Transabdominal ultrasound in inflammatory bowel disease. Conventional and recently developed techniques – Update

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Abstract

Transabdominal ultrasound is clinically useful in detecting Crohn’s disease (initial diagnosis) by evaluating bowel wall thickness and surrounding structures including perirectal inflammatory reaction, extent and localization of involved bowel segments and detection of extraluminal complications such as fistula, abscesses, carcinoma and ileus.

Transabdominal ultrasound presently is accepted as a clinically important first line tool in assessing patients with Crohn’s disease irrespective of their clinical symptoms and/or disease activity. It helps to better characterize the disease course in individual patients and can guide therapeutic decisions. In this review the current literature will be analysed.

Keywords: ultrasonography, intestine, inflammation, complication

Introduction

Transabdominal ultrasound is most commonly used to obtain images of the hepatobiliary and urogenital tract and pelvic structures. Its utility for imaging the intestinal tract was less well established in the past and considered more difficult due to technical difficulties in obtaining high quality images of these regions. Improvements of technology and increasing experience with sonographic findings in a variety of intestinal diseases including inflammatory bowel disease (IBD), however, have contributed to firmly establish the role of ultrasound as a clinically important, non-invasive and widely available imaging modality. In addition, newer techniques such as color/power Doppler, harmonic imaging and contrast-enhanced ultrasound (CEUS) also have recently gained increasing attention as additional useful tools.

A general advantage of high resolution ultrasound compared with endoscopy and other (also contrast enhanced) imaging modalities (e.g., computed tomography [CECT], magnetic resonance imaging [MRI]) or other methods is that it permits evaluation of the transmural aspects of inflammatory or neoplastic pathology within its surrounding structures [1-5]. This can provide an important contribution for diagnosis and monitoring disease activity. Compared with other very recently developed imaging technologies such as computed tomography and magnetic resonance imaging, its major advantage is the absence of radiation exposure and low costs [6-8]. On the other hand, important limitations are that the alimentary tract cannot be visualized over its entire length, many of the findings are nonspecific and obtaining and interpreting the images is highly operator dependent. Additional difficulties may exist in obese patients in whom high frequency scanning is not possible or difficult.

The topic of this review will provide an updated overview of the role of transabdominal ultrasound in IBD while summarizing the results of recent studies with special reference to sensitivity/specificity in detecting the disease and sonomorphologic features to evaluate disease activity and its luminal and extraluminal complicati-
ons. Emphasis will be given to conventional as well as to more recently developed techniques. Finally, comparisons with other techniques such as CT and MRI will be discussed. The current state of ultrasonography with regard to extraintestinal manifestations of inflammatory bowel disease particularly sclerosing cholangitis will be reviewed separately.

**General considerations: technical aspects**

Imaging of the alimentary tract requires high frequency (5 to 15 MHz), high resolution linear or convex array transducers, a great deal of scanning experience, and patience. The standardized evaluation should optimally take place preprandially since images from filled intestines can be difficult to interpret, particularly when motility is being evaluated. On the other hand, reliable diagnoses under emergency conditions, such as ileus (obstruction, incarcerated hernia or intussusception), appendicitis or diverticulitis can be performed postprandially.

The ileocecal region and the sigmoid colon can be identified by ultrasound imaging in most patients [9]. Landmarks in the ileocecal region are the right iliac artery and vein while landmarks in the sigmoid region are the left iliac artery and vein. The remaining colonic segments also can be evaluated adequately by continuous scanning in many patients. Only the rectum and distal parts of the colon cannot always be displayed satisfactorily by the transabdominal route. In contrast perineal ultrasound has been useful in the evaluation of the perianal region and the distal rectum [10,11]. The technique has been summarized recently and indications and limitations have been pointed out.

**General considerations: intestinal wall thickness and sonomorphology**

A central problem of alimentary tract imaging is the correct estimation of wall thickness. More than thirty trials have been published within the last two decades measuring intestinal wall diameters, however, under varying conditions with greatly differing values defining normal from 1 up to 5 mm [12-37]. Table I summarizes the results from studies in which data concerning the thickness of at least three distinct bowel segments (jejunum, ileum and colon) are presented and comparable techniques and frequencies have been used. In contrast, measurements from our ultrasound unit differ from several studies as we have found lower diameters of all segments (table II).

