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Prospective Evaluation of Abdominal Sonography for the Diagnosis of Bowel Obstruction

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Objective
The authors determined the utility of sonography compared with plain x-rays in the diagnosis of bowel obstruction. In a contemporaneous group of patients, they compared the cost of operative *versus* nonoperative management of small bowel obstruction.

Summary Background Data
Nonoperative treatment of simple bowel obstruction usually succeeds. However, because of the difficulty in assured diagnosis and the possibility of strangulation or other complication, exploration of suspected bowel obstruction is recommended. Most of these explorations could be avoided if diagnostic accuracy were better, yielding a desirable decrease in the overall cost of managing bowel obstruction.

Methods
Fifty patients whose clinical or plain x-ray findings suggested bowel obstruction underwent prospective evaluation by abdominal sonography and by flat and upright abdominal x-rays. Presence or absence of bowel obstruction was determined at laparotomy and by clinical evolution of the abdominal episode. Direct costs of care were determined from the hospital and physician bills of 54 patients treated contemporaneously with the sonography study.

Results
Sonography demonstrated bowel obstruction by showing fluid-filled dilated bowel loops proximal to collapsed bowel in 22 patients with one false-positive and three false-negative examinations. X-rays demonstrated bowel obstruction in 32 patients with nine false-positive and one false-negative examination. Cost data showed that operative treatment of simple bowel obstruction increased costs nearly eightfold.

Conclusions
Sonography is as sensitive but more specific than plain x-rays in the diagnosis of bowel obstruction. Management based on sonographic findings has the potential to reduce costs of surgical care.

The diagnosis of bowel obstruction usually is made on the basis of the patient's history, symptoms, and physical signs, and then is confirmed by plain abdominal x-rays. At times, however, these conventional methods are not diagnostic, especially in cases of early small bowel obstruction (SBO) or early strangulation. In recent years, bedside abdominal sonography has been used in Japan for the diagnosis of bowel obstruction and for early recognition of strangulation.[1-3] In the United States, however, the use of abdominal sonography for the evaluation of an acute abdomen with possible bowel obstruction remains limited. Sonography employed by nonradiologist clinicians in the bedside diagnosis of early SBO and strangulation has not been evaluated prospectively in the United States.

The purpose of this study was to compare the sensitivity and specificity of initial bedside ultrasound diagnosis of suspected bowel obstruction with that of routine abdominal radiography, to evaluate the application of sonography in the diagnosis of strangulation obstruction, and to compare the costs and complications of operative *versus* nonoperative management of SBO.

METHODS

From July 15, 1992 to May 14, 1993, all patients who presented to the Emergency Department or the Surgical Services at the Milwaukee Regional Medical Center of the Medical College of Wisconsin, and who were determined to have possible bowel obstruction on the basis of clinical or plain x-ray findings, were candidates for this study. Abdominal sonography (model AU530 Esaote, Biomedica, Genoa, Italy) was performed shortly before or after the x-ray examination using a 3.5-MHz transducer. Patients were entered into this study only when a sonographer trained in the technique of intestinal imaging was available at the time of the patient's initial evaluation so that sonographic and radiographic images could be obtained contemporaneously. Patients were excluded if they refused consent or were believed to be unstable by the attending physician. Informed consent was obtained from each patient before the examination. No particular preparation was given to patients; interference by gas echoes from distended bowel was avoided by scanning the distended abdomen using oblique or coronal planes.

