

Sonography in Acute Colonic Diverticulitis

A Prospective Study

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The clinical value of high-resolution real-time sonography for the diagnosis of acute and complicated colonic diverticulitis was prospectively studied in 130 consecutive patients with abdominal complaints, because of which the disease entered into differential consideration. The results of ultrasound investigation were compared with those of clinical examination on admission. Regarding history and initial clinical evaluation, diverticulitis was graded as "highly suspected" in 19 (36.5 percent) out of a total of 52 patients with later proven colonic diverticulitis (prevalence 40 percent), as "possible but equivocal" in 24 (46.2 percent), and as "very unlikely" in the remaining nine (17.3 percent) patients. Ultrasonography enabled the diagnosis of diverticulitis with an overall accuracy of 97.7 percent, a sensitivity of 98.1 percent, and a specificity of 97.5 percent. The predictive values of positive and negative ultrasound examinations were 96.2 percent and 98.5 percent, respectively. The echomorphologic features of acute diverticulitis include visualization of a colon segment presenting with local tenderness on gradual compression, which showed hypoechogenic thickening of the wall and a targetlike appearance in transverse view due to inflammatory changes and muscular thickening. Sonographic signs of peridiverticulitis (hyperechoic halo) were found in 96 percent of patients, echogenic diverticula in 86 percent. Twelve (92 percent) of 13 abdominal abscesses were detected on initial ultrasound examination and could be treated by percutaneous drainage in seven cases, while six required surgical intervention. These results indicate that high-resolution sonography with graded compression is highly sensitive and specific for the imaging diagnoses of acute colonic diverticulitis and complicating abscess. [Key words: Colonic diverticulitis; Ultrasound]

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Until recently, the diagnosis of acute diverticulitis in patients with known diverticula of the colon largely rested on a collective interpretation of history, clinical signs and symptoms, and physical examination.

Contrast radiology and colonoscopy certainly are the best means of demonstration of the presence and extent of diverticula in the colon. These methods are, however, of limited value for the recogni-

tion of truly inflammatory complications of diverticular disease. Moreover, if there is evidence of an acute fulminating diverticulitis, barium enema by the double-contrast technique and endoscopy, both requiring air insufflation, should not be performed or should only be applied with extraordinary caution because of a possible danger of perforation.

In recent years, sonographic examination of the gut has gained increasing attention owing to technologic advances in ultrasound equipment with improved resolution capability and a greater knowledge of echographic appearances of normal and abnormal bowel.^{1, 2} Recent reports have emphasized the growing use of ultrasound for the imaging diagnosis of both acute and chronic inflammatory bowel diseases, such as acute appendicitis,³⁻⁵ Crohn's disease and ulcerative colitis,⁶⁻¹⁰ and colonic diverticulitis.¹¹⁻¹⁴

In a prospective study, we investigated the value of high-resolution real-time sonography in the diagnosis of acute colonic diverticulitis and its efficacy in the detection of complicating pericolic abscess.

MATERIALS AND METHODS

Patients

The study comprises a total of 130 patients who were seen at our clinic during a two-year period either with the admitting diagnosis of suspected diverticulitis or with abdominal complaints, because of which the disease initially entered into differential consideration. These included 66 (50.8 percent) female and 64 (49.2 percent) male patients with a mean age of 57.7 years (age range, 23 to 88 years).

Study Design

On admission to the hospital, all patients underwent thorough physical examination. A working diagnosis was performed by senior surgeons, who

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took into account history, symptoms, physical examination, and laboratory data. According to these preultrasound findings, all patients were allocated to one of the following three categories, which served for grading the clinical suspicion of acute colonic diverticulitis: Category I = highly suspected diverticulitis; Category II = possible but equivocal cases of diverticulitis; and Category III = diverticulitis very unlikely.

After clinical classification of patients, ultrasound examination was performed by one of us who had knowledge of the patient being a "diverticulitis-study patient" but who was blinded to details of the clinical examination. The sonographer was not involved in the initial categorization and medical management of patients (with the exception of required percutaneous interventions) and had no influence on the establishment of final diagnoses (Fig. 1).