Major reasons for this discrepancy may be different examination techniques, equipment and frequencies used, particularly the presence or absence of externally exerted compression during the examination by the operator [3]. In our experience the normal intestinal tract thickness in the terminal ileum, cecum and right and left colon is generally below 2 mm when examined with mild dose compression. It is important to mention that a contracted intestinal segment can be misinterpreted as a thickened wall and that on the other hand, an inflammed ileal/cecal wall structure may appear normal. In addition to wall thickness, its overall echotexture and appearance within surrounding structures should always be carefully considered when interpreting data, as determination of wall thickness alone may be clinically of very limited value [3,4,38,39].

<table>
<thead>
<tr>
<th>Jejunum</th>
<th>Ileum</th>
<th>Colon</th>
<th>Frequency [MHz]</th>
<th>Author year [reference]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>2.0</td>
<td>2.0-3.0</td>
<td>3.5; 5.0</td>
<td>Worlicek 1986 [16]</td>
</tr>
<tr>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
<td>2.0-5.0</td>
<td>5.0</td>
<td>Abu-Yousef 987 [15]</td>
</tr>
<tr>
<td>&lt;3.0</td>
<td>&lt;3.0</td>
<td>&lt;5.0</td>
<td>3.5; 5.0</td>
<td>Kedar 1994 [30]</td>
</tr>
<tr>
<td>&lt;4.0</td>
<td>&lt;4.0</td>
<td>&lt;4.0</td>
<td>5.0</td>
<td>Bozkurt 1994 [29]</td>
</tr>
<tr>
<td>&lt;4.0</td>
<td>&lt;4.0</td>
<td>&lt;4.0</td>
<td>3.5; 7.5</td>
<td>Maconi 1996 [31]</td>
</tr>
<tr>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>5.0</td>
<td>2.4-5.0</td>
<td>DiCandio 1986 [14]</td>
</tr>
<tr>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>Na</td>
<td>Dubbins 1984 [12]</td>
</tr>
<tr>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>3.5; 5.0</td>
<td>Sheridan 1993 [260]</td>
</tr>
</tbody>
</table>

Studies using methods other than transabdominal ultrasound are not included in this table. Those comprised trials using endoscopic ultrasound [(28;33;35-37)], hydrocolon ultrasound [(27)], in vitro measurements [(22)] or postmortem examination [(21)]; <: indicates values below this level are considered normal; na: not available

<table>
<thead>
<tr>
<th>Localization</th>
<th>Wall Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>terminal ileum</td>
<td>1.1+/-.0.1 [1.0-1.2]b</td>
</tr>
<tr>
<td>ascending colon</td>
<td>1.1+/-.0.1 [0.9-1.3]</td>
</tr>
<tr>
<td>right flexure</td>
<td>1.1+/-.0.1 [0.9-1.3]</td>
</tr>
<tr>
<td>sigmoid</td>
<td>1.4+/-.0.1 [1.2-1.8]</td>
</tr>
</tbody>
</table>

Measurements were performed after having identified corresponding landmarks for each bowel segment (see text) using a high resolution transducer (5.0 MHz) in the RES mode. mean +/- SE, b range; Data compiled from [3].
High resolution transducers usually permit visualization of five (up to nine) layers within the colonic and stomach wall, visualization being grossly enhanced in the presence of intraluminal fluid. Although the sonographic appearance cannot be completely assessed in terms of the exact anatomic wall structures, it can reasonably be assumed that these echolayers approximately reflect the structures as described in table III [1-5,19,40]. In addition, the small and large bowel usually can be distinguished by scanning the haustra of the colon and/or the circular folds of Kerckring in the small intestine. In unclear cases scanning of the intestine during various filling stages may be helpful [3,41].

Table III. Sonomorphology and intestinal wall structures from the lumen to serosa.

<table>
<thead>
<tr>
<th>Layer echogenicity</th>
<th>Anatomic structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumen echopoor (fluid), echorich</td>
<td>inner (luminal) layer transition lumen/mucosa</td>
</tr>
<tr>
<td>echo-rich entrance echo</td>
<td>inner layer</td>
</tr>
<tr>
<td>echopoor mucosa</td>
<td>outer layer</td>
</tr>
<tr>
<td>echorich submucosa</td>
<td>outer layer serosa/surrounding structures</td>
</tr>
</tbody>
</table>

Crohn’s Disease

Transabdominal ultrasound is clinically useful in detecting Crohn’s disease (initial diagnosis) by evaluating bowel wall thickness and surrounding structures including periintestinal inflammatory reaction, extent and localization of involved bowel segments and detection of extraluminal complications such as fistula, abscesses, carcinoma and ileus [1-6,24,42-44]. In addition several extraintestinal manifestations particularly mesenteric and perihepatic lymph node involvement such as in sclerosing cholangitis also can be reliably diagnosed [45,46].

