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ORIGINAL CONTRIBUTIONS

# The Effect of Stool Consistency on Rectal and Neorectal Emptying

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Although stool consistency is considered to be an important component of anorectal continence, its effect on rectal emptying has never been quantitated. In 12 healthy volunteers and 12 patients after ileal pouch-anal anastomosis (IPAA) (46 ± 5 months after the operation; mean ± SEM), perfused anal manometry was performed; movements of the anorectal angle were quantitated scintigraphically; and rectal capacity and compliance were measured by air insufflation of an intrarectal balloon at three infusion rates. The efficiency of rectal evacuation of three consistencies (5 percent, liquid; 7.5 percent semisolid gel; 11.25 percent solid gel; w/w) of Tc99m labeled artificial stool (aluminum magnesium silicate gel) was quantitated by gamma camera imaging. No abnormalities of pelvic floor function were demonstrated in either controls or patients. The mean neorectal capacity and compliance of patients with IPAA did not differ from control, (capacity; IPAA: 215 ± 22 ml *vs.* control; 245 ± 29 ml; compliance; IPAA: 5.5 ± 0.7 ml/cm $H_2O$ *vs.* control; 6.6 ± 0.7 ml/cm $H_2O$; $P > 0.05$). In controls, the percentage of the 7.5 percent consistency evacuated (81 ± 5 percent, mean ± SEM) was significantly more than the percentage evacuation of either the 5 percent consistency (67 ± 7 percent) or the 11.25 percent consistency (77 ± 2 percent) ($P < 0.05$). After IPAA, the mean overall percent evacuation of the three stool consistencies was significantly less than control (52 ± 6 percent after IPAA; 75 ± 5 percent control, $P < 0.05$). However, there was no significant difference in neorectal emptying between the liquid, the semisolid gel and the solid gel (56 ± 6, 55 ± 6, 51 ± 9 percent, respectively, $P > 0.1$). We concluded that in healthy subjects but not in patients after IPAA, stool consistency affected the efficiency of evacuation of enteric content. [Key words: Rectal evacuation; Scintigraphy; Consistency; Compliance]

Fecal continence and the process of defecation depend upon the complex interaction of various factors including: 1) the anal canal high pressure zone (the anal sphincter mechanism), 2) the anorectal angle, 3) anorectal sensory and reflex mechanisms, 4) rectal capacity and distensibility, 5) rectal motility and evacuability, and 6) stool volume and consistency. Although some of these factors have been studied in detail, both in health and disease, the contribution of others remains poorly understood.[1,2]

Colonic absorption of water reduces the 1,000–1,500 ml of small bowel content introduced to the cecum per day to the approximately 150 ml of stool evacuated daily. The consistency of stool is normally firm. It seems apparent that if the consistency of the stool is altered, continence and defecation mechanisms might be stressed. For example, small pellets of hard stool introduced slowly into the rectum likely decrease the degree of rectal disten-

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Diseases of the Colon & Rectum

sion and, in turn, the presence of content goes unrecognized. This may occur because the rectoanal inhibitory reflex is not initiated.[3] This sequence of events occurs commonly in older people. On the other hand, increased volumes of liquid stool emptied rapidly into the rectum may quickly overcome the continence mechanism, causing incontinence. Although seemingly of a central importance, the role stool consistency plays in maintaining continence and facilitating defecation is unknown.

Patients who have undergone ileal pouch-anal anastomosis (IPAA), an operation designed to maintain fecal continence in patients requiring total proctocolectomy, generally enjoy good functional results. However, some patients have frequent stools and episodes of incontinence.[4–7] Of the many studies that have investigated the influence of the ileal reservoir and of the anal sphincters on function after IPAA,[8–11] not one has addressed the role of stool consistency in neorectal emptying.

We sought to determine the effect of stool consistency on the efficiency of rectal emptying in healthy volunteers and neorectal emptying in patients after ileal pouch-anal anastomosis, using low-radiation, real-time scintigraphic imaging of radiolabeled artificial stool.

## METHODS

### Subjects

Twelve healthy volunteers were recruited to participate. There were four men and eight women, ranging in age from 21 to 62 years (40 ± 4 years; mean ± SEM). None had undergone a colon or anorectal operation, and none complained of incontinence, constipation, or any other anorectal problem. Twelve patients, 46 ± 5 months (mean ± SEM) after IPAA were studied. There were six men and six women, ranging in age from 21 to 53 years (35 ± 3 years). All 12 patients had a good result, defined as <8 stools/24 hour, few if any episodes of leakage, full defecation function, return to active life style and return to work and school.