Results of initial clinical examination and sonography with regard to the diagnosis of colonic diverticulitis were later evaluated and compared on the basis of ultimate diagnoses at patients' discharge. Diagnostic accuracy of sonography was determined concerning sensitivity, specificity, and predictive values of positive and negative ultrasound findings.

Equipment and Procedures

Abdominal ultrasound was performed using commercially available electronic real-time scanners with 3.5-MHz and 5-MHz curved-array transducers. Images were recorded on photographic paper.

During examination, gradual compression was applied to the area of interest *via* the transducer. Thus, it was possible to localize and simultaneously visualize the area of greatest abdominal pain and

tenderness and to improve sound transmission and imaging by displacing obscuring bowel gas. Gradual compression was generally well tolerated by the patients.

Colonic sonography was performed following the normal echographic aspect of the large bowel, which is characterized by haustral sacculations of the ascending and transverse part, and a more tubular pattern of the descending and rectosigmoid colon. Visualizations of the psoas muscle, the iliac vessels, and the urinary bladder were considered landmarks in the exploration of the rectosigmoid area.

In general, not only the large intestine and the left lower quadrant but also the entire abdomen and pelvis were examined to provide alternative diagnoses, particularly in those patients without evidence of colonic diverticulitis.

Criteria for Evaluation and Calculations

Ultrasound examinations were evaluated with regard to presence and extent of mural thickening of the colon, length of the colon involved, visualization of diverticula, and presence of echographic signs of periserosal inflammatory changes or abscess.

Sonographic visualization of a predominantly hypoechoic thickened segment of the colon presenting with pain on graded compression, hyperechoic diverticula, and a surrounding rigid zone of increased echogenicity (hyperechoic halo) was considered a positive finding of acute diverticulitis. These criteria were established before the onset of the study. Nonvisualization of such a segment was regarded as a negative result.

Thickness of bowel wall was assessed by measuring the maximum wall diameter of that colon segment most prominently exhibiting the so-called target configuration on the transverse scan.

The diagnostic accuracies of clinical examination on admission and sonography with regard to the final diagnosis of colonic diverticulitis were assessed considering the following statistical calculations: sensitivity (TP results) = $TP \times 100\% \div (TP + FN)$; specificity (TN results) = $TN \times 100\% \div (TN + FP)$; predictive value of positive results = $TP \times 100\% \div (TP + FP)$; predictive value of negative results = $TN \times 100\% \div (TN + FN)$; and overall accuracy = $(TP + TN) \times 100\% \div (TP + TN + FP + FN)$, where TP = true-positive, TN = true-negative, FP = false-positive, and FN = false-negative.

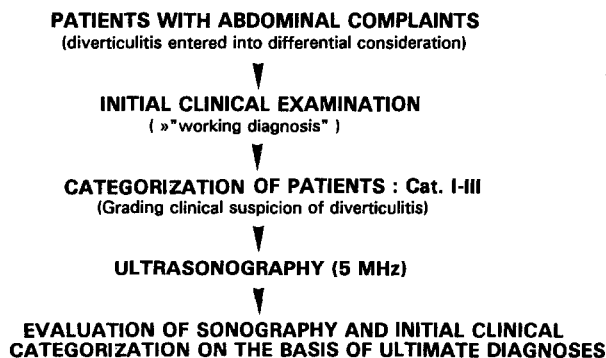


Figure 1. Study design.

RESULTS

Final Diagnoses and Prevalence of Colonic Diverticulitis

Among the 130 patients included in this study, 52 had a final diagnosis of colonic diverticulitis (prevalence 40 percent). These 52 patients comprised 33 (63.5 percent) men and 19 (36.5 percent) women with a mean age of 57.6 years (age range, 31–88 years). The pelvic colon was by far the most common site of acute diverticulitis. In this population, the frequency of involvement was 96 percent ($n = 50$) for the sigmoid colon and only 2 percent ($n = 1$) each for the cecum and the transverse colon.