Initial diagnosis by ultrasound

Sensitivity and specificity in detecting IBD were reported generally in the range from 70.0 to 94 percent and 67 to 97 percent, respectively [8,14,25,26,29,32,33,42]. When specified to Crohn’s disease alone similar data were found as demonstrated by a series of additional studies comparing transabdominal ultrasound with other methods such as endoscopy and/or radiology [47-58]. In these trials the sensitivity ranged generally from 73.0 to 96.0 percent and the specificity from 90 to 100 percent, respectively as seen from table IV.

Table IV. Sensitivity, specificity, positive and negative predictive value in the detection of Crohn’s disease

<table>
<thead>
<tr>
<th>No</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>Positive Predictive Value %</th>
<th>Negative Predictive Value %</th>
<th>Author,Year [Reference]</th>
</tr>
</thead>
<tbody>
<tr>
<td>175 (51)</td>
<td>84</td>
<td>91</td>
<td>80</td>
<td>93</td>
<td>Sonnenberg 1982 [(56)]</td>
</tr>
<tr>
<td>32</td>
<td>82</td>
<td>100</td>
<td>100</td>
<td>91</td>
<td>Dicandio 1986 [(14)]</td>
</tr>
<tr>
<td>181 (89)</td>
<td>81</td>
<td>80</td>
<td>79</td>
<td>81</td>
<td>Pera 1988 [(65)]</td>
</tr>
<tr>
<td>142</td>
<td>91</td>
<td>100</td>
<td>Na</td>
<td>Na</td>
<td>Limberg 1989 [(52)]</td>
</tr>
<tr>
<td>61</td>
<td>77</td>
<td>96</td>
<td>Na</td>
<td>Na</td>
<td>Statti 1990 [(57)]</td>
</tr>
<tr>
<td>36</td>
<td>86</td>
<td>97</td>
<td>Na</td>
<td>Na</td>
<td>Hata 1992 [(25)]</td>
</tr>
<tr>
<td>31</td>
<td>73</td>
<td>93</td>
<td>Na</td>
<td>Na</td>
<td>Brignola 1993 [(50)]</td>
</tr>
<tr>
<td>127 (46)</td>
<td>78</td>
<td>91</td>
<td>na</td>
<td>Na</td>
<td>Sheridan 1993 [(26)]</td>
</tr>
<tr>
<td>59</td>
<td>95</td>
<td>93</td>
<td>90</td>
<td>95</td>
<td>Solvig 1995 [(55)]</td>
</tr>
<tr>
<td>115</td>
<td>89</td>
<td>94</td>
<td>na</td>
<td>Na</td>
<td>Maconi 1996 [(28)]</td>
</tr>
<tr>
<td>47</td>
<td>81</td>
<td>86</td>
<td>96</td>
<td>57</td>
<td>Andreoli 1998 [(32)]</td>
</tr>
<tr>
<td>227 (69)</td>
<td>84</td>
<td>na</td>
<td>98</td>
<td>76</td>
<td>Hollerbach 1998 [(51)]</td>
</tr>
<tr>
<td>30</td>
<td>87</td>
<td>100</td>
<td>na</td>
<td>Na</td>
<td>Miao 2002 [(58)]</td>
</tr>
<tr>
<td>296a</td>
<td>93</td>
<td>97</td>
<td>na</td>
<td>Na</td>
<td>Parente 2002 [(42)]</td>
</tr>
<tr>
<td>296b</td>
<td>79</td>
<td>98</td>
<td>95</td>
<td>Na</td>
<td>Parente 2002 [(42)]</td>
</tr>
<tr>
<td>296c</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>Na</td>
<td>Parente 2002 [(42)]</td>
</tr>
<tr>
<td>46</td>
<td>76</td>
<td>na</td>
<td>na</td>
<td>Na</td>
<td>Potthast 2002 [(8)]</td>
</tr>
<tr>
<td>46</td>
<td>31</td>
<td>na</td>
<td>na</td>
<td>Na</td>
<td>Potthast 2002 [(8)]</td>
</tr>
<tr>
<td>48d</td>
<td>56</td>
<td>97</td>
<td>na</td>
<td>Na</td>
<td>Schmidt 2003 [(96)]</td>
</tr>
<tr>
<td>48e</td>
<td>56</td>
<td>97</td>
<td>na</td>
<td>Na</td>
<td>Schmidt 2003 [(96)]</td>
</tr>
<tr>
<td>48f</td>
<td>67</td>
<td>100</td>
<td>na</td>
<td>Na</td>
<td>Schmidt 2003 [(96)]</td>
</tr>
</tbody>
</table>

