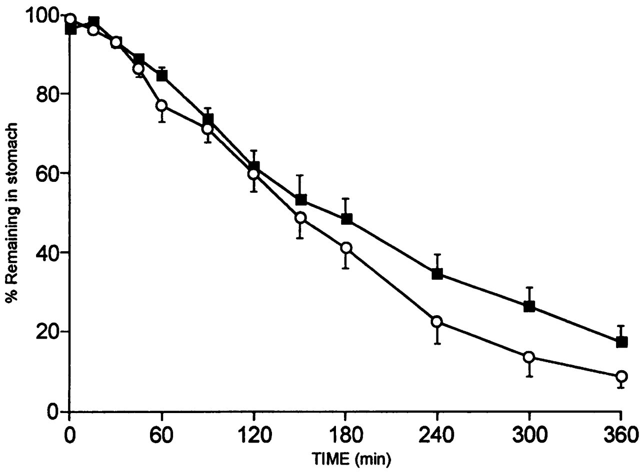

Figure 2. Gastric emptying curves for solid radiolabel (mean ± SEM) of 12 patients with ileocecal reservoir reconstruction after mesorectal excision and 12 matched controls. Gastric emptying did not differ in patients and controls (see Table 2).

the transanally introduced stapler, which was then fired. The tightness of the anastomosis was tested with Betadine solution transanally. The transected ileum of the transplant was anastomosed end to end with the transected sigmoid or descending colon. The oral end of the ileum was anastomosed to the ascending colon. A protective temporary right transverse loop colostomy was constructed and closed 3 months later.[1]

Study Procedure

Gastric, small bowel, and colonic transit times were measured by the noninvasive scintigraphic method developed at the Mayo Clinics.[5,8-11] In short, polystyrene Amberlite 120-IR-Plus resin pellets (average diameter 1 mm; range, 0.5–1.8 mm) were labeled with 100 μCi of $^{111}InCl_3$.[6] The efficiency of the labeling was >98%, as judged by thin-layer chromatography.[6] A capsule filled with approximately 0.5 g of pellets and coated with one layer of methacrylate was given to the fasting volunteers. As shown previously,[10] the capsule dissolves in the ileocecal region and therefore can be used to assess ileocecal transfer and colonic transit of markers. External radioactive markers were placed over both anterior superior iliac spines to estimate the location of the capsule. As soon as the radiolabeled capsule passed into the small bowel, a breakfast was ingested within 10 minutes consisting of two scrambled eggs, one piece of whole-wheat bread, and milk. The scrambled eggs were mixed and cooked with 1 mCi of ^{99m}Tc-labeled Amberlite 410 resin pellets (average diameter 1 mm) to a firm consistency to provide a solid medium. Four hours after breakfast, a standardized nonradiolabeled lunch was eaten; 8 hours after breakfast, a dinner was consumed.

Gamma Camera Imaging

Gamma camera imaging started immediately after ingestion of the radiolabeled breakfast, using a large field-of-view gamma camera with a medium-energy, parallel-hole collimator. Anterior and posterior images were acquired with the subject erect. A 140-keV energy window was used for the ^{99m}Tc counts, a 245-keV one for the ^{111}In counts (each with ±20% window). For each image, two minutes of acquisition were selected. Using variable regions of interest, the radioactivity was quantitated in the stomach and ascending colon for ^{99m}Tc and in four regions of the colon (ascending, transverse, descending, rectosigmoid) for ^{111}In.[10] The geometric means of the counts obtained from anterior and posterior images were calculated for each region and then corrected for radionuclide decay. The downscatter of ^{111}In into the ^{99m}Tc window was adjusted.

Data Analysis

Gastric emptying was assessed by the gastric lag time and postlag emptying rate and the half emptying time (T_{50}). The gastric lag time (in minutes) was the time taken for 10% of radiolabel to empty from the stomach.[11] The gastric postlag emptying rate (percent per minute) was characterized as the slope estimated by the linear regression analysis of the data points from the first point beyond the lag time until the time when 90% of the radiolabel had emptied from the stomach.[6] Small bowel transit time (in minutes) was assessed by subtracting the time for 10% of the radiolabeled breakfast to empty from the stomach from the time taken to enter the colon.[12]