### Consent

All subjects gave informed, written consent to a protocol approved by the Institutional Review Board of the Mayo Clinic.

### Conduct of Study

Subjects were admitted to the outpatient study area of the Clinical Research Center at the Mayo Clinic, where all tests were performed. Each subject had fasted overnight and had taken one phosphate enema one hour before the study began. To quantitate pelvic floor function, anal manometry was performed, rectal (neorectal) capacity and compliance were determined, and the anorectal angle was evaluated before assessing the evacuation of three consistencies of artificial stool.

### Anorectal Manometry

Anorectal manometry was performed using a perfused four-channel plexiglass probe (outer diameter = 1.2 cm).[12] The four 0.14-cm channels were oriented 90 degrees apart and were located 1 cm proximal to the tip. The channels were perfused with distilled water at the rate of 0.3 ml/minute via a low-compliance, pneumohydraulic perfusion system connected to Statham P23 strain gauges (Gould Recording Systems, Cleveland, OH) and a multichannel recorder (Honeywell 1600, Honeywell Corp., Denver, CO).

Each volunteer was placed in the left lateral decubitus position, and the probe inserted through the anal canal into the rectum or neorectum. The probe was withdrawn at 1-cm intervals and resting pressures were recorded throughout the anal canal. The test was repeated and the subject asked to squeeze the anal sphincter muscle; in this way squeeze pressure was recorded at each 1 cm interval in the anal canal.

### Rectal Capacity and Compliance

A 600-ml noncompliant thin-walled flaccid polyurethane bag was placed in the rectum (or neorectum), connected to a Gas Cystometer (Model N7410, American Medical Systems, Inc., Golden Valley, Minnesota) and inflated at a rate of 50, 100, and 200 ml/min. Continuous pressure recordings were obtained during each infusion. The volumes and pressures at which the subject: 1) sensed the balloon, 2) felt the urge to defecate, and 3) experienced discomfort were recorded.

Rectal compliance was determined as slope$^{-1}$ $\Delta V/\Delta P$ from time zero to the discomfort volume. The discomfort volume and compliance were calculated as the mean of the values determined for each filling rate.

### Anorectal/Neorectal Angle

A latex balloon (12 cm in length, 2.2 cm in diameter) attached to a flexible rubber catheter

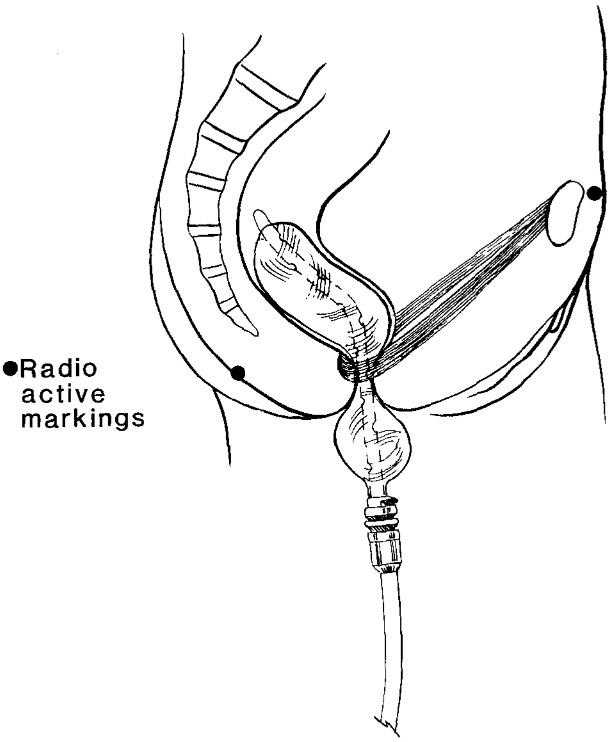


**Figure 1.** Diagram of the scintigraphic balloon device in place. A portion of the balloon rests in the rectum, a portion traverses the anal canal, and a portion rests outside of the anal canal. Radioactive markers are taped to the skin over the pubis anteriorly and over the coccyx posteriorly (by permission; Ref. 13).