In 42 (32.3 percent) of our study patients, abdominal pain was associated with other specific diagnoses such as carcinoma of the colon, ulcer disease, abdominal abscess, urinary tract disorders, pancreatitis, intestinal wall hemorrhage, colitis, aortic aneurysm, and omental hernia.

The remaining 36 (27.7 percent) of our study patients had a "diagnosis" of nonspecific abdominal pain. Their abdominal complaints finally were considered to be "functional" owing to irritable bowel syndrome, uncomplicated colonic diverticulosis, or constipation.

Confirmation of Diagnoses

In the group of 52 patients with final diagnoses of colonic diverticulitis, 14 underwent surgery and histologic proof of the disease. The remaining 38 diverticulitis patients had definite diagnoses based on radiographic ($n = 25$) or endoscopic ($n = 13$) demonstration of colonic diverticula associated with clinical signs and symptoms of inflammatory complications, which responded well to medical therapy on clinical follow-up.

In the second group of 42 patients with abdominal pain due to other specific diagnoses, final diagnoses were confirmed at surgery ($n = 11$), barium enema ($n = 6$), colonoscopy ($n = 7$), and various other endoscopic and radiographic measures ($n = 18$).

In the third group of those 36 patients with nonspecific abdominal pain, final diagnoses were based on clinical follow-up ($n = 36$), barium enema ($n = 14$), and colonoscopy ($n = 6$). Diverticula of the colon without any clinical, radiologic, or endoscopic evidence of inflammatory complications were identified in 11 of these patients.

Clinical Examination and Sonography

The results of clinical and ultrasound examinations on admission concerning the diagnosis of acute diverticulitis are summarized and compared in Tables 1 to 3.

On the basis of preultrasound findings, 19 (36.5 percent) of the 52 patients with proven diverticulitis were initially placed into Category I. Twenty-four (46.2 percent) and another nine (17.3 percent) cases, however, presented with signs and symptoms, which led to clinical classification of Categories II and III, respectively.

Table 1.

Results of Clinical Categorization on Admission and Sonography (US) Concerning the Diagnosis of Acute Colonic Diverticulitis in 130 Patients with Abdominal Complaints

	Category			Total
	I	II	III	
Clinical categorization	28	68	34	130
Colonic diverticulitis	19	24	9	52
US true-positive	19	23	9	51
US true-negative	8	43	25	76
US false-positive	1	1	—	2
US false-negative	—	1	—	1

For Categories I to III, see Materials and Methods. Data indicate number of patients.

Table 2.

Diagnostic Accuracy of Ultrasound Concerning the Diagnosis of Acute Colonic Diverticulitis

Sensitivity	98.1%
Specificity	97.5%
PV pos	96.2%
PV neg	98.5%
Overall accuracy	98.7%
Prevalence of diverticulitis	40.0%

PV pos/PV neg = positive/negative predictive values.

Table 3.

Comparison of Clinical Categorization on Admission and Sonography (US) Concerning the Diagnosis of Colonic Diverticulitis in 130 Patients with Abdominal Complaints

Diagnosis	Clinical Categorization (n)	US (n)
True-positive	19	51
True-negative	25	76
False-positive	9	2
False-negative	9	1
Possible/equivocal	68	—

In contrast, ultrasound examination enabled the visualization of abnormal segments of the colon with pain on graded compression in 51 (98.1 percent) of 52 patients with acute diverticulitis. Among these were two patients who presented with the clinical features of cholecystitis and acute appendicitis, respectively, in whom ultrasound, however, detected unusual sites of acute diverticulitis located in the hepatic flexure of the colon and the cecum.

