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Failure of Psyllium Mucilloid to Hasten Evacuation of Sand From the Equine Large Intestine

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Objective—To examine the efficacy of psyllium mucilloid in evacuating sand from the equine large intestine.

Animals—12 clinically healthy pony geldings.

Procedure—Twelve ponies were assigned to 2 groups of six each. One group was treated with psyllium and the second was a control group. All ponies had an exploratory celiotomy and 10 g/kg body weight of sand was placed into the cecum. Ponies were fed a grain mixture alone at 1 g/kg (controls), a grain mixture plus psyllium pellets, each at 1 g/kg body weight (3 ponies), or fed a grain mixture and given psyllium powder by nasogastric tube at 1 g/kg body weight divided into two daily doses in 3 L of water (3 ponies). Radiographs were taken on days 1 (3 per group), 5 (all ponies), and 11 (3 per group) to monitor sand transit through the large intestine. Ponies were euthanatized 11 days after surgery. Sand was collected from the contents of the cecum, ventral colon, dorsal colon, and small colon. Dry weight of the recovered sand was compared between the two treatment groups as a percentage of the dry weight of sand placed in the cecum.

Results—No significant differences were detected in the mean percentage of sand recovered between the two treatment groups ($P < .05$), with 39.2% recovered in ponies treated with psyllium and 27.4% recovered in control ponies.

Clinical Relevance—Psyllium mucilloid had no apparent effect on sand evacuation from the equine large intestine. When intake of sand is prevented, the equine large intestine can reduce and possibly eliminate its sand burden.

IN VARIOUS GEOGRAPHICAL areas of the United States, chronic diarrhea, weight loss, and colic caused by the ingestion of sand are common.[1-3] Problems arise when sand accumulates in the intestinal tract in sufficient amounts to cause mucosal damage or luminal obstruction. Although long-term survival after surgery for sand impaction can be as high as 90%,[4] a mortality of 40% has been reported.[5]

Most cases of mild sand impaction respond to medical treatment with nonsteroidal antiinflammatory drugs, mineral oil, dioctyl sodium sulfosuccinate, and brief periods of food deprivation.[6] Psyllium is fed to horses to prevent or treat sand impactions because it is believed that it can dislodge sand from the intestine and hasten its evacuation by lubrication.[6-11] This use of psyllium is an adaptation from its use as a bulk-forming laxative in humans, in whom its contribution of soluble fiber to a fiber-deficient diet is of considerable benefit.[12,13] In humans, psyllium has been shown to soften feces and

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physically bind bile salts, thus reducing cholesterol.[14] It has also been associated with a reduction in the incidence of colon cancer.[15] Fermentation of psyllium by intestinal bacteria results in the production of short-chain fatty acids that may facilitate mucosal healing in the intestine.[12,16,17]

Psyllium has been used for many years in the treatment of sand impaction in horses,[6] although claims of a beneficial effect are largely anecdotal. It is also used as a general-purpose laxative in horses,[10,11] most likely because of its use for this purpose in humans.[12,13] The high-fiber diet and proportionately greater bulk of colon contents in horses compared with humans, would appear to diminish the possible laxative properties of psyllium fiber in horses. However, psyllium could hasten sand removal by virtue of putative physical properties that would allow it to permeate and disrupt a sand mass in a way that other laxatives cannot.

In a literature review, only one published report was found of a controlled study evaluating the efficacy of psyllium for removal of sand from the equine intestine.[18] In that study, a small dose of sand was given by stomach tube and sand excretion in feces was monitored. The single dose of psyllium did not increase sand excretion over 5 days, although the frequency of administration and dose of psyllium used were less than currently recommended.

