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# Recovery of Fasted and Fed Gastrointestinal Motility After Open *Versus* Laparoscopic Cholecystectomy in Dogs

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**Objective**

The authors investigate the recovery of gastrointestinal motility in the fed and fasted state after laparoscopic and open cholecystectomy.

**Summary Background Data**

Clinical recovery after laparoscopic cholecystectomy is known to be more rapid than after conventional open cholecystectomy. However, the actual effect of a laparoscopic approach on gastrointestinal motility, particularly fed-state motility, is not well investigated.

**Methods**

Laparoscopic (LAP, n = 6) or open (OPEN, n = 6) cholecystectomy was performed in 12 dogs. Bipolar recording electrodes were placed on the antrum, small intestine, and the transverse and descending colon, and fasting myoelectric data were recorded after operation. Solid meal gastric emptying studies were performed before surgery and on postoperative days 1 and 2. Transit time studies were performed using 10 radiopaque markers.

**Results**

Gastric emptying was significantly delayed in the OPEN group at 120 minutes on postoperative day 1 compared with pre-operative emptying ($p < 0.05$), but was not delayed on postoperative day 2. Gastric emptying was not delayed in the LAP group after operation. Transit time was the same between groups. Gastric dysrhythmias were more frequent on postoperative day 3 ($p < 0.05$) in the OPEN group. There were no significant differences in the presence, cycle length, or propagation velocity of the migrating motor complex on any postoperative day. Discrete or continuous electrical response activity in the colon was observed by postoperative day 1 in both groups.

**Conclusions**

Fed-state gastric motility is the only parameter for which laparoscopic cholecystectomy showed an improvement in postoperative recovery. Recovery of fasted gastrointestinal motility in dogs is equally rapid after either operation.

After its introduction by DuBois et al.,[1] laparoscopic cholecystectomy has become the treatment of choice for symptomatic cholelithiasis in both the United States and other countries. Most reports in the literature have focused on the clinical benefits of this technique, which include less postoperative pain, more rapid return to normal activities, shorter hospitalization, and fewer pulmonary complications.[2-5] The rapid adoption of laparoscopic cholecystectomy has caused the study of physiologic effects of this technique to occur only after the successful confirmation of its clinical benefits. Only a few studies evaluate the physiologic benefits of laparoscopy, including pulmonary, metabolic, and immunologic responses after surgery.[6-9]

Based on patients' more rapid recovery after laparoscopic than open cholecystectomy, it is generally believed by many clinicians that symptoms of postoperative ileus, such as nausea and vomiting, are reduced by laparoscopic surgery. However, confirmatory data based on physiologic parameters are relatively scarce. Some authors[10,11] have investigated the effect of laparoscopic cholecystectomy on recovery of the migrating motor complex (MMC) pattern in the small intestine after operation. Ludwig et al.[10] found no difference in the return of MMC activity between laparoscopic and open cholecystectomy. Because MMC activity is observed only in the fasted state, the relationship between return of MMC activity and resolution of postoperative ileus is still controversial.[12] Recovery of gastrointestinal motility in the fed state or recovery of motility within separate organs of the gastrointestinal tract after laparoscopic surgery has not been well investigated. Moreover, the relationship between the recovery of fasted- and fed-state gastrointestinal motility about resolution of postoperative ileus is not well understood.

The purpose of this study was to investigate the recovery of gastrointestinal motility, especially in the recovery of fed-state gastrointestinal motility, in dogs after either laparoscopic or conventional open cholecystectomy.

## ANIMALS AND METHODS

Surgical procedures and conducted experiments were approved by the Animal Research Committee of the University of Virginia. Animals in this study were maintained in accordance with the guidelines prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.

Twelve female mongrel dogs weighing 24 to 32 kg were used for this study. Dogs were randomly divided into either the laparoscopic (LAP) (n = 6) or open (OPEN) (n = 6) group. Animals were fasted for 24 hours before operation.