Sonographic findings were classified as false-positive with regard to the diagnosis of diverticulitis in two (1.5 percent) patients who presented with severe cramping pain and localized peritonitis in the left lower quadrant (specificity 97.5 percent). Both underwent urgent surgery and resection of the sigmoid colon for a volvulus in one patient and a perforated sigmoid carcinoma in the other. From histologic examination, it became evident that the basically correct ultrasound identification of an abnormally thickened colon segment was caused by mural hemorrhage and edema in one case and by tumor infiltration and localized peritonitis in the other.

One (0.8 percent) false-negative ultrasound examination was encountered, concerning a case of acute diverticulitis complicated by localized perforation and abscess. In this patient, the abscess and sigmoid involved were located deep in the small pelvis and were probably obscured by overlying bowel gas.

Detection of Abscess

Confirmed by surgery or nonoperative percutaneous interventions, abdominal and pelvic abscesses were present in a total of 13 (10 percent) patients. According to preultrasound clinical examinations, nine of these patients were allocated to Category I and four were allocated to Category II (Table 4).

Twelve (92 percent) of the 13 abscesses, which ranged in diameter from 1.5 cm to 16 cm, could be detected on ultrasound scanning. One abscess probably was obscured by overlying bowel gas. This group of patients with verified abscesses comprised eight subjects with perforated diverticulitis, one with penetrating sigmoid carcinoma, one with perforated appendicitis, one with ischemic necrosis of a small bowel loop, one with chronic pancreatitis, and one with unknown underlying disorder.

Seven (58 percent) of the 12 ultrasonically visible abscess collections were successfully treated by ultrasound-guided percutaneous aspirations ($n = 4$) or catheter drainage ($n = 3$) to avoid emergency surgery. The other five (42 percent) patients with abscesses underwent surgical drainage because the collections were considered inaccessible for percutaneous drainage in view of precarious access routes.

Ultrasound Findings in Acute Diverticulitis and Abscess Formation

The frequencies of sonographic signs found in 51 patients with confirmed diagnoses of colonic diverticulitis are listed in Table 5.

Echomorphologic findings suggestive of acute colonic diverticulitis comprise (Figs. 2–5): hypoechoic thickening of the wall along the segment involved with a target appearance on transverse section, a more tubular pattern on longitudinal scan, and narrowing or complete obstruction of the lumen; local pain and tenderness on gradual compression; a rigid zone of increased echogenicity (omental covering, pericolonic fat), which walled off the inflammatory process; visualization of intramural and extramural diverticula; and real-time demonstration of decreased peristaltic activity.

The basically nonspecific target appearance of the cross-sectioned bowel loop in colonic divertic-

Table 4.

Clinical Categorization on Admission and Sonography (US) in 13 Patients with Abdominal Abscess (Incidence: 10 Percent)

	Category			Total
	I	II	III	
Clinical categorization	9	4	—	13
US true-positive	9	3	—	12
US false-negative	—	1	—	1

For Categories I to III, see Materials and Methods. Data indicate number of patients.

Table 5.

Echomorphologic Findings in 51 Patients with Colonic Diverticulitis

Echomorphologic Findings	n
Target appearance	50 (98%)
Hyperechoic halo	49 (96%)
Visible diverticula	44 (86%)