This study was designed to test the hypothesis that psyllium does not affect sand evacuation from the equine large intestine. A measured volume of sand was placed surgically in the large intestine of ponies to evaluate the ability of psyllium to facilitate sand evacuation from the large intestine. The sand used was composed of different-sized particles to simulate the clinical situation and because the intestinal tract appears to handle fine sand differently than coarse sand.[9]

MATERIALS AND METHODS

Animals

Twelve clinically normal, pony geldings scheduled for an exploratory celiotomy in a student surgery laboratory were used for this study. Ponies were vaccinated against tetanus, dewormed with ivermectin, and housed in an approved laboratory animal facility. They received fresh water and grass hay ad libitum daily for 4 to 6 weeks before the study. Temperature, pulse, respiratory rate, incisional healing, ventral edema, attitude, and appetite of each pony were monitored twice daily by the students responsible for each individual pony, and the ponies were checked for all but vital signs 2 to 3 times daily by the principal investigator. This study design was approved by the Animal Care and Use Committee of the University of Illinois, College of Veterinary Medicine.

Sand

Sand (Torpedo FA-01-02 Sand; Champaign Builders Supply, Champaign, IL) used for this study is a type commonly found in horse stalls and arenas. The sand was dried in an oven and all measurements were performed on basis of dry weight obtained on an electronic balance. The mean percentage of large particles in the sand was 21.8%, with a range of 15.3% to 29.9% for individual doses, as determined by separation with a household wire colander with a 3-mm mesh size. Preweighed sand was placed in autoclavable plastic tubes, the tubes were taped closed with autoclave tape, and autoclaved before surgery.

Experimental Design

During an exploratory celiotomy laboratory performed by junior students, sand was placed in the cecum of treated and control ponies by one of the investigators (Hammock or Freeman), according to the following method: A 10-cm typhlotomy was made 5 to 10 cm from the cecal apex, along the convex curvature of the cecum (Fig 1). A preweighed volume of sterilized sand was placed in the cecum at a dose of 10 g/kg body weight on a dry weight basis. For this purpose, the plastic sterilization tube containing the preweighed dose of sand was opened by cutting off one end of the tube. The open end was then closed with a snare created by inserting a loop of 2 nylon suture material through the lumen of a Chambers mare catheter. The loop was placed around the open end of the tube, pulled tightly, and secured with a hemostat placed on the tails of suture material at the other end of the catheter. This closed end of the tube was then inserted into the cecum while the typhlotomy site was stabilized between two stay sutures (Fig 1). When the tube was in the base of the cecum, the hemostat was removed and the suture was pulled out of the catheter, thus allowing the tube to open. The sand was allowed to flow into the cecum by gravity flow and agitation of the plastic tube. Through a sterile funnel, 1 L of sterile saline was added to the cecal contents and sand. The typhlotomy was closed with a Lembert then a Cushing pattern with use of 2-0 polydioxanone. Ponies were recovered from anesthesia after abdominal closure. Ceftiofur sodium (2.2 mg/kg intramuscularly [IM], once daily) and flunixin meglumine (1.1 mg/kg intravenously [IV], twice daily) were administered for 72 hours after surgery.

Fig 1. Method of inserting the sterile plastic tube of sand through a typhlotomy stabilized between stay sutures.

Treatment With Psyllium

Control ponies received a concentrate mix (Sweet Feed; Prairieland Feeds, Savoy, IL) once daily at a rate of 1 g/kg body weight. Psyllium treated ponies received the same mix at the rate of 1 g/kg in addition to psyllium mucilloid pellets (Equi-Aid 99% Psyllium Pellets; Equi-Aid Products, Phoenix, AZ) at a rate of 1 g/kg body weight once daily. All feeding and treatment regimens were started 3 days before surgery. Three ponies would not eat the psyllium supplement when it was added to the concentrate as pellets or as a powdered top dress. They were therefore given psyllium powder at the same rate of 1 g/kg, (100% Psyllium Powder; Equi-Aid Products, Phoenix, AZ) divided into two doses, by nasogastric intubation every 12 hours. Water, to a final volume of 3 L, was added immediately before intragastric infusion. Food and psyllium were withheld from all ponies for 12 hours before surgery and were provided again immediately afterwards.

Abdominal Radiographs

Abdominal radiographs were obtained on 3 control ponies and 3 treated ponies on days 1, 5, and 11 postoperatively. Radiographs were taken in the other 3 ponies in each group on day 5 only. Routine radiographic techniques were used with a 1200 mAs radiographic unit (MSI-1250; General Electric, Plainville, CT), rare earth screens (Lanex; Eastman Kodak, Rochester, NY) and film (TML; Eastman Kodak, Rochester, NY), a 5:1 criss-cross grid, and standard positioning for standing lateral radiographs.[19] Sedation was not used.