na: not available, a: localization, disease spread; b: strictures, gold standard; endoscopy and radiological methods; c: gold standard: operation; d: localization, disease spread; e: fistula; f: abscess; parentheses indicate the number of patients with proven Crohn’s disease. No: Number of patients
It should be emphasized, however, that different values may be due to different reference methods (gold standard). Although positive and negative predictive values would be clinically more relevant as they take prevalence and incidence of disease into account [59], only a minority of studies have reported such values in the range from 79 to 100 percent and 57 to 95 percent, respectively. Another objection may be that in some studies the diagnosis of Crohn’s disease was proven only indirectly. Additional sonographic criteria included asymmetric segmental bowel wall thickening assumed to correspond to endoscopic signs of focal ulcerations and/or polyloid mucosal changes with pathological thickened skip areas adjacent to areas of normal appearing mucosa (cobblestone appearance), a pattern found to be different from the continuous involvement observed in ulcerative colitis (see below).

Assessment of bowel wall thickness and disease activity

Assessment of bowel wall thickness and structures has been considered a particularly important issue. Attempts have been made to correlate wall thickness with disease activity particularly Crohn’s disease activity index (CDAI)[1-6,25,38,60-63]. Although an association of wall thickness and disease activity generally is assumed, detailed data including correlation coefficients (e.g. Spearman rank coefficient) (Rs) with corresponding significance levels have only rarely been reported. In a large series of patients (n=255) we have found that wall thickness is significantly higher compared to normal (4.9+/−2.7 mm versus <2.0 mm) and greater in active (CDAI >150) than in inactive disease (CDAI <150): 5.8+/−2.9 mm versus 4.3+/−2.2 (p<0.0001) [61]. In addition, in a second trial including 100 consecutive patients we have found a weak, but significant correlation of wall thickness with the CDAI (Rs:0.44, p<0.0001) [data not yet published] (fig 1).

In view of the conflicting results concerning a relationship between altered wall morphology such as a blurred aspect and/or transmural inflammatory reaction with disease activity [1-6,25,38] we have determined those characteristics and observed that a blurred wall layer morphology was significantly more frequent in active than in inactive disease (62.0 % versus 5.0 %, p<0.05) and that conversely, accentuated wall layers were more frequent in inactive than active disease (table V). In contrast, transmural inflammatory reaction (definition see above) was present only in 8 percent of the patients. The differences between active and inactive disease was not significant. However, this finding has to be further investigated with a greater number of patients in this category.

Assessment of bowel wall involvement (length and extent) and disease activity

The evaluation of the length and extent of the involved bowel segments with possible relations to clinical disease activity may be an additional goal of abdominal ultrasound examination. As Crohn’s disease often comprises more than one bowel segment it may be important to estimate the overall length of the involved segments and to examine as many areas as possible. As this question has not been sufficiently addressed so far, we prospectively investigated 100 patients, of whom sixty-seven had a bowel wall thickness >2.0 mm at initial presentation. Thirty-nine showed uni-segmental and twenty-eight multi-segmental involvement. The majority

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**Table V. Sonomorphologic criteria and clinical activity in patients with Crohn’s Disease (n=100) [data not yet published].**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Total (N)</th>
<th>CDAI&lt;150</th>
<th>CDAI&gt;150</th>
<th>Significancea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Thickness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>33/100</td>
<td>26/7</td>
<td>1/21</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>pathologic (≥2mm)</td>
<td>67/100</td>
<td>45/71</td>
<td>20/21</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Mean</td>
<td>5.0+/−2.0</td>
<td>4.0+/−1.0</td>
<td>6.0+/−3.0</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Wall Layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accentuated</td>
<td>49/100</td>
<td>41/71</td>
<td>7/21</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Blurred</td>
<td>18/100</td>
<td>4/71</td>
<td>1/21</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Transmural inflammation</td>
<td>8/100</td>
<td>4/8</td>
<td>3/8</td>
<td>p=0.1</td>
</tr>
</tbody>
</table>

---

a comparison between CDAI >150 versus CDAI <150;

b the sum of the number of patients with CDAI <150 and CDAI <150 does not yield N=100 as eight patients with ileostoma were excluded from calculations, because the CDAI was not applicable
c mean +/- SD, range in brackets.