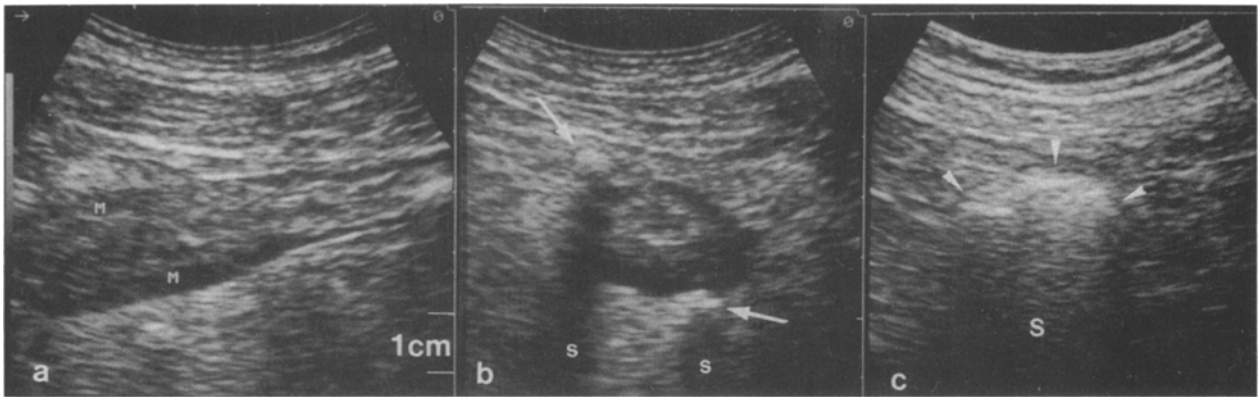


Figure 2. Sigmoid diverticulitis (clinical Category II) in comparison with the normal aspect of the sigmoid colon. a. Longitudinal view of the affected segment showing varying degrees of mural thickening and luminal narrowing. M = hypoechoic muscularis externa. b. Transverse view. Arrows point to adjacent echogenic diverticula casting sound shadows (S). c. Transverse section of normal sigmoid colon showing less than 3-mm wall thickness (arrow heads). Reverberation artifacts and sound shadowing (S) are due to highly reflective luminal gas.

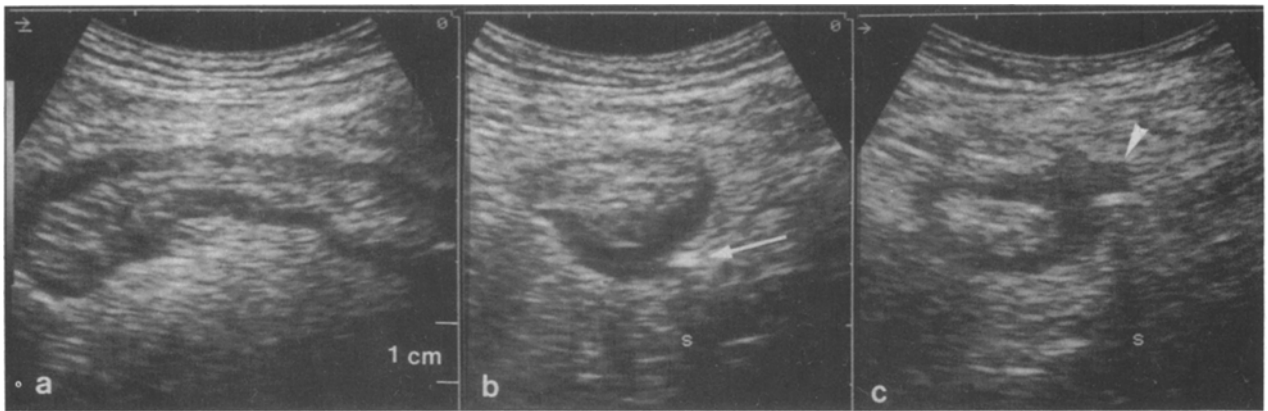


Figure 3. Sigmoid diverticulitis (clinical Category II). a. Longitudinal section showing inflammatory and muscular thickening of the affected wall. b and c. Transverse sections at different levels. Arrow and arrow head point to hyperechoic diverticula with distal sound shadow(s). Muscular and inflammatory thickening is not uniform around the bowel wall.

