Colonic diverticulosis is one of the commonest colonic conditions, particularly in Western industrial countries. Its precise prevalence is unknown; a large endoscopic study found that the prevalence was about 27%, increasing with age (1). Two thirds of persons aged over 70 have diverticulosis; 10 to 25% of this group later develop diverticulitis (2). The exact pathogenesis of diverticulosis is unknown. Predisposing factors include age, low fiber and high fat diet, an increase in intraluminal pressure, chronic constipation, and lack of exercise. It is thought that genetic factors also predispose to diverticular disease. There is no dependence on gender.

Diverticula are evaginations of the colon mucus membrane through the intestinal wall (pseudodiverticula); the sites of emergence of the arteries (vasa recta) should be regarded as points of least resistance. In about 95% of cases, the sigmoid colon is involved. The right hemicolon is only involved in about 15% of cases. During its passage through the intestine, feces are then intermittently pressed into the opening of the diverticulum. This can cause obstruction of the diverticular neck, invasion of intestinal bacteria and ulceration of the mucous membrane.

Typical complications of diverticulitis include the development of peridiverticulitis, intra-abdominal abscess or fistula formation, or stenosis. Severe diverticulitis can lead to perforation and even fecal peritonitis. Complicated disease is also associated with diverticular bleeding.

There is no standard staging for colonic diverticulitis. The most usual classifications are the classified stages of perforated diverticulitis, as specified by Hinchey in 1978 (3), and the clinically based classification of Hansen and Stock (4) (table 1).

Imaging techniques often provide important support to the clinical and laboratory findings, which may be non-specific. The objective of imaging is to confirm the diagnosis and to provide precise information about the severity and extent of the complicated disease (for a synopsis, see the diagram and box).

Sonography
Sonography – including duplex sonography and harmonic imaging – is a widely available imaging procedure. In principle, the patient should fast before the investigation, but no
Other preparation is necessary. After a preliminary investigation of the whole abdomen, a specific image is taken of the intestinal structures with a high resolving linear transducer (7.5 to 10 MHz). Modern ultrasound transducers are capable of resolving the individual layers of the intestine and of directly imaging the inflammatory thickening of the intestinal wall and the resulting constriction of the lumen (target sign).

Sonographic studies have shown that localized thickening of the intestinal wall can be imaged with high sensitivity. In particular, the so-called dome sign is thought to be highly specific for diverticulitis. This is a hypoechogenic hemispherical lesion, eccentrically positioned near the intestinal wall. The center of this lesion is hyperechogenic, corresponding to the inflamed diverticulum (5) (figure 1).

According to the literature, the sensitivity of sonography for diverticulitis lies between 79% and 98% (6, 7) and its specificity, between 80% (8) and 98% (7). Direct imaging of the inflamed diverticulum is moderately sensitive (77%), but highly specific (99%) for diverticulitis. Sonography's sensitivity for the uncomplicated form is as high as 96% (9). However, imaging the inflamed diverticulum is often not possible, particularly in complicated diverticulitis (9).

In addition, there is often an increase in the echogenicity of the pericolic fat tissue, corresponding to inflammatory edematous changes (sensitivity: 15% to 50%). Additional sonographic signs of complicated colonic diverticulitis include pathologicalcockades with a very narrow lumen (inflammatory stenosis) and the direct detection of peridiverticular abscesses. These may be hypoechogenic and also exhibit an intermediate reflection pattern, with or without gas (sensitivity about 40%).

Nevertheless, there are limits to sonographic diagnosis and these are often linked to the conditions of the ultrasound investigation. Thus even severe inflammation may be missed in obese patients or in patients with marked meteorism. Disease in the area of the pelvis and retroperitoneum are also often poorly accessible to transabdominal sonographic imaging (6).

In doubtful cases, the investigation can be complemented with endorectal or endovaginal ultrasound probes. This increases the investigation's sensitivity, particularly if there is involvement of the lower sigmoidal sections (e1). However, this complementary procedure is unsuitable for routine clinical use.

In addition, if the inflamed diverticulum cannot be imaged directly and there is marked thickening of the intestinal wall on sonography, it is difficult to make a distinction with other inflammatory bowel diseases, such as Crohn's disease or ulcerative colitis. It may be possible to distinguish ischemic colitis with color coded duplex sonography (6). In addition, it is not always possible to identify colonic changes related to cancer. Fistula formation is usually difficult to detect by sonography.

As well as its role in diagnosis, sonography also offers the possibility of treatment monitoring. If conditions are good and the practitioner is experienced, abscesses can be punctured and drained.