(5.3 mm outer diameter) was inserted through the anal canal and positioned in such a manner that the proximal portion rested in the lumen of the rectum (neorectum) and the distal portion traversed the anal canal (Figs. 1 and 2).[13] The balloon was filled with 40 ml of water containing 5 mCi of Technicium-99 and the rubber catheter was filled with 2 ml of water containing 15 mCi of Technicium-99 for improved resolution. Images were collected by a large-field-of-view gamma camera (Model #500A, General Electric Inc., Milwaukee, WI). The camera was linked to an $A^2$ computer (Medical Data Systems Inc., Ann Arbor, MI). Each subject was placed in the left lateral decubitus position with thighs drawn up at right angles to the longitudinal axis of the body. Fifteen-sec images with the balloon in place were taken with the subject at rest, with the pelvic muscles squeezed and with attempted defecation of the balloon.

## Rectal/Neorectal Evacuation

Rectal and neorectal emptying were estimated for three artificial stool consistencies by dynamic scintigraphic imaging.[14] The artificial stool was a colloid dispersion of aluminum magnesium silicate to which 1 mCi of Technicium-99 was added. The three consistencies were liquid (5.0 percent colloid dispersion w/w), semisolid gel 7.5 percent) and solid gel (11.25 percent). Binding of the 99 mTc was 99.8 percent for each of the artificial stool consistencies. Each consistency of the radiolabeled artificial stool was inserted into the rectum (or neorectum) of each subject using an enema

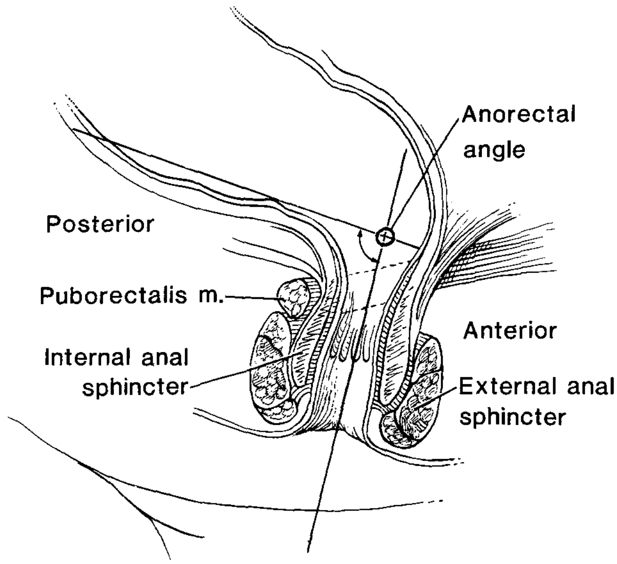


**Figure 2.** Diagram demonstrating the angle formed by the axis of the anal canal and the rectum (by permission; Ref. 13).

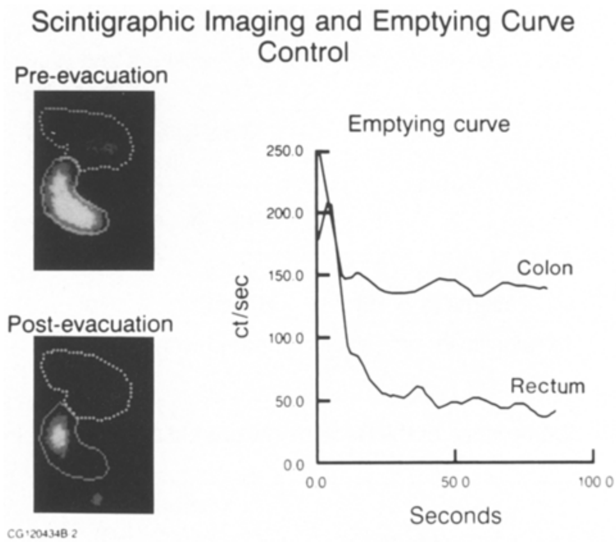


**Figure 3.** Lateral pre- and postdefecation scans (left) and emptying curves (right) in a healthy control subject with regions of interest drawn around the distal sigmoid colon and the rectum. Note that the sigmoid colon emptied first into the rectum and then the rectum emptied. Note also the rear completeness of emptying compared with Figure 4.

tube. The volume inserted was equal to the discomfort volume that had previously been determined by the balloon insufflation technique. The order of administration of the three consistencies was computer randomized.