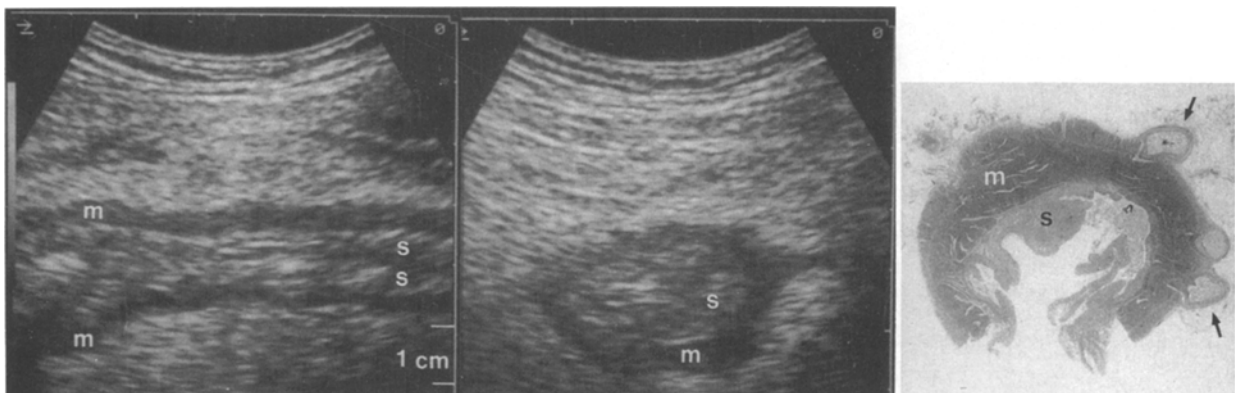


Figure 4. Sigmoid diverticulitis (clinical Category I). Longitudinal and transverse section showing thickening of both the entire wall and the hypoechoic muscularis externa (m) and luminal narrowing. s = mucosa/submucosa. Corresponding histologic section (far right) confirmed abnormal thickening of muscularis propria (m). Diverticula (arrows) are penetrating the muscle layer to lie in the pericolic fat.

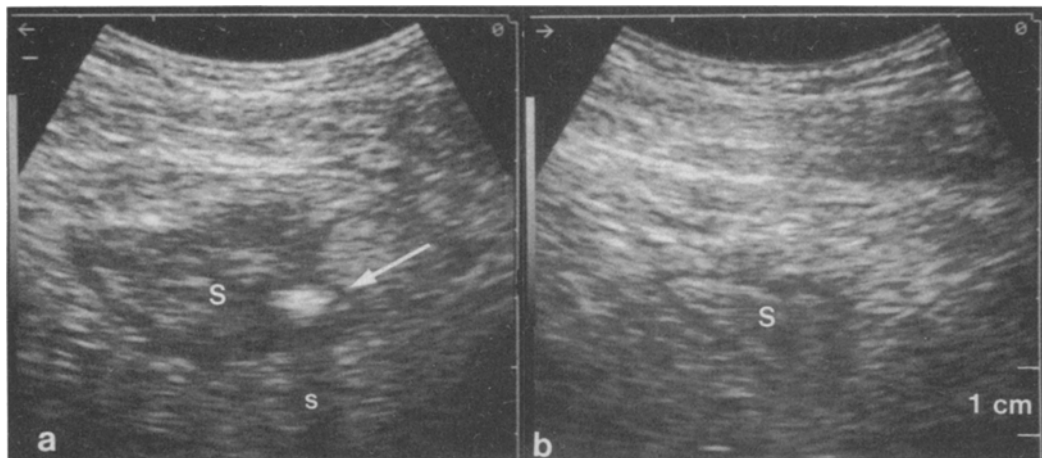


Figure 5. Ultrasound follow-up in sigmoid diverticulitis. a. Acute stage. Transverse scan of sigmoid colon (S) showing predominantly hypoechoic thickening of the bowel wall, luminal narrowing, and hyperechoic intramural diverticulum (arrow) with associated acoustic shadowing. b. Follow-up sonogram after medical treatment and resolution of diverticulitis. Lesser degree of wall thickening but still visible "target" appearance.

ulitis is caused by alterations of the echoarchitecture of the wall induced by inflammation and various degrees of abnormal thickening of the lamina muscularis externa (Fig. 4).

Some patients with colonic diverticulitis, particularly those with more severe episodes of the disease complicated by transmural and longitudinal progression of inflammation, presented with a predominantly hypoechoic thickening of the entire wall along the segment involved. In other patients, however, clearly separated concentric layers of varying echogenicity could be identified within the thickened wall of the affected loop.