Sonographic findings were interpreted on the basis of predetermined criteria and documented on study forms immediately after the examination. The criteria for simple SBO included: 1) the presence of fluid-filled dilated small bowel (diameter $\geq$ 25 mm) proximal to collapsed small bowel or ascending colon and 2) the presence of peristaltic activity (observed as peristalsis of the intestinal wall or to-and-fro movements of spot echoes inside the fluid-filled dilated small bowel) in the entire dilated proximal small bowel. The criteria for early strangulation included: 1) the presence of an akinetic dilated loop, 2) the presence of peristaltic activity in dilated small bowel proximal to the akinetic loop, and 3) rapid accumulation of peritoneal fluid after the onset of obstruction. Akinesis of the loop was established by observation for more than 5 minutes to identify the lack of peristaltic movement or to-and-fro movement of spot echoes. An established strangulation was recognized by the presence of increased intestinal wall thickness (>3 mm), flattened Kerckring's folds within the akinetic loop, or the presence of a large amount of peritoneal fluid containing scattered spot echoes. The criterion for large bowel obstruction was the presence of dilated colon (diameter $\geq$ 50 mm) filled with spot echoes located proximal to normal or collapsed large bowel. The sonographic diagnosis of ileus was based on the absence of a distinct point of transition between dilated proximal small bowel and collapsed distal bowel, less accumulation of fluid inside the intestinal lumen, and impaired peristaltic activity in the entire bowel, in addition to a clinical presentation consistent with ileus.

Treatment was determined by the attending surgeon on the basis of clinical and laboratory findings, as well as plain x-ray findings, but without the sonographic data. Final clinical diagnoses were established at laparotomy in patients who were treated operatively and by clinical judgment (based on the overall clinical findings) in patients who were relieved of their symptoms and signs with nonoperative treatment.

The sensitivity and specificity of the initial sonographic diagnoses recorded on the study forms and the written diagnoses recorded by the radiologist were determined and compared with the final clinical diagnoses. The 95% confidence interval (CI) was calculated for each of the proportions. In addition, the current status of treatment for SBO caused by postoperative adhesions was evaluated by reviewing the choice of surgical intervention or nonoperative treatment, the length of hospital stay, the total cost of hospital treatment, and the morbidity and mortality occurring in all patients with a final diagnosis of SBO caused by adhesions admitted during the study period.

RESULTS

Fifty patients having ultrasound evaluation were entered in the study. They ranged in age from 19 to 82 years

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Table 1. FINAL DIAGNOSIS OF 50 PATIENTS EXAMINED BY SONOGRAPHY

Final Diagnosis	No. of Cases
Small bowel obstruction	22 (8)
Due to adhesions	18 (6)
Due to cecal carcinoma	1 (1)
Due to incarcerated inguinal hernia	1 (1)
Due to peritoneal carcinomatosis	1
Cause unknown	1
Acute gastritis or enteritis	5
Ileus	4 (2)
Due to bile peritonitis	1 (1)
Due to SMA occlusion	1 (1)
Due to acute pancreatitis	1
Due to diabetic ketoacidosis	1
Large bowel obstruction	2 (1)
Constipation	2
Urinary tract infection	2
Peritoneal carcinomatosis	1
Liver cirrhosis with ascites	1
Crohn's disease	1
Abdominal pain of unknown origin	10

SMA = superior mesenteric artery.
Numbers in parentheses refer to number of cases whose final diagnosis was established at laparotomy.

(mean 54 years); there were 23 men and 27 women. Forty-eight patients had abdominal pain and 40 patients reported nausea or vomiting. Physical examination revealed abdominal distension in 32 patients, tenderness in 48 patients, and more ominous peritoneal signs (rebound or percussion tenderness, tender mass) in four patients. Forty-one patients had a history of one or more previous abdominal operations. The final diagnosis was established at laparotomy in 11 patients and on the basis of the overall assessment of the clinical course in 39 patients. Twenty-two of the 50 patients had a final diagnosis of SBO, two had large bowel obstruction, four had ileus, and 22 had other diagnoses (Table 1).