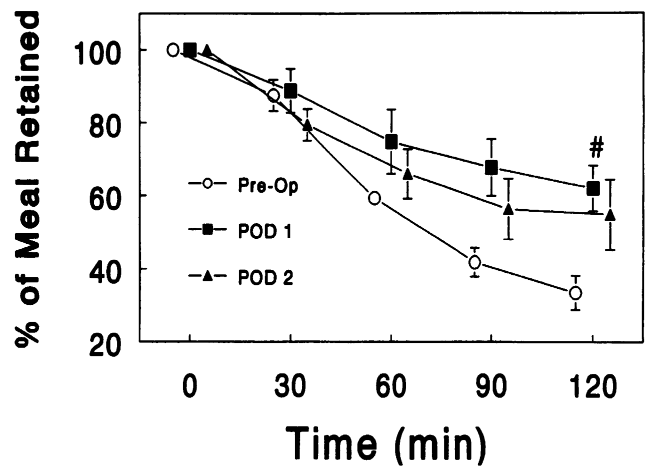


**Figure 1.** Results of solid meal gastric emptying studies after open cholecystectomy. Data are expressed as mean ± SEM. # : $p < 0.05$ *vs.* pre-op (analysis of variance).

### Operative Procedure

Dogs undergoing surgery received intravenous thiopental sodium (25 mg/kg) with inhaled halothane for anesthesia. We used standard surgical techniques for laparoscopic cholecystectomy that have been reported elsewhere.[2] In brief, two 10-mm (one epigastric, one umbilical) and two 5-mm (right subcostal, medial and lateral) trocars were inserted after establishing the pneumoperitoneum. The gallbladder was removed from the liver bed using monopolar cautery. The cystic duct was divided between clips. Gallbladder extraction followed *via* the 10-mm epigastric port.

A 20-cm long midline celiotomy was performed for dogs in the OPEN group. Gallbladder removal was with a similar approach as with the LAP group except *via* the celiotomy.

No local anesthetic drug was infiltrated subcutaneously at the skin incisions nor were any postoperative analgesics used in either groups. Dogs were given water just after operation, beef stew (gastric emptying study) on postoperative days (PODs) 1 and 2, soft food on PODs 2 and 3, and regular food from POD 3 on.

### Myoelectric Activity Recording

At the end of their surgical procedures, all dogs underwent placement of 28-gauge stainless steel bipolar re-

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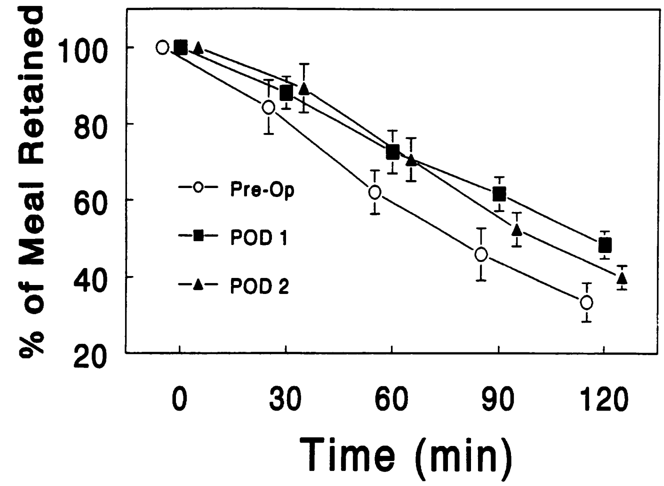


**Figure 2.** Results of solid meal gastric emptying studies after laparoscopic cholecystectomy.

cording electrodes (cardiac pacing wires, A and E Medical Corp., Farmingdale, NJ). These wires were partially embedded into the seromuscular layer of the following locations: the distal antrum (5 cm proximal to the pylorus), the small intestine (10, 30, and 50 cm distal to the pylorus), the transverse colon, and the descending colon. Two wires were placed 1 cm apart at each site to serve as bipolar recording electrodes. Wires were tunneled subcutaneously and brought out percutaneously on the back of the animals.