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**Fig 1.** Spearman Rank-Correlation of bowel wall thickness and CDAI in 92 patients with Crohn’s disease (R = 0.45; p < 0.00001) [data not yet published].
of patients with unisegmental involvement (74.0 %) had quiescent disease (CDAI<150) and a mean length of involved bowel segments of 16.0+/−8.0 cm, the differences between patients with active and inactive disease, however, were not significant (p=0.8). In patients with multiple segment disease exact determination of the total length of involved segments was not possible, but sonographic and clinical features including disease activity were not different from those with unisegmental involvement [data not yet published].

Detection of complication

Besides morphologic evaluation of mural, transmural and adjacent structures ultrasound is able to detect complications such as fistulas (and the early stage of fistula, transmural inflammation), abscesses, carcinoma and ileus/subileus with a high sensitivity and specificity. Estimates of the sensitivity and specificity for detecting fistulas have ranged between 50 to 89 and 90 to 95 percent, respectively [63]. Estimates of the sensitivity and specificity for detecting abscesses have been reported in a somewhat higher range i.e. between 71 and 100 for the sensitivity and between 77 to 94 percent for the specificity [53,64-67]. Contrast enhanced ultrasound has been proven to be helpful in the delineation of abscess [68,69].

Ultrasound as screening procedure

A prospective study suggested that routine ultrasound in patients with Crohn’s disease can reveal unexpected pathologic findings that have therapeutic implications [61]. The study included 255 patients with Crohn’s disease who underwent regular ultrasound irrespective of symptoms and disease activity. Patients with abnormal findings underwent further evaluation with additional radiologic and/or endoscopic imaging and treatment as needed. Of 17 patients with inactive disease ultrasound revealed four with an interenteric fistula, seven with a mesenteric or perirectal fistula and six with transmural mesenteric inflammation without a fistula. Ultrasound of the remaining abdominal organs revealed pathologic findings with further diagnostic implications in 25 of 255 (10 percent) patients and with therapeutic implications in 4 percent [61]. In other series with 100 consecutive patients we found 13 fistulas, seven of which were not previously known [data not yet published], a percentage very close to our previous findings [61]. The majority of the fistulas were again entero-enteric, one was entero-rectal and another entero-cutaneous (table VI).

In a third trial comprising 46 consecutive patients nineteen cases with communicating fistulas were detected by ultrasound, 13 of which were entero-enteric with nine patients having a CDAI >150 (median 222), thus further supporting the view that fistula formation reflects a more active disease. Six of these had to be treated surgically, in seven immunosuppressive therapy was started. In this context the question arose whether the presence of a fistula per se is associated with greater bowel wall thickness and/or otherwise altered morphology. In this same series we found that the mean bowel wall thickness in patients with fistula formation was significantly greater than in those with no fistulas: 8.0+/−3.0 mm versus 4.3+/−1.2 mm (p<0.0002). Eight of 10 (80.0 %) patients with fistula showed a blurred wall structure compared to only nine of 54 without fistulas (17 %, p<0.0002). Signs of transmural inflammatory reaction were present in all patients with fistula formation. The median wall thickness in these patients was almost twofold higher than in those lacking these features (7.0+/−2.0 versus 4.0+/−1.0 mm, p=3x10^{-5}). In 42% mesenteric lymph nodes could be detected, however, no significant correlation to disease activity and/or sonographic/laboratory findings was found.

Extraluminal findings (ascites, lymphadenopathy)

Transabdominal ultrasonographic examination of extraluminal phenomena such as free fluid collection and/or mesenteric lymph nodes also may reflect disease activity, but clinical data corroborating such a view are scanty.

In the recent trial comprising 100 patients as mentioned above we have found free abdominal fluid in 13 percent of the patients, there was, however, no significant correlation with disease activity and/or laboratory parameters (p=0.236) [data not yet published].

Although lymph node enlargement is a common sonographic finding in Crohn’s disease [45,46,61,70,71], it appears that ultrasonographic assessment of lymph nodes with regard to clinical parameters particularly disease ac-

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Total (N)</th>
<th>CDAI&lt;150</th>
<th>CDAI&gt;150</th>
<th>Significancea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fistula</td>
<td>13/100</td>
<td>3/17</td>
<td>8/21</td>
<td>P&lt;0.05</td>
</tr>
<tr>
<td>(13 %)</td>
<td>(4 %)</td>
<td>(38 %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previously known</td>
<td>3/10</td>
<td>1/71</td>
<td>2/21</td>
<td></td>
</tr>
<tr>
<td>known</td>
<td>(30 %)</td>
<td>(1 %)</td>
<td>(5 %)</td>
<td></td>
</tr>
<tr>
<td>Newley detected</td>
<td>7/10</td>
<td>5/71</td>
<td>2/21</td>
<td></td>
</tr>
<tr>
<td>enteric</td>
<td>(70 %)</td>
<td>(7 %)</td>
<td>(10 %)</td>
<td></td>
</tr>
<tr>
<td>Entero-enteric</td>
<td>10/13</td>
<td>3/71</td>
<td>7/21</td>
<td></td>
</tr>
<tr>
<td>(77 %)</td>
<td>(4 %)</td>
<td>(33 %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entro-vesical</td>
<td>1/13</td>
<td>0/71</td>
<td>0/21</td>
<td></td>
</tr>
<tr>
<td>(0 %)</td>
<td>(0 %)</td>
<td>(0 %)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a comparison between CDAI >150 versus CDAI <150