**TABLE 1**

<table>
<thead>
<tr>
<th>Staging of diverticulitis</th>
<th>Hinchey</th>
<th>Hansen and Stock</th>
<th>Ambrosetti</th>
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<td>Stage 0</td>
<td>Periocolic abscess</td>
<td>Diverticulosis</td>
<td>Moderate diverticulitis, Pericolic infiltration</td>
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<td>Stage I</td>
<td>Encapsulated abscess in the lower abdomen, retroperitoneum, or pelvis</td>
<td>Uncomplicated, simple diverticulitis</td>
<td>Severe diverticulitis, abscess formation in the mesocolon</td>
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<td>Stage II</td>
<td>Peridiverticulitis, phlegmonal diverticulitis</td>
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<td>Stage IIa</td>
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<tr>
<td>Stage IIb</td>
<td>Abscess forming, covered perforated diverticulitis</td>
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<tr>
<td>Stage III</td>
<td>Free perforation with generalized purulent peritonitis</td>
<td>Chronic recurrent diverticulitis</td>
<td>Perforated diverticulitis, diffuse purulent or fecal peritonitis</td>
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<td>Stage IV</td>
<td>Free perforation with generalized fecal peritonitis</td>
<td>Free perforation</td>
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**X-ray investigation /colonography**

Either double-contrast or mono-contrast techniques may be used for conventional X-ray investigations of the colon. The reliability of both procedures depends directly on how well the patient is prepared. The double-contrast technique with aqueous barium sulphate solution is principally restricted to the postacute phase (after at least 7 days). This technique is contraindicated for acute diagnosis, as there is a risk of perforation – indeed a covered perforation may already have developed – and this can lead to loss of barium, with the risk of barium peritonitis. In addition, contrast medium containing barium may remain in the intestine for long periods and may complicate an operation should this become necessary (e2, e3).

The mono-contrast technique uses aqueous contrast medium containing iodine. A spasmolysant is injected intravenously to prevent misinterpretations due to peristaltic movements.

There is usually no problem in imaging the typical segmental thickening of the intestinal wall and the resulting constriction of the affected intestinal section ("gold rolls phenomenon"). The imaging of the diverticulum is also adequate, although the inflamed diverticulum is only observed as "spicule-like" mucous membrane avulsions, due to the obstruction in the diverticulum neck. The segmental extension of the inflammation can be well documented. Free perforations can be easily recognized by the detection of extra-intestinal contrast medium (figures 2 a, b). On the other hand, it is difficult to detect a covered perforation. This can often only be indirectly inferred from the extra-mural indentations of the intestinal wall from small pericolic micro-abscesses.

A colon contrast enema often gives inadequate images of peridiverticular inflammatory reactions and of changes in complicated diverticulitis. The colon contrast medium investigation only detected a peridiverticular abscess in 29% of cases demonstrated by computed tomography (10).

Moreover, the overall extent of the inflammatory reaction is markedly underestimated by both procedures (11).

According to the literature, the sensitivity of the two procedures lies between 71% (12) and 94% (13), with specificities between 61% (13) and 72% (12).
Computed tomography has become the diagnostic gold standard. It is performed as spiral-CT on single or multi detector row CT (MDCT) scanners. The patient is then given both an oral and a rectal dose of contrast medium (CM). The investigation is performed after intravenous administration of contrast medium (ca. 120 ml of a water soluble non-ionic contrast medium; 300 to 370 mg iodine/ml) in a portal vein CM phase. Intravenously administered spasmolytics can also greatly facilitate intestinal imaging. In modern MDCT, primary layer collimations of 0.6 to 1.5 mm are primarily selected. In addition, multiplanar

**Value of different investigations in the diagnosis of sigmoid diverticulitis**

**Plain abdominal X-ray**
- Only to exclude significant abnormalities in intestinal passage and free intra-abdominal gas
- Not suitable for detecting diverticulitis

**Sonography**
- Generally available and cheap method of investigation
- Highly dependent on the ease of imaging and the experience of the practitioner
- Complicated disease is difficult to recognize (pelvic abscesses, fistulas, etc.)

**Mono-contrast barium enema**
- Inadequately sensitive for detecting peridiverticular inflammation, abscesses, and fistulas.
- Only recommended when CT not available for organizational reasons.

**Computed tomography**
- Method of choice, also for recognition of the complicated disease
- CT guided drainage is possible

**Magnetic resonance imaging**
- Used in trials, routine use still premature

**Colonoscopy**
- Mainly indicated for the reliable exclusion of tumors – during periods free of inflammation

**Computed tomography**

Computed tomography has become the diagnostic gold standard. It is performed as spiral-CT on single or multi detector row CT (MDCT) scanners. The patient is then given both an oral and a rectal dose of contrast medium (CM). The investigation is performed after intravenous administration of contrast medium (ca. 120 ml of a water soluble non-ionic contrast medium; 300 to 370 mg iodine/ml) in a portal vein CM phase. Intravenously administered spasmolytics can also greatly facilitate intestinal imaging. In modern MDCT, primary layer collimations of 0.6 to 1.5 mm are primarily selected. In addition, multiplanar
reformatting can be used to improve the presentation and documentation of the findings. Data acquisition is performed from the level of the sub-phrenic space to the symphysis pubis, with the aim of directly detecting any alternative diagnosis which might imitate the symptoms of diverticulitis.