Initial ultrasound was interpreted as SBO in 20 patients (Fig. 1), large bowel obstruction in two patients (Fig. 2), and no bowel obstruction in 28 patients (7 of these were interpreted as ileus). The mean maximum diameter of dilated small bowel was 38 mm (range, 25–54 mm). Free peritoneal fluid was delineated in 13 patients. Initial x-ray showed SBO in 22 patients, possible SBO in 8 patients, large bowel obstruction in 2 patients, and no bowel obstruction in 18 patients (5 of these were read as ileus) (Table 2). The sensitivity and specificity of ultrasound in the diagnosis of bowel obstruction was 88% (95% CI = 75–100) and 96% (95% CI = 89–100), respectively, whereas that for plain radiographs was 96% (95% CI = 88–100) and 65% (95% CI = 47–83), respectively (Table 2). Abdominal sonography revealed specific

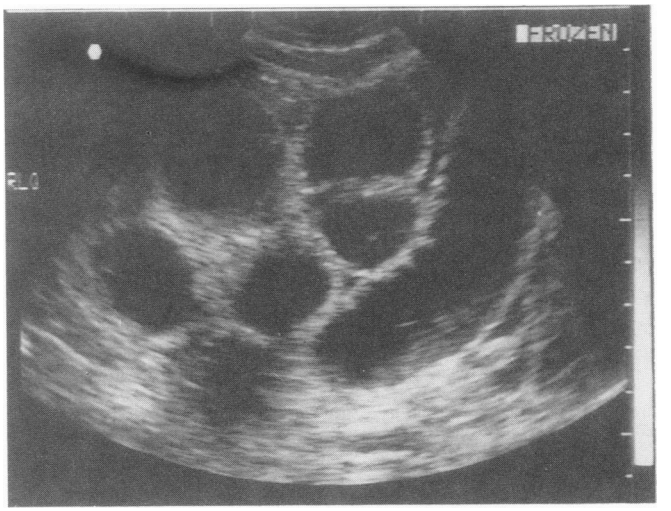

Figure 1. Ultrasonogram of simple small bowel obstruction (3.5 MHz). Real-time sonography revealed peristaltic activity, as reflected by movement of the intestinal wall and to-and-fro movements of spot echoes inside the fluid-filled dilated small bowel.

causes of obstruction in three patients—cecal carcinoma, peritoneal carcinomatosis, and incarcerated inguinal hernia—which were not demonstrated by clinical examination or plain x-ray findings.

Of the 20 patients in whom sonography showed SBO, seven were confirmed to have SBO at laparotomy. Although one patient met our predetermined criteria for early strangulation on the basis of sonographic criteria, no patient had strangulation at laparotomy. Thirteen of 20 sonographically positive patients were managed non-

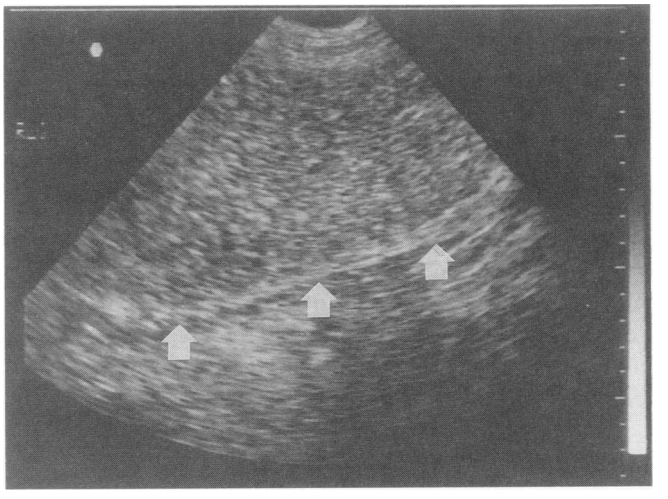

Figure 2. Ultrasonogram of large bowel obstruction (3.5 MHz). Dilated ascending colon was delineated as distended bowel filled with spot echoes. Because all the visualized large bowel loops are filled with solids, they may not be identified as readily as fluid-filled small bowel loops. The dilated colon is located above the filled arrows.