Myoelectric recordings were performed on PODs 1 to 4, 7, and 10. The dogs were fasted at least 14 hours before each recording session. The dogs rested comfortably in a Pavlov sling without any sedation or analgesics, and recordings were performed during continuous 5-hour sessions each study day. The electrical signals from the wires were recorded using a Gould ES 1000 Electrostatic Recorder with Gould Model 13-4615-58 Universal amplifiers (Gould, Inc., Valley View, OH).

Recordings were visually analyzed independently by two co-authors. A dysrhythmia in the antrum was identified according to the criteria used by Kim et al.[13] Bradygastria was identified if the slow wave frequency was $\leq 3$ cycles/minute and tachygastria if the slow wave frequency was $\geq 8$ cycles/minute and was sustained for a minimum of 1 minute. Recordings were analyzed for presence, conduction velocity, and cycle length of the MMC. Phase III of the MMC was determined according to the criteria established by Code and Marlett.[14] Recordings were analyzed for the presence of discrete and continuous electrical response activity (DERA and CERA, respectively) in the transverse and distal colon. The occurrence of DERA was confirmed by the presence of short duration ($<10$-second) bursts of response potentials associated with individual control potentials of electrical control activity. The long duration ($>10$-second) bursts of response potentials without relation to electrical control activity were considered as CERA.[15]

## Gastric Emptying Study

Solid meal gastric emptying studies were performed before operation (pre-op) and on the first and second days after surgery (PODs 1 and 2). Chicken livers (15 to 20 g) were prepared using an *in vitro* labeling technique.[16] Each liver was cooked in a microwave oven for approximately 1 minute and then cut into 1 cm cubes. A total of 2 MCi of $^{99m}$Tc-sulfur colloid (6 hour $t_{1/2}$, 140 keV) was evenly injected throughout the liver cubes. The cubes then were mixed into a commercially available beef stew (212 g, 630 kJ, Heinz, Pittsburgh, PA) and fed to the dogs.

After the meal was consumed, images of the posterior scintigraphic view of the abdomen were obtained for 15 seconds each at 0, 30, 60, 90, and 120 minutes. The gamma camera (PHO/GAMMA 37, Searle Radiographics, Des Plaines, IL) was set up to record activity with a 20% window around the 140 keV photopeak of $^{99m}$Tc. Images were stored on an image processing computer (Sophy GX+, Sopha Medical Systems, Columbia, MD) attached to the camera. Images were corrected for nonuniformities and the stomach region of interest defined. The stomach region of interest counts were obtained for each image and corrected for radionuclide decay and ambient background. Percentage of food in the stomach was obtained by normalizing the corrected stomach counts with respect to the time 0 count.

## Transit Time

Radiopaque markers were made using 18 French (6-mm) nasogastric tubes (Argyle Salem Sump Tube, Sher-

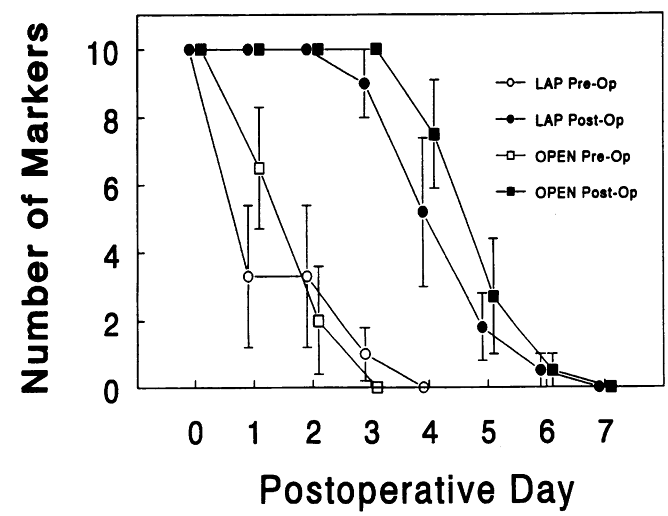


**Figure 3.** Results of transit time studies.

**Table 1. GASTRIC DYSRHYTHMIAS**

| | OPEN (n = 6) | | | | | | LAP (n = 6) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| POD | Total | T | B | TA | TB | A | Total | T | B | TA | TB | A |
| 1 | 1 | | 1 | | | | 2 | 1 | | 1 | | |
| 2 | 4 | 1 | | 3 | | | 1 | 1 | | | | |
| 3 | 5 | 3 | 1 | 1 | | | 1* | 1 | | | | |
| 4 | 5 | 2 | | 3 | | | 3 | 2 | | | | 1 |
| 7 | 4 | 1 | | 3 | | | 3 | 1 | | 2 | | |
| 10 | 5 | | | 3 | 1 | 1 | 2 | 2 | | | | |