Histologic examinations on surgical specimens revealed that edematous swelling and inflammation, but also an abnormal muscular hypertrophy, which is represented by the hypoechoic external wall layer, account for mural thickening and the sonographic target pattern. Regarding the variety of echomorphologic findings, from histologic studies it became evident that different disease states, *i.e.*, different extents of transmural spread of inflammation, may affect individual anatomic layers and thus may alter the echographic appearance of the bowel wall.

The length of the most prominently thickened segment of the colon involved varied from 5 to 25 cm, with an average length of 13.2 ± 4.8 cm. Maximum thickness of the wall ranged between 5 and 19 mm (mean, 10.2 ± 3.6 mm) (Fig. 6).

Like elsewhere in the body, pericolic abscesses presented with a spectrum of ultrasound findings.

This ranged from almost echo-free liquid collections to solid-like lesions, which may contain gas responsible for sound shadows or reverberation artifacts.

Unlike free peritoneal fluid, abscess collections usually did not change in shape or location under external compression or alteration of the patient's position. Depending on inflammatory reaction and localized peritonitis, almost all abscesses exhibited a surrounding rigid zone of increased echogenicity (hyperechoic halo) and edematous thickening of adjacent bowel walls.

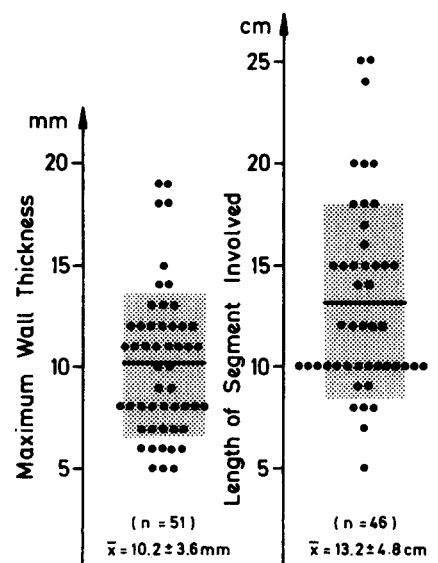


Figure 6. Maximum wall thickness and length of the segment involved in acute colonic diverticulitis. Ultrasonic *in vivo* measurements.

DISCUSSION

Unlike in uncomplicated diverticular disease of the colon, barium enema and colonoscopy are of limited value in the recognition of truly inflammatory complications of the disease. These imaging procedures basically provide visualization of mucosal and endoluminal details of the gut. The inflammatory process in acute diverticulitis, however, essentially causes extraluminal, *i.e.*, intramural and periserosal, abnormalities rather than mucosal changes.

Within its resolution capability, ultrasound tomography displays the transmural aspect of neoplastic and inflammatory bowel disease. Thus, this noninvasive technique offers the possibility to visualize intramural and periserosal abnormalities of the gut, which might develop in colonic diverticulitis owing to abnormal thickening of muscle layer and inflammatory changes.

In this prospective investigation, we were able to demonstrate that high-resolution real-time sonography provided accurate detection of both acute colonic diverticulitis and the complicating abdominal abscess. The diagnostic accuracy for ultrasonography in the present study was found to be advanced when compared with the recently published results of Verbanck *et al.*¹² These authors reported an 84.6 percent sensitivity for sonography in detecting colonic diverticulitis, a specificity of 80.3 percent, and predictive values of a positive and negative sonogram of 76 percent and 87.7 percent, respectively. They supposed that the more localized disease with perforation of a single diverticulum and obscuring bowel gas accounted for most of their false-negative diagnoses.¹²

Considering the high accuracy of ultrasound in the diagnosis of acute diverticulitis found in our prospective investigation, it should, however, be mentioned that these results might have been influenced by two favorable conditions.

First, our study population consisted of patients who attended the hospital and who, therefore, could have been those with the more severe episodes of the disease. It remains, however, speculative whether an increasing percentage of patients with only mild "subclinical" attacks of diverticulitis would cause a decrease in the ultrasound detection rate.