Table 2. FINAL SONOGRAPHIC AND PLAIN X-RAY DIAGNOSES COMPARED

	Obstruction (n = 24)	No Obstruction (n = 26)
Sonographic diagnosis*		
Small bowel obstruction	19 (TP)	1 (FP)
Large bowel obstruction	2 (TP)	0 (FP)
No obstruction	3 (FN)	25 (TN)
Total ultrasound	24	26
Plain x-ray diagnosis†		
Small bowel obstruction	17 (TP)	5 (FP)
Possible small bowel obstruction	4 (TP)	4 (FP)
Large bowel obstruction	2 (TP)	0 (FP)
No obstruction	1 (FN)	17 (TN)
Total x-ray	24	26

TP = true-positive; FP = false-positive; FN = false-negative; FP = false-positive.
Sensitivity = TP/(TP + FN); specificity = TN/(TN + FP).
* Sonographic diagnosis: sensitivity = 21/24 = 88%; specificity = 25/26 = 96%.
† Plain x-ray diagnosis: sensitivity = 23/24 – 96%; specificity = 17/26 = 65%.

operatively. Twelve had a final diagnosis of SBO, whereas one patient received a diagnosis of pancreatitis or gastroenteritis, although his plain x-rays also were interpreted as demonstrating SBO. Of 30 patients in whom sonography showed no evidence of SBO, three had a final clinical diagnosis of SBO. One of these patients, in whom sonography suggested ileus and plain x-ray suggested SBO, underwent laparotomy, which revealed both dilated and somewhat collapsed small bowel, but no distinct point of transition between them; the other two patients were managed nonoperatively. Plain x-rays suggested possible SBO in one of these patients; the other patient showed no evidence of bowel obstruction or ileus. Both abdominal sonography and plain x-rays correctly diagnosed large bowel obstruction in two patients.

In addition to identifying the specific cause of obstruction in three patients, abdominal sonography also identified additional findings that were not apparent by plain x-ray or clinical examination: bilateral hydronephrosis in a case of urinary tract infection, thickened wall of the colon in a case of Crohn's disease, focal accumulation of peritoneal fluid and diffusely dilated small bowel without peristaltic activity in a case of bile peritonitis after laparoscopic cholecystectomy, clinically inapparent ascites in a patient with cirrhosis, and two additional instances of peritoneal carcinomatosis.

To measure the costs of treating SBO, we reviewed the records and determined the average total charges (including hospital and physician bills) for 54 patients admitted during the study period who had a final discharge diagnosis of SBO caused by adhesions (18 of whom were captured by the sonography study). Thirty-two were treated operatively ($36,976 [range, $9,389–$130,230]) and 22 were relieved of their obstruction nonoperatively ($4,834 [range, $919–$13,810]). Among the patients undergoing surgery, 19 of 32 were explored on hospital day 1 or 2 ($27,687 [range, $9,389–$74,852]), with 18 of 19 receiving diagnoses of simple SBO ($26,849 [range, $9,389–$78,852]); the other 13 of the 32 patients had their laparotomies on hospital days 3 to 6 ($50,552 [range, $18,431–$130,230]). Three patients had strangulated bowel discovered at operation on hospital day 2, 3, and 6, respectively ($69,370 [range, $35,110–$130,230]); none had been examined by ultrasound and none had the diagnosis of strangulation recorded preoperatively. The length of hospital stay ranged from 6 to 51 days (median 13 days) in the operative group and from 1 to 29 days (median 5 days) in the nonoperative group.

DISCUSSION

Patients undergoing evaluation for possible early bowel obstruction have signs and symptoms that are not always diagnostic of this illness. Our study demonstrated that a bedside ultrasound examination has a sensitivity similar to that of plain abdominal (flat and upright) x-rays, but is more specific than x-rays for the initial early diagnosis of bowel obstruction. Ultrasound also has the advantage of providing additional information about the etiology of obstruction or of abdominal pain that is not obtained with plain radiographs. More importantly, ultrasound has the potential to diagnose complications of bowel obstruction that are not easily identified using clinical x-ray criteria, and the examination can be performed in the emergency department or at the bedside, thus facilitating patient care.