Lateral preevacuation scans were obtained using a gamma camera with the subject seated on a radiolucent commode (Figs. 3 and 4). Dynamic scanning over a 90-second interval was performed during defecation of each of the radiolabeled artificial stools, followed by a postevacuation scan. Regions of interest were drawn around the rectum/neorectum and distal sigmoid colon/distal ileum. The counts within each region were plotted every 2 sec during defecation. The time required to expel 80 percent of the total radiolabeled artificial stool evacuated from the rectum or neorectum for each consistency was determined from the dynamic scanning plots. The percentage rectal (neorectal) evacuation was obtained by comparing the pre- and postevacuation counts from the lateral scans.

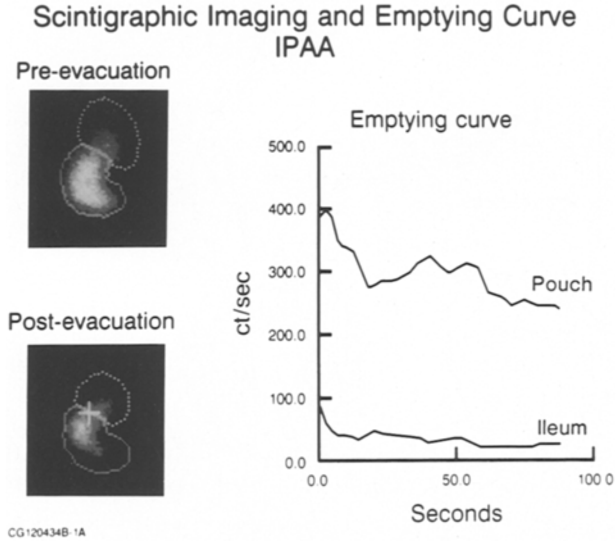


**Figure 4.** Lateral pre- and postdefecation scans (left) and emptying curves (right) in an IPAA patient with regions of interest drawn around the distal ileum (dotted line) and the ileal pouch (solid line).

## Statistical Analysis

All data are expressed as mean ± SEM. The results were evaluated using the Student's *t*-test for unpaired data. A logit transformation of the proportion evacuated for each consistency was performed and a paired Student's *t*-test was applied to data obtained serially from within individuals. Under these circumstances, a Bonferroni correction for multiple comparisons was made.

# RESULTS

## Anal Manometry

Resting and squeeze anal canal pressures for the 12 controls and 12 IPAA patients are listed in Table 1. Although the mean resting and squeeze

**Table 1.**
Anal Canal Resting and Squeeze Pressures and Sensation Volumes in Controls and Patients after IPAA (All Values Mean ± SEM)

| Group | Anal Canal Pressures (mm Hg) | | Volume (ml) at | | |
|---|---|---|---|---|---|
| | Resting | Squeeze | First Sensation | Urge to Defecate | Discomfort |
| Controls (n = 12) | 74 ± 7 | 117 ± 10 | 115 ± 14 | 186 ± 23 | 245 ± 29 |
| Patients (n = 12) | 67 ± 6* | 105 ± 9* | 97 ± 14* | 178 ± 17* | 225 ± 22* |

* No significant difference compared with controls ($P > 0.1$).

**Table 2.**
Compliance of the Rectum in Controls and of the Neorectum in Patients after IPAA at Different Rates of Balloon Inflation (Mean ± SEM)

| Group | Compliance ($ml/cm\ H_2O$) | Compliance ($ml/cm\ H_2O$) at Infusion Rates (ml/min) of | | |
|---|---|---|---|---|
| | Overall | 50 | 100 | 200 |
| Controls (n = 12) | 6.6 ± 0.7 | 7 ± 0.9 | 7.2 ± 0.8* | 5.9 ± 0.6 |
| Patients (n = 12) | 5.5 ± 0.7† | 3.7 ± 0.4 | 7.2 ± 1.2‡ | 5.2 ± 1.1 |

* Significantly greater than the 200 ml/min filling rate in control group ($P < 0.05$).
† Not statistically different from control group ($P > 0.1$).
‡ Significantly greater than either the 50 ml/min or the 200 ml/min filling rate in patient group ($P < 0.05$).

anal canal pressures for the IPAA group were lower than control, this difference was not statistically significant.