Collection and Measurement of Sand

Ponies were euthanized 11 days after surgery and the contents of the cecum, ventral colon, dorsal colon, and small colon were collected into separate, white, plastic, 20-L containers. White containers were used to facilitate identification of small amounts of sand that settled to the bottom. Water was added to each container to thoroughly dilute the contents and the containers were allowed to sit for 24 hours before sand recovery. The first dilution of intestinal contents typically resulted in recovery of greater than 75% of the sand present in each segment. Subsequent dilutions resulted in collection of progressively smaller volumes of remaining sand. The sand settled to the bottom of the container in which it was collected, whereas intestinal contents remained suspended and could be progressively diluted and removed by decantation. The collected sand was then dried in an oven and weighed on an electronic balance. After drying, the sand was separated into large and small particles with a screen colander. The large particles were weighed in addition to the smaller sand particles for recovery analysis.

Validation of Method for Sand Recovery

Test recovery of sand was performed on intestinal contents from horses euthanized for reasons other than sand colic. A total of 500 g of sand was added to 20 L of intestinal contents with 825 g of psyllium pellets (n = 1), 825 g of psyllium powder (n = 1), or no psyllium (n = 2). The sand, psyllium, and intestinal contents were thoroughly mixed and allowed to sit for a 24-hour period before sand recovery. The method for sand collection and recovery was as described for intestinal contents.

Statistical Analysis

The dry weights of fine sand, coarse sand, and both combined (total sand) were expressed as percent recovered from each of the four intestinal segments and for all segments combined. Descriptive statistics indicated a normal distribution of data and homogeneity of vari-

Table 1. Recovery of Fine and Coarse Sand Particles Expressed as the Mean Percentage of the Total Amount Given (±SEM) in the Four Intestinal Segments Examined 11 Days After Intracecal Infusion of Sand

Group	Sand	Cecum	Ventral Colon	Dorsal Colon	Small Colon	Total % Recovered
Controls	Fine	1.9 ± 0.8	4.6 ± 3.4	11.6 ± 4.5*	1.7 ± 0.6	19.7 ± 5.4
	Coarse	10.3 ± 4.7	11.6 ± 4.1	36.3 ± 9.6*	0.4 ± 0.2	58.6 ± 7.5
	Total	3.5 ± 1.5	5.9 ± 3.4	16.7 ± 5.5*	1.4 ± 0.4	27.4 ± 5.2
Treated	Fine	3.2 ± 1.6	6.9 ± 3.2	21.1 ± 8.5*	1.6 ± 0.4	32.8 ± 10.5
	Coarse	14.3 ± 6.2	14.1 ± 5.5	32.0 ± 6.6*	1.2 ± 0.5	61.6 ± 3.6
	Total	5.5 ± 2.5	8.5 ± 3.4	23.8 ± 7.4*	1.5 ± 0.4	39.2 ± 8.7

* Significantly different than other segments in the same row ($P < .05$).

ance.[20] A unidirectional hypothesis was used in completing a Student's *t*-test for comparison of group means. Analysis of variance was used to determine if there were differences in fine, coarse, and total sand accumulations between intestinal segments. A post-hoc comparison was done using Tukey's test. Significance was set at $P < .05$. Power analysis was completed at the end of the study because expected effect size was not known.[21]

RESULTS

The postoperative course, frequency of abdominal incisional swelling, drainage, and adhesion formation between the cecal apex and abdominal incision appeared, subjectively, to be similar to surgery ponies of previous years, when only an exploratory celiotomy was performed. One pony had mild colic signs that responded to flunixin meglumine administration within a few hours after surgery. Another pony had an adhesion from the typhlotomy to the right ventral colon. One pony had a broad adhesion of the ventral colon to the body wall. Postoperatively and at necropsy, ponies did not have any evidence of sand-induced complications, such as sand impaction, diarrhea, or mucosal damage. Typhlotomy sites had healed well along mucosal and serosal surfaces.