The overall colonic transit was analyzed by the geometric center method at 6 and 24 hours.[5] The geometric center was the weighted average of proportions of counts in four regions of interest in the colon. Those regions, designated by numbers 1 to 4 as weighting factors, were, respectively, ascending, transverse, descending, and rectosigmoid colon. The stool was designated by number 5. The proportion in each indicated region was multiplied by

Table 2. GASTRIC EMPTYING TIMES

	Patients with Ileocecal Reservoir (n = 12)	Controls (n = 12)
Lag phase (min)	43 (31–50)	45 (34–63)
T_{50} (min)	143 (125–197)	204 (152–249)
Slope of emptying curve (%/min)	0.31 (0.2–0.4)	0.23 (0.2–0.3)

Data are median (95% confidence interval).

the weighting factor and the sum was calculated. A low geometric center suggested that most radiolabel was closer to the cecum; a high value indicated that the major part of the radiolabel was closer to the stool. The advantage of describing colonic transit as a geometric center rather than depicting it in time is that the bulk of luminal content in different segments can be assessed.

Statistical Analysis

Gastrointestinal transit data were expressed as medians (with 95% confidence intervals) and by Box-Whisker plots showing the median, the interquartile, and the total ranges. Gastric emptying rates and small bowel transit values were evaluated by the Wilcoxon's signed rank test; colonic transit was evaluated by analysis of variance. Significance was considered to be $p < 0.05$.

RESULTS

Functional Outcome

Eight patients had complete continence for gas and stool and 4 patients had occasional staining with liquid stool at night. One patient suffered from occasional imperative urgency (*i.e.*, the patient could not defer the urge for at least 10 minutes). Three patients reported fragmented, multiple evacuations, defined as the need to empty the neorectum twice or more within 1 hour. No patient was taking any medication other than natural fiber supplements to regulate bowel movements. All patients in the control group had normal bowel habits.

Scintigraphic Transit Studies

The results of gastric emptying are shown in Figure 2, Table 2, and Table 3. The lag phase for solid meals, the gastric emptying rate, and the half-time for gastric emptying were not significantly different between patients and healthy controls. Small bowel transit, defined as the time for 10% of isotope to move from the stomach to the colon, was of similar magnitude in both groups (Table 3 and Fig. 3). Colonic filling was nonlinear in both groups (data not shown). Finally, colonic transit time, expressed as the geometric center at 6 and 24 hours, showed no significant difference between the two groups (Table 3, Figs. 4 and 5).

Table 3. GASTROINTESTINAL TRANSIT TIMES

	Gastric Emptying T_{50} (min)	Small Bowel Transit (min)	Geometric Center 6 hr	Geometric Center 24 hr
Patients	161 ± 16	150 ± 15	1.53 ± 0.13	2.96 ± 0.23
Controls	201 ± 22	177 ± 22	1.27 ± 0.16	2.57 ± 0.25

Data are mean ± SEM.
T_{50} = gastric emptying time for half of the meal.

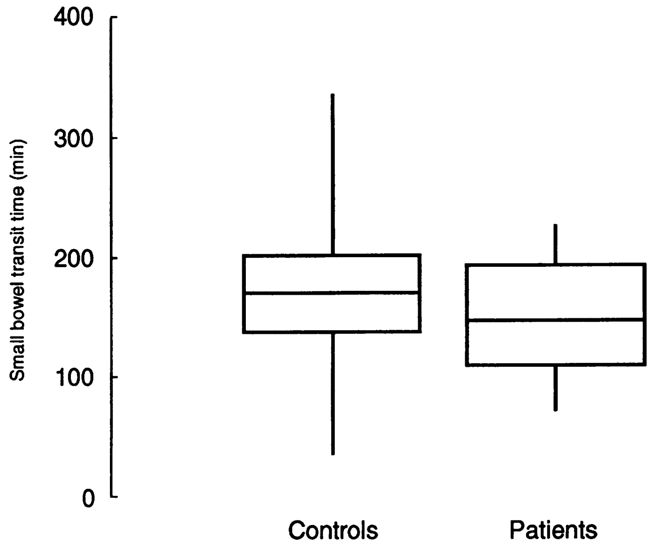

Figure 3. Scintigraphic assessment of small bowel transit in 12 patients with ileocecal reservoir reconstruction after mesorectal excision and 12 matched controls. Data are given as Box-Whisker plots. Small bowel transit times did not differ in patients and controls.