Typical changes found in diverticulitis are symmetrical thickening of the inflamed intestinal wall (normal thickness about 3 to 5 mm), with segment size of > 10 cm (sensitivity 95%, specificity 31%), and diffuse edematous infiltration of the pericolic fat tissue (sensitivity 95%, specificity 35%) (14) (figure 3a). Padidar et al. (15) found fluid accumulation around the root of the mesentery and increased vascular injection in the mesosigmoid, with the high predictive values of 89% and 100% for diverticulitis.

In carcinoma of the colon, there is usually asymmetric and less extensive thickening of the wall. Larger intraluminal soft tissue formations and the so-called shouldering sign – corresponding to the "apple core phenomenon" of the contrast enema – are specific for malignant disease. In addition, fat tissue infiltration (lymphangiosis) may be only slight and local in malignant disease.

Pericolic lymph node enlargement is found particularly in tumor disease, but rarely in diverticulitis. If paracolic lymph nodes are not accompanied by pericolic fat tissue edema, a tumor is more likely than inflammation (specificity 92%, sensitivity 78%) (14). Nevertheless, the size of lymph nodes detected on CT does not in principle allow any general conclusion about the underlying disease.

Even with colorectal carcinoma, most of the detected lymph nodes may be smaller than 1 cm (4). On the other hand, large abdominal lymph nodes may be found in non-malignant disease, such as Crohn’s disease, celiac disease, Whipple's disease or sarcoidosis.

Even though some of the individual CT findings provide relatively good diagnostic information, there are some patients (about 10%) for whom reliable differentiation between carcinoma and inflammation is not possible. Current studies employ procedures, such as CT perfusion imaging, to improve the differentiation between carcinoma and inflammation (16). However, these have not yet provided reliably validated data.

Aside from imaging inflammatory intestinal wall changes and the associated reactions, computed tomography is especially useful in detecting the complications of diverticulitis. The following are found in CT, in order of decreasing frequency: pericolic abscesses (35%),

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**Figure 2:** Freely perforated sigmoid diverticulitis. a) Erect plain abdominal film b) Mono-contrast image of the colon with sigma perforation. The plain X-ray clearly shows free gas, which is both intra- and retroperitoneal. The contrast image of the colon shows the perforation site in the rectosigmoid transition, with marked extra-intestinal contrast medium (arrow). (a and b taken from: Piroth W, Haage P, Wildberger JE, Günther RW: Divertikulitis – wann Kolonkontrasteinlauf oder CT? In: Divertikulitis. Eine Standortbestimmung. Berlin, Heidelberg, New York: Springer 2001; 176–83, with the kind approval of Springer Verlag, Heidelberg).
peritonitis (16%), fistulae (14% to 20%), extrapelvic abscesses (12%), and colonic obstruction (12%) (17).

Covered or free perforations can be imaged from the intraluminal gas or with contrast medium (figure 3b). Abscesses are diagnosed by computed tomography in 100% of cases. There is then also the possibility of performing CT-controlled puncture and of inserting drainage. Many studies have demonstrated the advantage of primary CT-controlled abscess drainage. Even with computed tomography, detection of fistulae is difficult. Colovesicular fistulae or fistulae between the colon and uterus can be indirectly inferred from the gas in the area of the urinary bladder and/or the uterus, if there has been no prior use of the instruments which might have interfered (e.g. a urinary bladder catheter) (figure 3c). Computed tomography can also detect rare complications, such as septic thrombosis of the mesenteric veins (e5).

**Magnetic resonance imaging**

Because of the lack of radiation exposure and the high soft tissue contrast, MRI has become established as an alternative to computed tomography for intestinal imaging, particularly in younger patients and for some specific indications. 1.5 Tesla MR tomographs are usually used. Imaging mostly employs either body coils or highly resolving surface coils.

There is not yet any reliably established and standardized procedure for the diagnosis of diverticulitis. There has been wider experience with imaging processes linked to chronic inflammatory bowel disease, particularly Crohn’s disease. For these measurements, intestinal
contrast is achieved using 2.5% mannitol solution administered orally. One study (e6) measured not only fluid-sensitive signals (T2-TSE, HASTE), but also T1-weighted spin echo and gradient sequences, both before and after administration of contrast medium. The fastest and best sequence turned out to be the true-FISP sequence, which was also able to be used to observe intramural CM uptake following gadolinium administration. This sequence exhibited only very slight motion artifacts and very high spatial resolution. In particular, coronar reformations gave a good overview of the findings, even for practitioners with less experience with cross-sectional images.