The distribution of sand was the same for each group, with some sand in the cecum, ventral colon, and small colon, and the greatest amount in the right dorsal colon (Table 1). The mean percentage of total sand recovered from the control group was 27.4% and from the treated group was 39.2% (Fig 2). When the pony with an extremely high value in the treated group and the pony with an extremely low value in the control group were omitted from the calculations (Fig 3), the means were 31.8% and 31.6%, respectively. No significant differences were detected between the control group and treated group of ponies for fine, coarse, and total sand recoveries (Fig 2, Table 1), and the method of psyllium administration did not appear to affect sand recovery (Fig 3). However, the numbers treated by nasogastric intubation (3 ponies) and by feeding pellets (3 ponies) were too small to allow statistical comparisons between these methods of administration. Greater percentages of fine, coarse, and total sand were recovered from the right dorsal colon compared with the other intestinal segments in both groups (Table 1). There was a trend for a greater ratio of coarse to fine particles in the more proximal segments of intestine than in the distal segments (Table 1). In tests to validate our method for recovering sand from intestinal contents, the percentage of recovered sand exceeded 98% for the four trials.

Passage of sand through the large intestine was evident on abdominal radiographs, but there were no qualitative differences between groups. One day

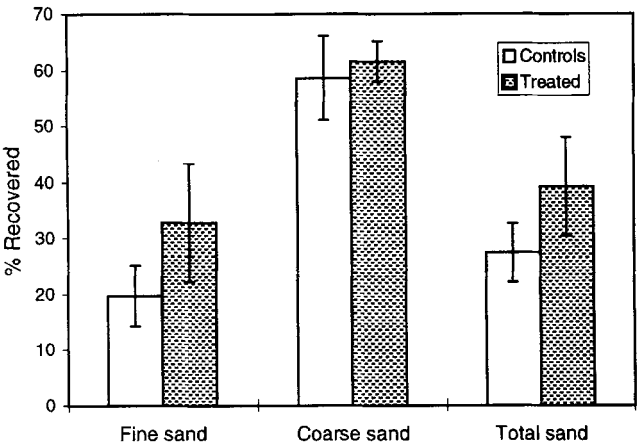

Fig 2. Amount of fine, coarse, and total sand (both fine and coarse) in the entire large intestine, expressed as mean percent of the dose recovered ± SEM.

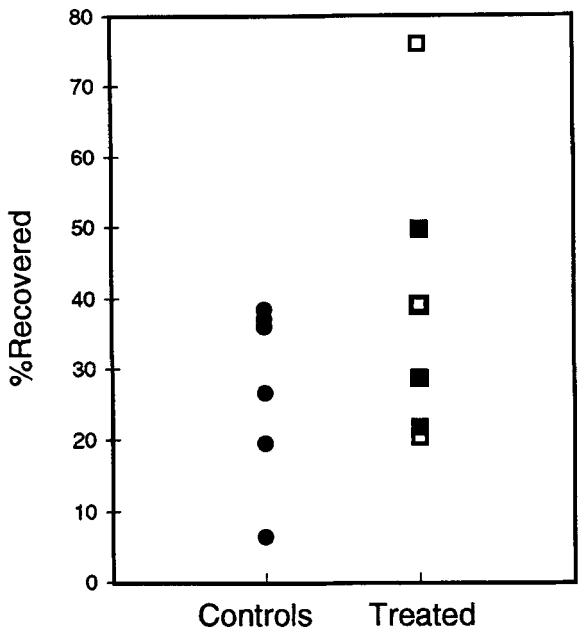

Fig 3. Amount of sand in the entire large intestine, expressed as percent recovered for each individual pony. In the treated group, the open squares are ponies fed psyllium pellets and the closed squares are ponies given psyllium by nasogastric tube.

after surgery, there was a small amount of sand in the cecum, whereas a larger, diffusely distributed volume of sand was seen in the ventral colon (Fig 4A). Five days after surgery, most of the sand was still in the ventral colon (Fig 4B), but on day 11, only small accumulations of sand were evident in the ventral colon (Fig 4C). On days 5 and 11, mottled densities were seen scattered throughout colon contents and were interpreted as evidence of more diffuse distribution of sand being dispersed for removal.