DISCUSSION

Located between two distinct segments of the gastrointestinal tract, the ileocecal region determines how intesti-

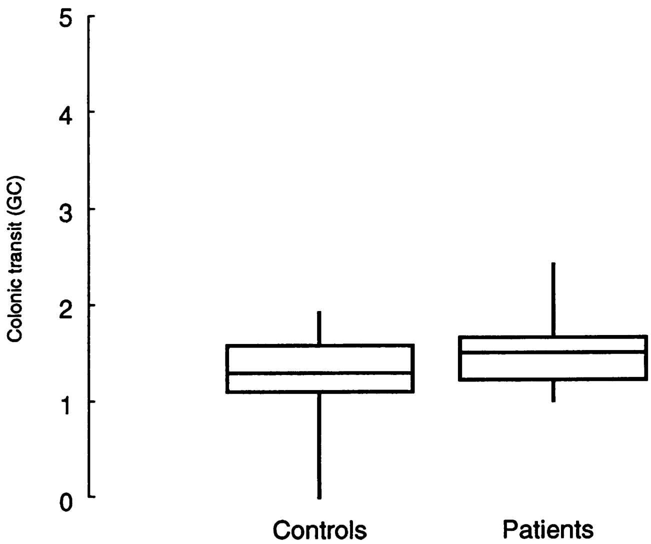

Figure 4. Scintigraphic assessment of colonic transit after 6 hours in 12 patients with ileocecal reservoir reconstruction after mesorectal excision and 12 matched controls. Data are given as Box-Whisker plots. The geometric center was not significantly different in patients and controls.

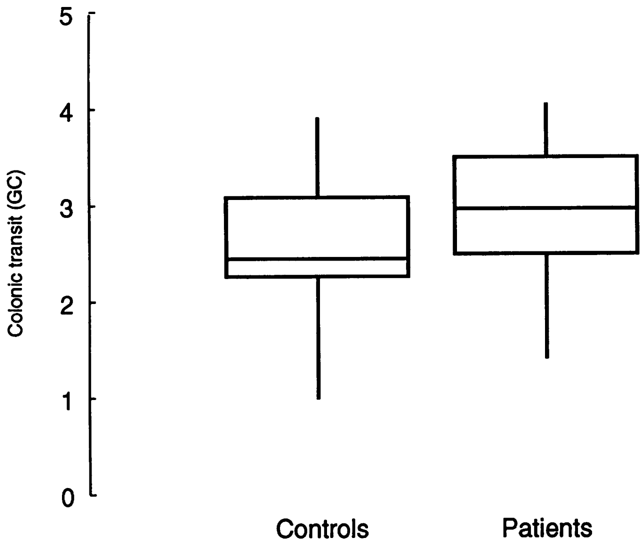

Figure 5. Scintigraphic assessment of colonic transit after 24 hours in 12 patients with ileocecal reservoir reconstruction after mesorectal excision and 12 matched controls. Data are given as Box-Whisker plots. The geometric center was not significantly different in patients and controls.

nal contents move between the two.[3] The following functions of the region have been identified: 1) optimized delivery of chyme into the colon after completion of digestion; 2) mechanical barrier as a safeguard against colonic reflux; and 3) inhibitory feedback effects on the proximal gastrointestinal tract, also described as the "ileal brake."[3,13-18] Therefore, the functional integrity of the gastrointestinal tract, and especially that of the ileocecal junction, could represent an important physiologic prerequisite.[3] The transposition of the ileocecal segment could not only induce functional deficits in the original anatomic area but could also create additional functional disorders in the new position. Along these lines, it is conceivable that transposition of the ileocecal segment with intact extrinsic neurovascular supply between the sigmoid colon and the anal canal may potentially disrupt gastrointestinal transit.

In this study, we did not intend to analyze fully the different functions of the ileocecal region. Instead, we attempted to determine the effect of the surgical procedure on transit times in various segments of the gastrointestinal tract (stomach, small intestine, colon) to gain more insight in the physiologic importance of this area. Therefore, we cannot comment on the flow of chyme to the colon or on motility consequences in the large bowel after elimination of the mechanical barrier. We can only state that the patients did not exhibit any clinical or laboratory sign of malabsorption or of bacterial overgrowth in the small intestine. The discussion is therefore focused on the consequences of ileocecal valve transposition on gut transit.