b the sum of the patients with CDAI <150 and CDAI <150 does not yield N=100, as eight patients with ileostoma were excluded from calculation, because the CDAI is not applicable. data compiled from [(61)]
activity is only of limited value and the clinical implications remain to be further clarified. Very early manifestation of Crohn’s disease in children might be mesenterial lymphadenopathy with or without bowel wall thickening [data not yet published]. Other acute and chronic intestinal diatheses have to be excluded by appropriate stool and serological test.

In summary, transabdominal ultrasound presently is accepted as a clinically important first line tool in assessing patients with Crohn’s disease irrespective of their clinical symptoms and/or disease activity as it helps to better characterize those individuals with the potential to further guide therapeutic decisions.

**Color Doppler imaging**

**Intestinal wall vascularity**

As in a variety of inflammatory intestinal disease states particularly in Crohn’s disease the vascularization is involved and was conceived already more than a decade ago to qualitatively assess perfusion and other flow parameters by special ultrasound techniques [60,72-88]. Although a number of authors have described the utility of colour Doppler imaging in gastrointestinal disorders, particularly Crohn’s disease [72-78], celiac disease [79] and mesenteric artery stenosis [80], its exact role in diagnosis and/or monitoring disease activity remains to be further established.

In a trial with twenty-two patients with confirmed Crohn’s disease a high concordance between a power Doppler ultrasound score (measuring vascularization) and the degree of local inflammation assessed with an endoscopic severity score could be demonstrated with values from 0.83 to 0.98 [83]. A pilot study prospective-lying twenty patients could demonstrate a highly significant correlation between the mean blood vessel density assessed by power Doppler sonography and the semi-quantitative score tested by Limberg showing its potential applicability in routine clinical practice [89].

**Intestinal wall vascularity combined with mesenteric infow parameters**

A newer promising approach is combining mesenteric inflow by Duplex scanning such as systolic and diastolic peak velocities and resistance index with end-organ vascularity by color Doppler imaging [81-83]. Recent advances including harmonic imaging, power Doppler and contrast enhanced ultrasound have been added to further improve sensitivity/accuracy with regard to different disease aspects and potential therapeutic decisions, but their definitive clinical role still has to be more precisely defined [38,60,84-88,90;91].

**Mesenterial inflow and prognosis**

Investigations by Ludwig et al. indicate that the pulsatility index measured postprandially as well as in the fasting state allows calculating the probability of a relapse in patients with active Crohn’s disease. Positive and negative predictive values range between 0.77 and 0.89 [74,92,93]. Fifty-two patients were prospectively followed for one year. The major finding was that a decreased pulsatility index of the superior mesenteric artery was significantly associated with remission in Crohn’s disease, but not in ulcerative colitis [92]. This has lead the authors to the conclusion that repeated Doppler ultrasound measurements may predict response to immunosuppressive therapy. In view of other studies at discrepancy to those findings [94], further research and experience in larger patient populations clearly are needed.

**Contrast Enhanced Ultrasound**

Newer techniques such as power Doppler and the administration of echoenhancing agents (Leovist® or SonoVue®) have further improved sensitivity and accuracy [60,85-88]. Although 2D and Doppler techniques have been grossly improved over the last decade, the performance of these techniques still can be limited by a variety of factors such as tissue motion artifacts (peristalsis) and/or transmural vessel perfusion below the detection threshold [88]. To circumvent such limitations contrast harmonic imaging at a low mechanical index has been proposed [95-103], but its use in IBD presently is not yet widespread and confined to few specialized centers, introduction into clinical routine depending on further developments and experience. Studies comparing new with more conventional approaches will help to clarify these issues. In a small pilot study including fifteen patients with ileal Crohn’s disease contrast-enhanced power Doppler and conventional power Doppler were compared with regard to clinical disease activity and laboratory tests. Results were promising when bowel wall perfusion was evaluated at the site of maximum bowel wall thickness. As the major result contrast-enhanced ultrasound (CEUS) was found to be superior compared to conventional techniques with respect to those parameters [95-98]. In an other study one hundred four consecutive patients with Crohn’s disease were prospectively examined using CEUS with respect to the disease activity index [100]. It was found that the pattern of contrast enhancement and the ratio of enhanced to entire wall thickness had a positive predictive value of 63.0 % and 58.6 %, respectively, in distinguishing active from inactive disease [100]. It was, therefore, proposed, that CEUS may be particularly able to more precisely characterize bowel wall thickness by differentiating fibrosis from edema and may, thus, grade inflammation by assessing presence and distribution of vascularity within the intestinal layers particularly the submucosa and/or the entire bowel wall [90]. Peri-intestinal inflammation
also can be characterized in more detail [90], a view, however, which has to be confirmed in the up-coming future. Some authors postulate that CEUS can also provide prognostic data concerning relapse and/or response to therapy.