## Rectal/Neorectal Sensory Threshold and Capacity

The volumes 1) at which the intrarectal/intraneorectal balloon was perceived, 2) at which the urge to defecate was reproduced and 3) at which discomfort was noted did not differ significantly between the IPAA patients and controls (Table I).

## Rectal/Neorectal Compliance

The mean compliance determined from the three rates of filling for the control group did not differ significantly from the patient group (Table 2). Compliance was, however, dependent on rates of filling. Among both controls and patients, the rectum/neorectum was most compliant at a filling rate of 100 ml/min. This difference was significantly greater than the 200 ml/min. rate among controls and significantly greater than both the 50 ml/min and 200 ml/min filling rates among the IPAA group (Table 2).

## Anorectal and Anoneorectal Angle

The *anorectal* angle of control subjects was significantly more acute than the *anoneorectal* angle of IPAA patients at rest and during squeeze (Table 3). During defecation, this difference approached significance ($P = 0.05$). The direction and magnitude of the change in the angle, however, was not different between groups with attempted defecation, indicating that functional movements of the perineum are maintained in the patients after IPAA.

## Rectal Evacuation

The volume of each of three consistencies of radiolabeled aluminum magnesium silicate gel instilled in each subject was equivalent to the discomfort volume previously determined. All volunteers were able to retain the labeled aluminum magnesium silicate until asked to evacuate. The preevacuation lateral scans demonstrated that the labeled aluminum magnesium silicate was distributed in both the rectum and sigmoid colon in the control group (Fig. 3), and in the pouch and distal ileum in the IPAA group (Fig. 4). Interestingly, there was no difference between controls and patients in the time required to evacuate 80 percent of each of the three artificial stool consistencies (Table 4).

Table 5 lists the mean percent *rectal* evacuation for each of the three consistencies of labeled aluminum magnesium silicate among the controls; the mean percent rectal evacuation of all consistencies was 75 ± 5 percent. The percent semisolid gel evacuated was significantly greater than either the liquid or the solid gel ($P < 0.05$) (see also Fig. 5). Among controls, the difference between the percent evacuation of the liquid and the solid gel was not significant ($P > 0.1$) (see also Fig. 5).

The mean *neorectal* evacuation of all consistencies in the IPAA patients was 54 ± 6 percent, which was significantly less than that of controls ($P < 0.05$) (Table 5). All consistencies emptied less efficiently among patients compared with controls

**Table 4.**
Eighty Percent Evacuation Time in Controls and Patients after IPAA (Mean ± SEM)

| Group | Evacuation Time (sec)/ Consistency | | |
|---|---|---|---|
| | Liquid | Semisolid Gel | Solid Gel |
| Controls (n = 12) | 13 ± 2* | 20 ± 4* | 14 ± 2* |
| IPAA (n = 12) | 19 ± 4† | 19 ± 3† | 22 ± 4† |

* No statistical difference between consistencies ($P > 0.05$).
† No statistical difference between patients and controls ($P > 0.05$).

**Table 3.**
Movement of Anorectal and Anoneorectal Angles and Magnitude of Perineal Descent in Controls and in Patients after IPAA (Mean ± SEM)

| Group | Angle (°) | | | Δ Angle (°) with Defecation | Perineal Descent (cm) |
|---|---|---|---|---|---|
| | Rest | Squeeze | Defecation | | |
| Controls (n = 12) | 108 ± 6 | 93 ± 8 | 120 ± 8 | +12 ± 4 | 1.6 ± 0.4 |
| Patients (n = 12) | 130 ± 7* | 123 ± 7* | 140 ± 6† | +10 ± 3‡ | 1.6 ± 0.4‡ |

* Statistically significant difference from controls ($P < 0.05$).
† Approaches statistical significance compared to controls ($P = 0.05$).
‡ Not statistically significant compared with controls ($P > 0.1$).