The results of our study show that gastric emptying, small intestinal transit, and colonic transit times remained within the limits of matched normal controls, suggesting that gut transit is not significantly affected by the operative procedure. How can these results be reconciled with the above-mentioned and accepted functions of the ileocecal region? The role of the ileocecal region in regulating transit has been a controversial topic for many years. Johansson et al.[19,20] have reported that surgical excision of the rat ileocecal junction resulted in a moderate delay rather than an acceleration of ileocolonic transit, suggesting a limited role for this region in regulating transit. However, Lundqvist et al.,[21] using a similar rat model, came to opposite conclusions and suggested that the ileocecal junction was an important regulator of ileocolonic transit. Along the same lines, Kruis et al.[22] and Neri et al.[23] concluded that the ileocolonic sphincter had only a small effect on transit in the ileocecal region. No data were given on gastric emptying, small intestinal transit, or colonic transit times in the latter studies. The procedure in our patients was a surgical excision and transposition of the whole intact ileocecal area to another anatomic location, and not a sphincterotomy, as performed in the animal studies. Thus, a direct comparison to these animal studies cannot be made.

The major caveats of the present experiments relate to the physiologic implications; these are related to the limitations of our methodology for measuring transit. Minor changes in transit in any distinct region could have been missed. Also, no data on flow rates in the ileocecal region can be given. Important clinical information can be derived from previous human studies, and this may be more relevant. Patients have been studied after various types of resections. Neal et al.[24] looked at effects of proctocolectomy and ileostomy for ulcerative colitis: gastric emptying remained unchanged. The Mayo group[25] demonstrated in patients with ileal pouch-anal reconstruction that oleic acid placed into the ileal pouch slowed gastrointestinal transit and delayed defecation. They concluded that the ileal brake may be of clinical importance. However, the same group showed later[4] that gastric emptying, small bowel transit, and segmental colonic transit times were unchanged in patients after right hemicolectomy. It must be stressed that in the latter patients, the ileocecal valve was removed; in our patients, it was still functioning. Taken together, these observations are still in keeping with our present results and an extension of canine studies performed by the Mayo group.[22,23]

In summary, the results imply that the transposition of the ileocecal region has little effect on the movement of chyme through the gastrointestinal tract. From this observation, we infer that this part of the gastrointestinal tract is not crucial for regulating chyme transport. More striking, the results provide no evidence for an important role of the ileal brake as a regulator of gastric emptying in humans, confirming data from Fich et al.[4] in patients with right hemicolectomy. The ileocecal reservoir reconstruction did not affect the lag phase or gastric emptying rates or late gastric emptying.