All ponies had sand sounds on auscultation of the ventral cranial part of the abdomen beginning approximately 3 days after surgery. The sounds were similar to those described by Ragle et al.[22] They persisted for 24 to 48 hours and then gradually diminished and disappeared by day 11. After day 3, small quantities of fine sand particles were found in feces by fecal floatation in a rectal sleeve.

Power analysis indicated a power of 0.35. This was obtained from a calculated effect size of 0.67 and by use of power tables.[21]

DISCUSSION

According to results of this study, psyllium had no effect on removing sand placed surgically into the large intestine of ponies and interruption of sand intake can allow gradual removal of sand from the large intestine. These results raise the concern that overreliance on the ability of psyllium to remove sand may lead to a false sense of security when treating known sand impactions. This could lead to increased morbidity and mortality in horses exposed to sand or that have a tendency to eat sand. Also, treatment with psyllium could replace the use of more effective forms of treatment, such as preventing access to sand. Although the power of this study was weak, the results would suggest that use of a larger number of ponies would not show a clinically relevant response to psyllium.

Ponies are suitable as models of equine gastrointestinal disease and function,[23] and we are not aware of any clinical evidence that ponies handle sand differently than horses. There is no apparent reason why the findings of this study would not apply to horses. This study was not designed to examine the potential benefits of psyllium in preventing sand accumulation when fed to horses that continuously ingest sand, but to examine its ability to remove sand that had accumulated. The results should raise concern about the ability of psyllium to affect sand removal, either from a large accumulation (Fig 4A) or when sand is dispersed among intestinal contents (Figs 4B and 4C).

The surgical model we used was designed to simulate the clinical situation in which horses ingest a sufficient amount of sand over time to accumulate a sand burden similar to the one we placed surgically. The dose of sand selected produced a heavy sand burden without causing a sand impaction or diarrhea. The dose was based largely on clinical experience with sand impactions treated by surgery. We felt that the dose used by Lieb[18] and Ragle et al[22] was too small to give psyllium an opportunity to work. Our method allowed us to place a larger volume of sand into the large intestine than can be achieved by nasogastric infusion.[18,22] Also, with radiographs, we could document a sand accumulation of similar or greater quantity than documented in horses with sand-induced diarrhea.[24,25] The surgical model described did not cause adverse effects to this group of ponies during the 11-day test period. The presence of sand at the typhlotomy site did not appear to interfere with wound healing. Also, the 11-day period left a sufficient amount of sand in the large intestine to allow demonstration of increased sand