In a preliminary trial with twenty patients CEUS was suggested to be useful in the follow-up of infliximab treatment [97]. In addition, surgical issues recently have been focused using this technique particularly in helping the decision of conservative versus surgical treatment [102,104]. Although results are promising, much more work is needed before CEUS can be considered a clinically useful tool in such decisions.

Elastography

Elastography has been described recently in patients with IBD [105-107] but studies so far lacking (fig 2).

Differential diagnosis of inflammatory and fibrotic bowel wall changes

In patients with Crohn’s disease, the analysis of vascularity may facilitate the differentiation between inflammatory or cicatrical-fibroid stenosis but results are controversial discussed [88,89]. It has to be taken into account that cicatrical-fibroid stenoses are mostly in segments with wall thickening < 20 - 30 mm whereas inflammatory segments are > 30 mm which is more important for differential diagnosis of inflammatory and fibrotic bowel wall changes. Recently 200 consecutive patients with Crohns disease have been examined displaying hypervascularity in 180 patients with adequate visualization of the bowel wall (Siemens Elegra advanced, 7 MHz) [90]. In 15 patients hypervascularity could not be displayed due to reduced sensitivity in patients with a body mass index > 30 (n = 14), depth penetration > 40 mm (n = 14) and therefore, inadequate visualization and insensitivity of the methods. In three patients the thickened bowel wall segment was < 20 mm and hypovascularity was observed indicating cicatrical-fibroid stenosis. In the remaining two patients hypovascularity was found. It was concluded that patients with Crohns disease and thickened bowel wall with a segmental length of more than 30 mm hypervascularity can virtually always be displayed. Lack of hypervascularity might be due to insensitivity of the equipment, inadequate chosen Doppler parameters, and depth penetration > 40 mm with loss of sensitivity. In certain cases contrast enhanced sonography with a 2 – 5 MHz transducers can be helpful because there is less depth dependency as in Doppler techniques. Analysis of time intensity curves using contrast enhanced techniques might be more promising than colour Doppler imaging alone [90].

Ulcerative colitis

The diagnosis of ulcerative colitis usually is based on the patient’s history and typical endoscopic appearance of the mucosa and histology after exclusion of infectious agents by microscopic examination and stool cultures [105]. As treatment is based in part upon the extent of the disease, it is useful at the initial presentation to document the extent of inflammation, which can be accomplished by combining flexible sigmoidoscopy and ultrasound, when complete colonoscopy is not possible and/or contraindicated. Early sonographic signs of active ulcerative colitis may include a thickened hypoechoic layer, reflecting endoscopic findings of congestion of the swollen mucosa with petechiae, exudates and friability. More severe cases may be associated with transmural bowel wall thickening and patients with fulminant disease may...
reveal also transmural inflammation similar to Crohn’s disease [25,51,52]. However it should be mentioned that all these sonographic findings are not specific and may be seen also in a number of other colonic disorders due to infectious agents and/or drugs [3,106,107]. As a consequence the value of transabdominal ultrasound in ulcerative colitis is less well established than in Crohn’s disease [3,25,51,52]. In order to address the role of ultrasound in ulcerative colitis in more detail we evaluated in a series of thirty-six consecutive patients sonomorphologic characteristics including wall thickness, symmetry of thickness, thickened mucosa/submucosa, transmural reaction and extraluminal signs (>2 lymph nodes) in a similar fashion as in Crohn’s disease [61]. Disease activity was assessed by the Ulcerative Colitis Index (CAI), a numerical index indicating active disease when >4 points and inactive disease <4 points. Taken together there were no significant correlations/associations between any of these sonographic features and the clinical disease activity and/or laboratory parameters (table VII). Based on the data from the literature [25,51,52] and these findings we consider the role of transabdominal ultrasound in ulcerative colitis less important than in Crohn’s disease, but helpful in evaluating the extent of the disease for treatment decisions.