Second, our study patients were selected insofar as they all presented with abdominal complaints in view of which colonic diverticulitis entered into

differential consideration. On the other hand, even those patients in whom initial clinical evaluation led to the assumption of colonic diverticulitis being very unlikely (Category III) were included in our study.

We found a spectrum of ultrasound patterns and a wide range of wall thickening of the involved segment in colonic diverticulitis. This was probably due not only to a different degree of inflammatory changes but also to abnormal thickening of the muscle layer.

From histologic studies, abnormal thickening of the lamina muscularis propria was long ago identified as accompanying diverticular disease of the colon, particularly along the sigmoid and even in the absence of any inflammatory changes.¹⁵ According to these histologic findings, we have been able to visualize localized thickening and the target appearance of the sigmoid wall—obviously owing to abnormal muscular thickening only—in patients with diverticulosis who had no evidence of inflammatory complications. This is why the ultrasound diagnosis of colonic diverticulitis should only be made when local pain and tenderness additionally can be induced by graded compression during real-time examination and when pericolic abscess or extraluminal signs of inflammatory reaction are identified.

In the present study, there were patients with colonic diverticulitis in whom sonographic signs of peridiverticulitis largely dominated the pathologic transformation of wall architecture. In contrast, others presented with accentuated hypoechoic thickening and a target appearance of the wall along the colon involved.

The reported ultrasound detection rate of diverticula in colonic diverticulitis ranged between 5.7 percent and 11.8 percent.^{12, 14} In the present study, prospective investigation enabled the visualization of diverticula in 86 percent of diverticulitis patients. Frequently, diverticula (containing gas or fecaliths) were seen as hyperechoic foci casting distal sound shadows (Figs. 2, 3, and 5). In general, they could be identified not only along the area of inflammation but also in contiguous segments of the colon, which presented with a lesser degree of wall thickening, obviously due rather to an abnormally thickened muscle layer than to acute inflammation.

Our study group involved a total of 13 patients with proven abdominal abscesses of various origin, 12 of which could be identified on ultrasound

scanning. In this context, it is of little more than academic interest whether mini abscesses, which additionally might have been developed owing to microperforation of the injured diverticular mucosa and possibly responded well to antibiotic therapy, could have been missed on ultrasonography.

Our false-positive diagnoses of colonic diverticulitis demonstrate that echomorphologic findings in acute diverticulitis, especially in the sigmoid colon, exceptionally may overlap with those of neoplastic infiltration and volvulus. This was particularly true in a patient with carcinoma of the sigmoid mimicking the ultrasound features of circular wall thickening in diverticulitis, who beyond that presented with echographic signs of periserosal inflammation and abscess due to perforation.

Cecal diverticulitis, which has been reported to occur in only about 0.1 percent of all cases of diverticular disease,¹⁶ is known to create a particular diagnostic problem. The frequency for a correct preoperative diagnosis of cecal diverticulitis ranged between 5 percent and 14 percent only,¹⁷⁻¹⁹ the most common misdiagnoses being acute appendicitis and cecal carcinoma.

Even though the present experience is limited, high-resolution sonography with graded compression seems to be of benefit in this setting for two reasons. First, the reported sensitivity and overall accuracy for ultrasound regarding the diagnosis of acute appendicitis is high, ranging between 75 percent and 88.5 percent and between 90 percent and 95.7 percent, respectively.³⁻⁵ Second, as has also been mentioned in a brief case report,¹³ ultrasound demonstration of a thickened cecal wall with adjacent diverticulum and local tenderness in the absence of any echographic evidence of acute appendicitis is strongly suggestive of cecal diverticulitis.

CONCLUSION

High-resolution sonography with graded compression has proved to be a highly sensitive and specific method for the imaging diagnosis of acute colonic diverticulitis and complicating abscess. This technique can diminish the time waiting for the diagnosis and can lead to an earlier institution of conservative and, if necessary, operative therapy or percutaneous interventional procedures.

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