References

1. von Flüe M, Harder F. New technique for pouch-anal reconstruction after total mesorectal excision. Dis Colon Rectum 1994;37:1160–1162.
2. von Flüe M, Degen LP, Beglinger C, et al. Ileocecal reservoir reconstruction with physiologic function after total mesorectal cancer excision. Ann Surg 1996;224:204–212.
3. Phillips SF, Quigley EMM, Kumar D, Kamath PS. Motility of the ileocolonic junction. Gut 1988;29:390–406.
4. Fich A, Steadman CJ, Phillips SF, et al. Ileocolonic transit does not change after right hemicolectomy. Gastroenterology 1992; 103:794–799.
5. Stivland T, Camilleri M, Vassallo M, et al. Scintigraphic measurement of regional gut transit in idiopathic constipation. Gastroenterology 1991;101:107–115.
6. Camilleri M, Colemont LJ, Phillips SF, et al. Human gastric emptying and colonic filling of solids characterized by a new method. Am J Physiol 1989;257:G284–G290.
7. MacFarlane JK, Ryall RD, Heald RJ. Mesorectal excision for rectal cancer. Lancet 1993;341:457–460.
8. Camilleri M, Zinsmeister AR. Towards a relatively inexpensive, noninvasive, accurate test for colonic motility disorders. Gastroenterology 1992;103:36–42.
9. Vassallo M, Camilleri M, Phillips SF, et al. Transit through the proximal colon influences stool weight in the irritable bowel syndrome. Gastroenterology 1992;102:102–108.
10. Proano M, Camilleri M, Phillips SF, et al. Transit of solids through the human colon: regional quantification in the unprepared bowel. Am J Physiol 1990;258:G856–G862.
11. Camilleri M, Zinsmeister AR, Greydanus MP, et al. Towards a less costly but accurate test of gastric emptying and small bowel transit. Dig Dis Sci 1991;36:609–615.
12. Greydanus MP, Camilleri M, Colemont LJ, et al. Ileocolonic transfer of solid chyme in small intestinal neuropathies and myopathies. Gastroenterology 1990;99:158–164.
13. Quigley EMM, Borody TJ, Phillips SF, et al. Motility of the terminal ileum and ileocecal sphincter in healthy man. Gastroenterology 1984;87:857–866.
14. Spiller RC, Brown ML, Phillips SF. Emptying of the terminal ileum in intact humans. Influence of meal residue and ileal motility. Gastroenterology 1987;92:724–729.
15. Nasmyth DG, Williams NS. Pressure characteristics of the human ileocecal region—A key to its function. Gastroenterology 1985;89:345–351.
16. Spiller RC, Trotman IF, Higgins BE, et al. The ileal brake— inhibition of jejunal motility after ileal fat perfusion in man. Gut 1984;25:365–374.
17. Quigley EMM, Phillips SF, Dent J, Taylor BM. Myoelectric activity and intraluminal pressure of the canine ileocolonic sphincter. Gastroenterology 1983;85:1054–1062.
18. Faussone Pellegrini MS, Ibba Manneschi L, Manneschi L. The caecocolonic junction in humans has a sphincteric anatomy and function. Gut 1995;37:493–498.
19. Johansson H, Nylander G. Ileocolic transit in rats subjected to ileocecal resection. Acta Chir Scand 1969;135:455–458.
20. Johansson H, Nylander G. Analysis of the ileocecal emptying mechanism in the rat. Acta Chir Scand 1968;134:296–302.
21. Lundqvist H, Jung B, Gustavsson S, et al. Analyses of small bowel propulsion, ileocecal passage and serum gastrin after truncal vagotomy. Acta Chir Scand 1975;141:298–303.
22. Kruis W, Phillips SF, Zinsmeister A. Flow across the canine ileocolonic junction: role of the ileocolonic sphincter. Am J Physiol 1987;252:G13–G18.
23. Neri M, Phillips SF, Fich A, Haddad AC. Canine ileocolonic sphincter: flow, transit, and motility before and after sphincterotomy. Am J Physiol 1991;260:G284–G289.
24. Neal DE, Williams NS, Barker MC, King RF. The effect of resection of the distal ileum on gastric emptying, small bowel transit and absorption after proctocolectomy. Br J Surg 1984;71:666–670.
25. Soper NJ, Chapman NJ, Kelly KA, et al. The "ileal brake" after ileal pouch-anal anastomosis. Gastroenterology 1990;98:111–116.

Discussion

DR. P. HAWLEY (London, United Kingdom): Thank you very much. Your department has two papers this afternoon on this subject, and so I have to be a little careful of what I say on each; otherwise, I shall run out of comments for the next one. Your results are perhaps not surprising, and thank you for explaining them so well. I was wondering what the geometric center was. We all see patients who have minimal resections at the ileocecal region, perhaps with tumors, where there is no resection of any major neurovascular supply, and most of them are fine. Every now and again you get a patient who has gross diarrhea with bowel actions going from one or two a day to perhaps six and eight, and this really is a big social problem. Now I don't know whether it is because your numbers are so small, but you have not shown this in any patient. What would have been nice to see, and I guess you cannot do it, is to do your transposition leaving the neurovascular bundle intact, but to divide the nerves in some patients to see if it makes any difference. It is perhaps surprising that there is no change in colonic transit. I would not have really expected any change in gastric emptying or small bowel transit, but presumably all these cases have had a high tie of the inferior mesenteric vessels, and so some of the descending and sigmoid colon autonomic nerve supply is changed. We are not always quite sure what difference that makes. I am not sure whether your message is that you can do this interposition, which seems a good operation, and we will come onto that later, or whether the interposition does not make any difference. What would have been very nice is a similar study on your colonic pouches to see if there was any difference in colonic transit in them. I would still like, and I guess it is impossible to do, to see you do an interposition and denervate it by skeletonizing the ileocolic vessels.

PROF. H. OBERTOP (Amsterdam, The Netherlands): I have a question, if I may. Since you are talking about ileal brake and neurohormonal control, did you estimate any hormones to check this, and what did you expect after this procedure?

PROF. R. SHIELDS (Edinburgh, United Kingdom): I was interested in this paper because a number of years ago we were interested in the use of ileal transposition in the treatment of postgastrectomy and postvagotomy diarrhea. We found that if an ileal transposition was put in between the stomach and the