**Table 5.**
Percent Evacuation of Different Consistencies of Artificial Stool in Controls and Patients after IPAA (Mean ± SEM)

| Group | Overall % Evacuation | % Evacuation by Consistency | | |
|---|---|---|---|---|
| | Mean | Liquid | Semisolid | Solid |
| Controls (n = 12) | 75 ± 5 | 67 ± 7† | 81 ± 5*† | 77 ± 2† |
| IPAA (n = 12) | 54 ± 6** | 56 ± 6*** | 55 ± 6*** | 51 ± 9*** |

* Differs from liquid consistency ($P < 0.05$) and solid gel consistency ($P < 0.05$) within control group.
† Differs from IPAA ($P < 0.05$).
** Differs significantly from controls ($P < 0.05$).
*** No significant difference from other consistencies among patients ($P > 0.1$).

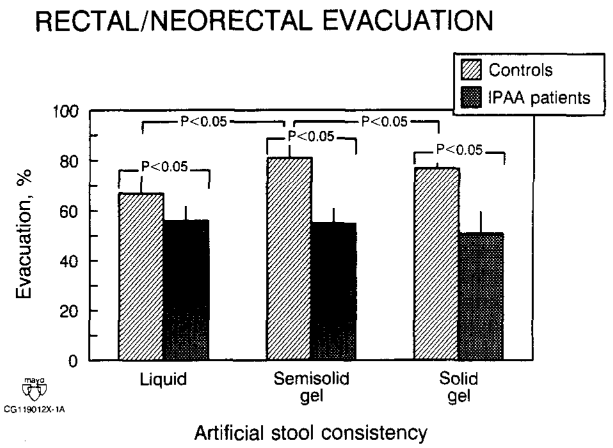


**Figure 5.** Percentage rectal and neorectal evacuation of each consistency of artificial stool. Among controls, the semisolid gel was emptied more efficiently than either the liquid or solid gels. All consistencies, however, emptied less efficiently among the patients compared with the controls.

($P < 0.05$). However, unlike the control group, the IPAA patients did not demonstrate any significant difference in their ability to evacuate the different consistencies of artificial stool (Fig. 5).

## DISCUSSION

The mechanisms responsible for maintaining enteric continence and facilitating defecation interact to perform three key functions: 1) provide an effective barrier to outflow, 2) ensure a capacious but adequate and readily evacuable reservoir and 3) facilitate a manageable volume and consistency of stool.

*Stool volume* is important in maintaining continence because large volumes delivered rapidly to the rectal vault will overwhelm the continence mechanism. A capacious, compliant rectum accommodates some of the excess. However, we have demonstrated in this study that at extremely rapid rates of rectal filling, rectal compliance *decreased.* This decrease might be the result of the viscoelastic properties of the rectal muscular wall or be due to a decreased sensory threshhold for rectal distention that may occur at the faster rates of filling.[15]

Although the contribution of stool *consistency* to maintaining enteric continence and facilitating defecation remains poorly understood, it has been accorded a central role.[16] We found that in healthy subjects, the majority of artificial stool was evacuated promptly, and that the consistency of that stool had a quantifiable effect on the efficiency of emptying such that artificial stool of a semi-solid gel consistency was evacuated from the rectum more efficiently than either a liquid or a solid consistency. Importantly, all controls and all patients after IPAA had normal pelvic floor movement and function. Each was able to achieve an incremental increase in anal canal pressure voluntarily. All subjects were able to sense the intraluminal balloon upon insufflation and all had a distensible and capacious rectum or neorectum. The movements of the pelvic floor and changes in the anorectal angle were appropriate during squeeze and straining to defecate. Differences in evacuation efficiency, therefore, could not be attributed to differences in pelvic floor function.

Although parameters of pelvic floor and anal sphincter function were similar between the IPAA patients and control subjects, the neorectum of patients after IPAA evacuated less efficiently than controls. The reasons for such inefficient evacuation are unknown. Moreover, in IPAA patients, consistency of the stool had no effect upon evacuation efficiency.

We concluded that in health, consistency of the stool affected the efficiency of evacuation. These results confirm the theoretical importance placed on stool consistency in the past[16] as a facilitator of defecation and lend credibility to the use of agents that alter consistency in patients with disturbances of defecation. Although IPAA did not alter pelvic floor function nor result in changes in reservoir capacity or compliance, efficiency of evacuation was less than in controls, and consistency of content did not alter that efficiency in any way. The reasons for these findings are unknown but suggest that attempts to alter stool frequency by changing stool consistency after IPAA will not be beneficial. In contrast, whether *retention* of contents may be enhanced by altering stool consistency, either in health or after IPAA, needs to be studied.

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