OPEN = open group; LAP = laparoscopic group; POD = postoperative day; B = bradygastria; T = tachygastria; A = arrhythmia; TA = tachygastria and arrhythmia; TB = tachygastria and bradygastria.
* $p < 0.05$ *vs.* OPEN.
Data show the number of the dogs in which dysrhythmia(s) were observed.

wood Medical, St. Louis, MO). The tubes were cut in a circular (5-mm diameter) pattern with the radiopaque line running down the center of the circle. Ten markers were given 6 days (pre-op) or just before the induction of anesthesia (postoperative) with 18 g of cheese. Feces were collected every morning after ingestion of markers, and x-ray films of the feces were taken until all markers were evacuated. Evacuated markers were counted and data are expressed as the number of markers retained in the dog.

## Statistical Analysis

Data are expressed as mean ± SEM. Statistical analysis was performed using either one-way analysis of variance followed by Tukey's test, unpaired Student's t test, or a two-sample proportion test when appropriate. A p value less than 0.05 was considered significant.

## RESULTS

All dogs tolerated anesthesia and surgery well. Dogs in both groups had good appetites after operation. Anesthesia and operation times of the LAP group (206 ± 11 minutes and 132 ± 8 minutes, respectively) were significantly longer than those of the OPEN group (170 ± 9 minutes, $p < 0.05$, and 94 ± 5 minutes, $p < 0.01$, respectively).

Figures 1 and 2 show the results of the gastric emptying studies in the OPEN and LAP groups, respectively. Gastric emptying was significantly delayed in the OPEN group on POD 1 at 120 minutes (62.0 ± 6.3%) compared with that of pre-op (33.5 ± 4.7%, $p < 0.05$). The percentage of residual meal in the OPEN group at 120 minutes on POD 1 (62.0 ± 6.3%) was higher than that in the LAP group (48.5 ± 3.6%), but no significant difference was observed. Gastric emptying was not changed significantly in the LAP group at 120 minutes on either POD 1 or 2 (48.5 ± 3.6% and 40.0 ± 3.1%, respectively) compared with that of pre-op (33.5 ± 5.1%).

Figure 3 shows the results of the transit time studies. Markers were evacuated by 4 days after ingestion before operation in both groups. Transit time of the markers was prolonged after operation in both groups, but all markers were evacuated by 7 days after operation. No significant differences in retained markers were observed between groups on any of the days after operation.

Gastric dysrhythmias, especially tachygastria and arrhythmia, were observed in the antrum from the early postoperative days to POD 10 (Table 1) in both groups. Gastric dysrhythmias were observed more frequently in the OPEN group than in the LAP group on POD 3. However, no significant differences were noted between groups for any of the other days studied. Table 2 lists the percentage of dogs in which MMC activity was observed. On POD 1, an MMC was observed in one of six dogs (16.7%) in the LAP group and three of six dogs (50%) in the OPEN group. This difference was not significant, and MMC activity returned in all dogs studied by POD 3.

Results of cycle length and conduction velocity of postoperative MMC activity in both groups are shown in Figures 4 and 5. Cycle length and conduction velocity of the MMC returned to normal in both groups on POD 1, and no significant differences were observed between groups for any of the days tested.

The DERA and CERA returned in the transverse and descending colon as early as POD 1 in both groups. There were no significant differences in the return of DERA or CERA between groups in any site studied.