Ultrasound versus other techniques in IBD

Despite the tremendous impact of transabdominal ultrasound in helping managing patients with IBD, particularly Crohn’s disease sonography has to compete with other modalities primarily magnetic resonance imaging [108]. A series of studies has compared MRI and computed tomography (CT) with sonography or other modalities in patients with Crohn’s disease with particular emphasis on luminal and extraluminal complications such as fistulas and abscesses [7,8,109-119]. As CT is associated with considerable radiation exposure particularly when repeated examinations are necessary, this technique is less desirable particularly in young individuals. A recent metaanalysis comparing ultrasound, MRI, CT, scintigraphy and positron emission tomography (PET) with respect to sensitivity and specificity found no significant differences in diagnostic accuracy among these techniques, but stated that non-ionizing modalities are preferable [119]. Attempts to quantify gut wall inflammation have been made using administration of paramagnetic contrast media with a high sensitivity and specificity with regard to the involved segments [110], direct comparison with contrast-enhanced ultrasound techniques, however, have not yet been undertaken. As a result the present state of the knowledge in comparing ultrasound with MRI suggests that each method has its advantages and disadvantages and that a major factor also may be the corresponding local expertise with one technique or the other. Whereas in evaluating intestinal pathologies ultrasound seems to be preferable particularly under the aspect of low costs and repeatability, MRI may be preferred in cases with extraintestinal involvement particularly those not directly accessible to transabdominal ultrasound such as the lower pelvic regions [113] and/or bone involvement [114]. Disadvantages of MRI are its susceptibility to air and motion artefacts, extended examination time and high costs. The major drawback of ultrasound is its high operator dependence. Interventional ultrasound techniques have been recently summarized [120,121].

Table VII. Sonomorphologic criteria and clinical activity in patients with ulcerative colitis (n=36) [data not yet published].

<table>
<thead>
<tr>
<th>Description</th>
<th>Total</th>
<th>CAI &gt; 4</th>
<th>CAI &gt; 4</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>36</td>
<td>11</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Wall Thickening</td>
<td>27/36 (75.0%)</td>
<td>11/11 (100.0 %)</td>
<td>16/22 (73.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Wall Thickness [mm]</td>
<td>4.5+/-1.3 (3.0-8.0)</td>
<td>4.6+/-1.2 (3.0-7.0)</td>
<td>4.4+/-1.3 (3.0-8.0)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Symmetric thickening</td>
<td>27/33 (82.0 %)</td>
<td>11/12 (92.0 %)</td>
<td>16/22 (73.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Accentuated mucosa</td>
<td>3/33 (9.0 %)</td>
<td>1/11 (9.0 %)</td>
<td>2/22 (9.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Thickened mucosa/submucosa</td>
<td>21/33 (64.0 %)</td>
<td>9/11 (82.0 %)</td>
<td>12/22 (55.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Transmural reaction</td>
<td>3/33 (9.0 %)</td>
<td>1/11 (9.0 %)</td>
<td>2/22 (9.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Pancolitis</td>
<td>17/33 (52.0 %)</td>
<td>9/11 (82.0 %)</td>
<td>8/22 (36.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Left-sided colitis</td>
<td>16/33 (48.0 %)</td>
<td>2/11 (18.0 %)</td>
<td>14/22 (64.0 %)</td>
<td>n.s.</td>
</tr>
<tr>
<td>&gt;2 mesenteric lymph nodes</td>
<td>4/36 (11.0 %)</td>
<td>2/11 (18.0 %)</td>
<td>2/22 (9.0 %)</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

n.s. not significant. CAI: Ulcerative Colitis Activity Index, for details see text. Wall thickness, symmetric thickening, accentuated mucosa, thickened mucosa/submucosa, transmural reaction and lymph nodes were assessed in the same manner as in Crohn’s disease.
Summary and conclusions

Transabdominal ultrasonography is useful for the detection of bowel wall thickening and for determining the extent of involved segments in inflammatory bowel disease. In ulcerative colitis, the sonographically assessed extent of disease can guide therapy decisions. In Crohn’s disease transabdominal ultrasound is able to detect complications and characterise disease activity. Several studies comparing the value of sonography with endoscopic and radiologic results in Crohn’s disease have found a sensitivity between 73 and 96 percent and a specificity between 90 and 100 percent.

Conflict of interest: There is no conflict of interest.

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