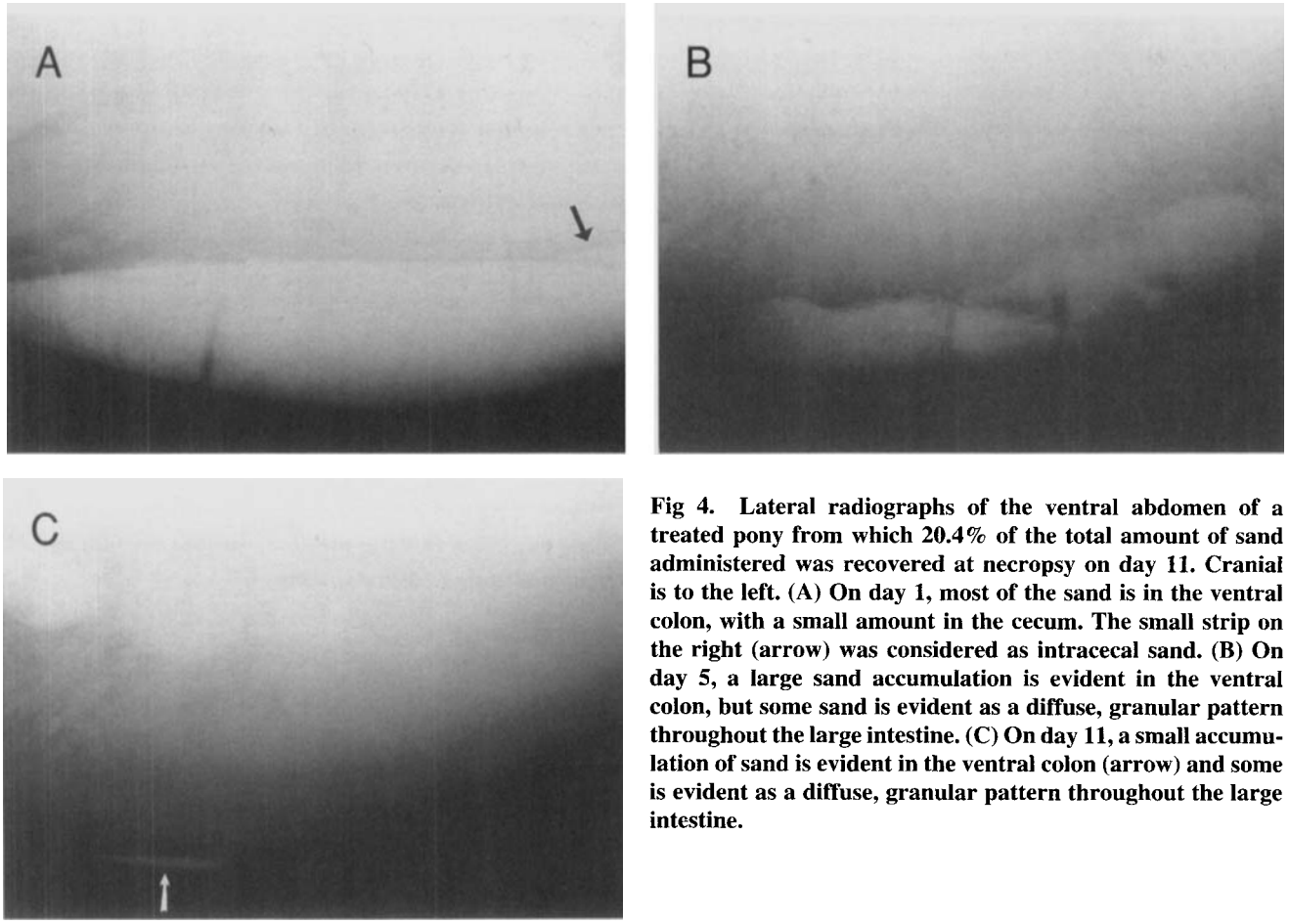

Fig 4. Lateral radiographs of the ventral abdomen of a treated pony from which 20.4% of the total amount of sand administered was recovered at necropsy on day 11. Cranial is to the left. (A) On day 1, most of the sand is in the ventral colon, with a small amount in the cecum. The small strip on the right (arrow) was considered as intracecal sand. (B) On day 5, a large sand accumulation is evident in the ventral colon, but some sand is evident as a diffuse, granular pattern throughout the large intestine. (C) On day 11, a small accumulation of sand is evident in the ventral colon (arrow) and some is evident as a diffuse, granular pattern throughout the large intestine.

elimination with psyllium, if such an effect were to occur (Fig 2).

The dose of psyllium used in this study was equivalent to 16 oz/1,000 lb body weight, which is the highest dose currently recommended by the manufacturer and most equine textbooks.[7-11] The psyllium used had a high husk content. Adding the pelleted formulation to daily grain rations was convenient and complied with recommendations for daily treatment; however, some ponies found the pellets unpalatable, which can be a problem with psyllium treatment. These ponies also refused to eat the powdered formulation when applied as a top dress to the grain ration. The dose of psyllium powder administered to these ponies by stomach tube was the same as that used for the pelleted formulation, but required a large volume of water (6 L) to dissolve and therefore had to be divided between two daily infusions. We chose an excess of psyllium to sand in our validation experiments to ensure that psyllium had no effects on the recovery method by day 11, when a small quantity of sand would remain in any segment relative to psyllium.