Strangulation in SBO, which involves interference of the blood supply to a loop of bowel, requires early surgical intervention.[4–7] The difficulty of reliable early recognition of strangulation has resulted in the recommendation that all cases of complete SBO have early surgical intervention.[4,6,7] Such a strategy is effective in reducing delay in operations for strangulation, but it increases the number of operations for simple obstruction that could have been relieved nonoperatively. In addition, plain x-rays sometimes show only incomplete SBO in cases of strangulation, and serial plain x-rays or fluoroscopy are required to define whether the obstruction is complete or incomplete.

During the study period, 59% of patients (32/54) admitted to the hospital and having a final diagnosis of SBO caused by adhesions underwent laparotomies (a subset of these patients were entered into the prospective ultrasound study). Fifty-nine percent of these operations (19/32) were performed on hospital day 1 or 2. These high percentages mainly are derived from the strategy that early surgical intervention should be done for SBO

that is thought to be complete or of high grade. However, our results demonstrate that early surgical intervention is associated with higher overall costs compared with nonoperative management for patients with simple SBO (average charges $26,849 [n = 18] *vs.* $4,834 [n = 22]). We suspect that the difference in cost is related primarily to surgical and operating room charges and increased length of stay for patients with operative management, but we did not evaluate other potential factors—such as severity of presenting or pre-existing illness—between the groups.

Strangulation was found in three patients, but had not been recognized preoperatively, and consequently, surgical intervention had been somewhat delayed in these cases. This experience is a reflection of the difficulty in recognizing the presence of strangulation on the basis of clinical and x-ray findings. Because the costs and complications of treatment are higher in patients managed operatively, it would be medically and economically beneficial to reduce the number of operations for simple obstruction, as well as delay in operations for strangulation, if such could be accomplished safely. If ultrasonography is reliable for the diagnosis of strangulation, a strategy that includes initial ultrasound examination would identify patients who require early surgical intervention. Serial ultrasound examination could be used to evaluate the response to nonoperative management and to determine the need for further intervention. It is anticipated that this strategy would lower costs by reducing complications for patients with strangulation and by permitting wider use of nonoperative management for patients with simple bowel obstruction.

Abdominal sonography has been used in recent years for diagnosis of SBO in Japan and in the German-speaking countries of Europe.[1-3,8] In Japan, ultrasound has been found to be useful in recognizing the presence of strangulation.[1-3,9] It was reported by Ogata et al.[3] that the presence of an akinetic dilated loop distal to dilated loops with peristaltic activity was a sensitive and specific finding associated with strangulation, and that the presence of peritoneal fluid also was a sensitive indicator of the possible presence of strangulation. Although the efficacy of sonography in the differentiation of strangulation *versus* simple obstruction was not directly determined in our study, real-time sonography allowed us to observe peristaltic activity in fluid-filled dilated small bowel as well as peritoneal fluid, without significant difficulties due to interference by gastrointestinal gas, and to confirm the accuracy of bedside ultrasound in detecting the presence of bowel obstruction.

Bedside abdominal sonography appears to be an accurate method for diagnosis of simple bowel obstruction and is more specific than plain x-rays in establishing this diagnosis. In addition, abdominal sonography may identify the cause of obstruction or other etiologies for the acute abdomen. The use of sonography to differentiate strangulation *versus* simple bowel obstruction may permit earlier operative intervention for strangulation while also allowing wider use of nonoperative management for simple bowel obstruction. In turn, the overall costs and complications associated with treatment of bowel obstruction might be significantly reduced. Wider employment by clinicians of bedside ultrasonographic examination merits further investigation.

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