## DISCUSSION

Laparotomy with manipulation of the bowel can cause transient gastrointestinal malfunction, termed *postoperative ileus.* Uncomplicated ileus has transient

**Table 2. RETURN OF MIGRATING MOTOR COMPLEX ACTIVITY**

| POD | OPEN | LAP |
|---|---|---|
| 1 | 50.0 | 16.7 |
| 2 | 83.3 | 100 |
| 3 | 83.3 | 100 |
| 4 | 100 | 100 |
| 7 | 83.3 | 100 |
| 10 | 100 | 100 |

POD = postoperative day; OPEN = open group; LAP = laparoscopic group.
Data show the percentage of the dogs in which migrating motor complex activity was observed.

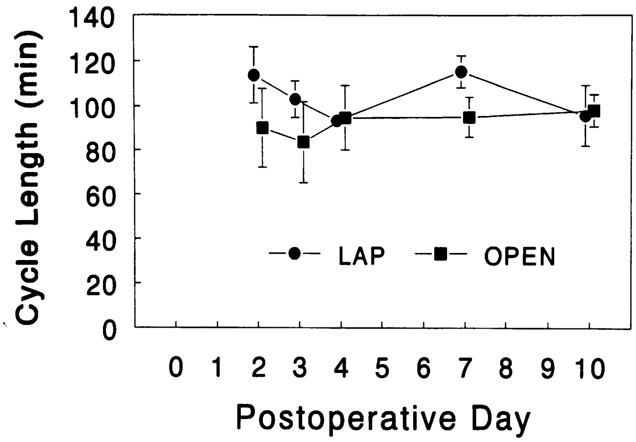


**Figure 4.** Recovery of migrating motor complex cycle length after operation.

effects on the small bowel and lasts 24 to 48 hours in the stomach and 72 hours or more in the colon after celiotomy in humans.[17] It is generally believed that laparoscopic cholecystectomy results in a more rapid recovery of the gastrointestinal tract in patients compared with open cholecystectomy. This clinical benefit of the laparoscopic technique was presumed because laparoscopic cholecystectomy resulted in a shorter postoperative stay and apparently fewer symptoms of nausea and vomiting.[2,3,5] However, there probably is some element of postoperative ileus in patients undergoing laparoscopic cholecystectomy.[18] This may be relatively obscured by the more obvious clinical well being and decreased amount of pain exhibited by most patients undergoing laparoscopic cholecystectomy as compared with those patients undergoing traditional celiotomy for cholecystectomy.

We performed this study to better quantify various elements of recovery of gastrointestinal motility after cholecystectomy *via* these two approaches, hoping to better quantify the degree of postoperative ileus seen with each approach in an animal model. Both administering general anesthesia and opening the peritoneum are known to abolish MMC activity, and manipulation of the bowel may prolong the duration of this inhibition.[19] We observed no difference in MMC return between laparoscopic and open cholecystectomy in this study, in agreement with previous findings by Ludwig et al.[10] Conversely, Schippers et al.[11] reported that recovery of MMC activity was observed significantly earlier after laparoscopic than was open cholecystectomy in dogs. The reason for this discrepancy in results is unclear. However, the discrepancy serves to underscore the potentially limited value of MMC activity in predicting resolution of postoperative ileus. This is particularly true based on our results, where differences in fed-state motility, specifically gastric emptying of solids, did exist, whereas no differences in return of MMC activity, a phenomenon of the fasting state of motility only, were observed. Our results suggest that return of MMC activity is not an important factor for reversal of postoperative ileus, especially the return of gastric function. This finding is supported by other reports in the literature as well.[12] It is evident that further studies are necessary to clearly define the relationship between fed- and fasted-state recovery of motility function after abdominal surgery.

Benson et al.[20] reported that the MMC cycle increases and conduction velocity decreases progressively over a 48- to 72-hour period after abdominal surgery in humans. Use of opiates after surgery might be one of the reasons for this phenomenon. In our study, where no opiates were used after operation, there were no significant differences in cycle length or conduction velocity of MMC between early and later PODs in either group.

Open cholecystectomy apparently results in a more delayed oral intake of regular diet compared with laparoscopic cholecystectomy in humans. This also may be a result of differences in narcotic use, because opioids are known to inhibit gastric emptying.[21] However, our observation of delayed gastric emptying after open cholecystectomy in dogs is similarly not because of differences in narcotic use. Moreover, duration of operation and anesthesia was not responsible for this difference in gastric emptying because these times were longer for the LAP group than for the OPEN group.