We chose a 3-day adjustment period for psyllium feeding before sand was placed, although a longer adjustment period would have allowed earlier identification and reassignment of ponies that would not eat psyllium. However, there is some concern that colonic flora, which can degrade psyllium,[12,17] could be induced to degrade a greater amount after chronic exposure. This could alter psyllium's effectiveness. Although the effects of fiber ingestion on colonic bacteria are controversial, an adjustment period was chosen that would diminish the possible risk of microbial fermentation of psyllium with time.

Infusion of psyllium through a nasogastric tube could alter gastrointestinal function in a way that could cause spurious results. The most likely response to intragastric infusion of 3 L of water would be stimulation of the gastrocolic reflex.[26] This would be expected to enhance sand movement through the large intestine and cause a false-positive response to

psyllium.[20] However, similar amounts of sand were recovered in the intubated group as in the other groups (Fig 3), suggesting that intragastric infusion of water did not impose an extraneous effect on the results.

A greater percentage of coarse particles than fine particles was recovered from all ponies in both groups (Table 1). These particles were all greater than 3 mm in diameter, evidence that the large particles are more likely to be retained and settle out in the large intestine because of their large size and greater weight. Large-size particles may also be less likely to bind with other intestinal contents that could facilitate their movement through the intestinal tract. It has been reported previously that coarse sand is more likely to accumulate in the right dorsal colon, transverse colon, and pelvic flexure, whereas fine sand is more frequently found in the ventral colon.[9] In our study, distribution of fine and coarse sand particles did not appear to follow this pattern. There was a trend for a higher ratio of coarse to fine particles in the more proximal segments than distally, and the largest amounts of both fine and coarse were recovered from the dorsal colon (Table 1).

The control group differed from the treated group in that the amount of sweet feed consumed by control group ponies was half the combined weight of sweet feed and psyllium consumed by or given to the treated group. The most likely effect of this difference would be on satiety, and this could cause the psyllium-treated ponies to reduce hay consumption.[27] However, a similar effect would apply to the clinical use of psyllium as a feed additive, and would only be relevant if hay consumption affected sand removal. Because we did not measure nor control hay consumption, we cannot draw any conclusions about effects it might have had in this study. Also any nutrient or non-nutrient filler given to the controls to correct for the volume difference could alter gastrointestinal function in an unpredictable fashion[27] or directly affect sand evacuation.[22] We used psyllium under conditions in which it would be expected to remove sand more rapidly than if ponies were fed a concentrate only.

By use of abdominal radiographs we were able, in a crude manner, to show that there were no qualitative differences in sand transit between groups and that sand moves slowly through the large colon. The ponies were not radiographed before surgery to determine if they were free of sand; however, they were housed on concrete floors without access to sand for approximately 4 to 6 weeks before surgery and no sand was palpable within the large intestine at the time of surgery. On abdominal radiographs, most of the sand we recovered at necropsy appeared as a diffuse granular pattern throughout the abdomen. A similar radiographic pattern might have been expected on day 1 radiographs if the ponies had a pre-existing sand burden. One day postoperatively, most of the sand appeared to have moved into the ventral colon from the cecum. This is consistent with other evidence that any effect on motility by the anesthetic regimen we used disappeared shortly after anesthesia ended.[28] We were able to identify accumulated sand easily on radiographs within the first 5 days, although identifying the exact location of sand within the large intestine became increasingly more difficult with time. Presumably horses that eat sand continuously will maintain sufficient sand in the ventral colon to allow its radiographic identification.

Under conditions of this study, psyllium mucilloid had no effect on removal of sand from the large intestine of ponies. This is consistent with results of a previous study.[18] When horses are not exposed to sand continually, normal intestinal motility will dislodge and remove most of the sand. During the 11-day test period, the ponies in this study were able to remove approximately 70% of the sand, whether treated or not. They were housed in stalls with concrete floors so that sand was not available from the environment. We recommend denial of access to sand as part of the treatment of clinical cases with sand-induced disease. This alone might be effective treatment in some cases. However, as observed in this study, ponies can vary in their ability to eliminate sand and therefore, the rate of response to restricted access to sand will vary. The surgical model used in this study can be applied to future studies on the efficacy of other drugs or treatment regimens in removing sand from the equine large intestine.

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