Other investigators have used primary T1-weighted sequences, after intraluminal intestinal contrast with water and intravenous gadolinium-DTPA, to image inflammatory changes in the intestinal wall in diverticulitis. The detection of diverticulitis was based not only on intestinal wall thickening, but also locally increased uptake of contrast medium and pericolic inflammatory reactions (e7). Magnetic resonance imaging gives good images of the pericolic inflammatory reactions. As with CT, abscesses can be imaged and treated, if appropriate. Fistulae can be mapped with high sensitivity, using both T2- and T1-sequences after CM administration.

In one study of 14 patients (18), MRI results were compared with CT as the gold standard. The authors found no significant difference between the two methods. Nevertheless, published results are limited and additional validation is required.

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Angiography
Diverticular bleeding in the colon is the most frequent cause of lower gastrointestinal bleeding. About 3% to 15% of patients with diverticulosis suffer bleeding in the course of their lives (19, 20); this is caused by rupture of the vasa recta. This event occurs independently of acute or chronic inflammatory reactions and tends to cease spontaneously. For reasons which remain unclear, this is much more frequent in diverticulae of the ascending colon than in sigmoid diverticulae. The primary procedure for diagnosis and treatment is currently endoscopy. If bleeding cannot be controlled, primary surgical treatment is indicated.

There are also rare cases in which the bleeding point can be localized with digital subtraction angiography, possibly combined with CT-angiography using an angiographic catheter in the mesenteric artery (e8). In some cases superselective catheterization and embolization of the bleeding vessel is possible. The success rates for primary hemostasis vary between 83% and 94%. 27% to 34% of patients suffer renewed bleeding, despite successful primary embolization (21). It should always be born in mind that intestinal wall ischemia is a possible complication.

Colonoscopy
Endoscopy is of most use in diverticulitis in the intervals free of inflammation. This method can reliably exclude colonic cancer and other inflammatory diseases of the colon.

Diagnostic procedure
In the initial phase of the diagnosis of acute sigmoid diverticulitis, sonography has become especially well established, taken in the context of the clinical presentation and the laboratory parameters. The plain abdominal X-ray only detects free intra- or retroperitoneal gas and provides evidence of disturbances in intestinal passage. It cannot sensitively detect diverticulitis.

The effectiveness of sonography is highly dependent on the conditions of the investigation and the experience of the practitioner. Nevertheless, bowel-wall changes can usually be imaged very effectively using highly resolving transducers of modern ultrasonography systems. Peridiverticular changes can also be detected, depending on the ease of imaging. However, there are physical limitations with obese patients or with meteorism and these can result in marked inflammatory reactions or major peridiverticular abscesses – for example, in the minor pelvis – being missed.

The authors are well aware that subsequent investigations in many hospitals are still performed with colonic mono-contrast imaging with aqueous contrast media. This approach usually provides satisfactory depiction of the directly inflammatory changes in the intestinal wall. In contrast, the pericolic inflammatory reactions and the changes in complicated diverticulitis are mostly not ade-quately recorded (22). For example, macroabscesses are only recognized in about 20% of cases. The extension of the inflammation is also markedly underestimated (11).

Computed tomography has become the reference method in complicated diverticulitis and should be used as the primary method of investigation, if this is logistically possible. CT is of particular value in imaging inflammatory changes in the intestinal wall and reactions associated with peridiverticulitis and also in the identification of the complications of diverticulitis. Thus, it sensitively detects peridiverticular abscesses, changes linked to peritonitis, fistulas, extrapelvic abscesses and colonic obstructions. Moreover, smaller covered perforations can be recognized as concentrations of gas or contrast medium in the area of the mesocolon – with sensitivity of about 76%. The corresponding sensitivity with the mono-contrast investigation of the colon is only about 46% (22).

Aside from its diagnostic advantage, computed tomography offers the opportunity of interventional radiology, for example, in the puncture and drainage of a peridiverticular abscess. This approach often permits conservative treatment of the acute inflammatory episode, with a single intervention (22, 23, e9, e10), with markedly reduced overall mortality.

CT can also demonstrate that there is no inflammation in the colon and, in about 50% to 58% of cases, support alternative diagnoses which can imitate the clinical findings of diverticulitis (24). Clinical diagnostics and treatment of diverticulitis will be discussed in detail by Germer et al. in issue 50/2007 of Deutsches Ärzteblatt.

Magnetic resonance imaging is of increasing importance in the primary diagnosis of chronic inflammatory bowel disease. However, it has not yet been incorporated into the
diagnosis of diverticulitis. Routine use of this procedure in patient care is therefore premature. Table 2 summarizes the costs and the radiation exposure of the different procedures.

Conflict of Interest Statement
The authors declare that no conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors.

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REFERENCES
For e-references please refer to the additional references listed below.

ADDITIONAL REFERENCES

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