Opening the peritoneum is known to abolish MMC activity, but cutting only the skin has no effect on MMC activity.[19] Celiotomy itself, therefore, may be an important factor for delayed gastric emptying after open cholecystectomy in dogs.

Plasma epinephrine and norepinephrine are reported to be higher after open surgery than after laparoscopic cholecystectomy,[9] and these catecholamines are known

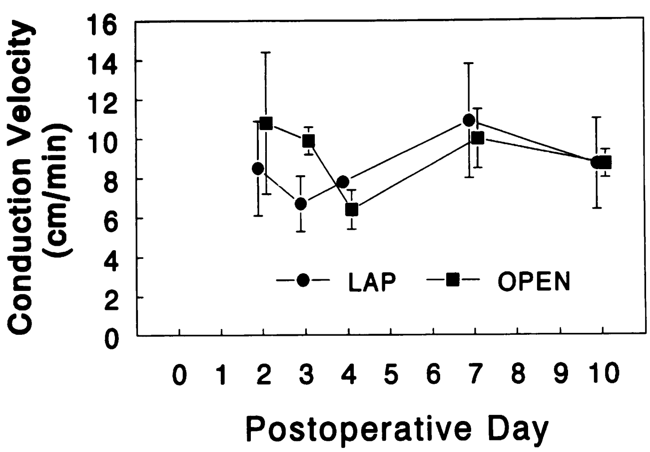


**Figure 5.** Recovery of migrating motor complex conduction velocity after operation.

to inhibit gastrointestinal motility.[22] Differences in the stress response after open and laparoscopic surgeries also may play a role in the difference in the recovery of gastric function.

Gastric dysrhythmias have been observed in the postoperative state.[23,24] Dysrhythmias, especially tachygastria, are associated with delayed gastric emptying.[24,25] Gastric dysrhythmias were observed in the majority of dogs in both groups after cholecystectomy in this study. Although gastric emptying was delayed on POD 1 after open cholecystectomy, there was no temporal association with an increased incidence of gastric dysrhythmias for the OPEN group at that time. It is unlikely the increased incidence of gastric dysrhythmias on POD 3 in the OPEN group is important, because gastric emptying seems to return to normal by this day in both groups. These data suggest that the presence of gastric dysrhythmias in this animal model is not closely associated with the presence of postoperative ileus.

Interestingly, transit time was not different between groups after operation. Colon motility is best reflected by the parameter of mouth-to-anus transit time.[26] It is possible that fasting before and after operation is the reason for delayed transit time in both groups because colonic motility is accelerated by ingestion of a meal.[27] However, there was no difference in the transit time of the markers between groups, suggesting that in the dog model, laparoscopic cholecystectomy has no advantage in early recovery of colonic function compared with open cholecystectomy. Since DERA and CERA were observed in the early days after operation in both groups, recovery of colonic motility might be rapid after cholecystectomy in dogs.

In a previous study, we showed that recovery of gastric emptying and transit time are more rapid after laparoscopic colectomy than open colectomy in dogs.[28] In the present study, only gastric emptying was delayed after open cholecystectomy. Laparoscopic abdominal surgery, therefore, does seem to offer some advantage in recovery of gastrointestinal motility compared with celiotomy, based on the results of our investigations. However, it is also clear that such differences are often subtle clinically, and only through the use of careful quantitative measures of gastrointestinal motility can they be clearly defined.

In conclusion, laparoscopic cholecystectomy resulted in a more rapid recovery of gastric function in dogs, whereas recovery of colonic motility was not different. Recovery of gastrointestinal myoelectric activity in the fasted state was not predictive for the benefits of a laparoscopic approach to cholecystectomy. Our results support further investigation of potential benefits of laparoscopic surgery compared with celiotomy in animal and human studies and point out the limitations of clinical parameters to define such benefits and the need for inclusion of careful quantitation of fed-state motility parameters as part of those studies.

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