Diverticula of the appendix and their complications: value of sonography (review of 21 cases)

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Résumé
Ruptures hyperéchogènes de la coiffe des rotateurs
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Objectifs. La diverticulose se définit comme l’existence de diverticule(s) en un point quelconque du tube digestif. Cette pathologie et ses complications inflammatoires peuvent concerner l’appendice cæcal, comme n’importe quel autre segment digestif. Les auteurs exposent une série de 21 cas avec des corrélations écho-histopathologiques.

Matériel et Méthode. L’échographie nous semble en effet, par son pouvoir de résolution spatiale, l’examen de choix pour en faire le diagnostic.

Résultats. Comme pour le colon, il s’agit de pseudo-diverticules, constitués de muqueuse et de sous-muqueuse, faisant hernie à travers la musculuse. La paroi appendiculaire est invariablement le siège de modifications inflammatoires chroniques. Ceci est prouvé par l’examen histologique. La traduction clinique va de la douleur itérative de la fosse iliaque droite au syndrome appendiculaire, voire la péritonite.

Conclusion. L’analyse rétrospective de ces dossiers nous permet de décrire une sémiologie sensible et spécifique, des formes simples et compliquées. L’intervention chirurgicale nous semble souhaitable pour prévenir le risque important de perforation.


Abstract

Purpose. Diverticulosis is defined by the presence of diverticula along any segment of the GI tract. Diverticulosis and its associated complications may involve the appendix. The appendix. Diagnosis is difficult based on surgical series is between 0.2 and 2.6% (3, 6, 9). It most frequently corresponds to a pseudodiverticulum or false diverticulum. Diagnosis is difficult to achieve due to multiple reasons. Clinical presentation, not necessarily correlated to the degree of inflammation, is not pathognomonic: recurrent episodes of vague spontaneously resolving right lower quadrant abdominal pain in patients with diverticulosis, clinical presentation of acute appendicitis, either typical or atypical (without fever or laboratory abnormalities) in patients with diverticulitis, clinical presentation of complicated appendicitis in patients with abscess formation or perforation. The diverticulum is seldom identified preoperatively because it is hidden by the meso-appendix. It may even be overlooked at routine histological evaluation. US, because of its higher spatial resolution compared to CT and MRI in the evaluation of the GI tract, is the best imaging technique to diagnose this condition. From a retrospective evaluation of 21 cases with pathological correlation, the US features of appendiceal diverticulosis and its complications are presented. This condition frequently coexists with underlying “chronic appendicitis”.

Materials and Methods

We have retrospectively reviewed 21 cases of appendiceal diverticulosis, complicated or not, diagnosed at US between March 1994 and March 2003. The US examinations were performed using Kretz technik® units that have changed over time with technical advances: Combison 330, Combison 530 MT® and Voluson 730®. High frequency transducers were always used. Power Doppler was only used after 1998.

For each case, the clinical and laboratory as well as US features consistent with a positive diagnosis were recorded. First, features of the appendiceal wall: measurement of global wall thickness, and when possible, measurement of each wall layer thickness, integrity of wall layer anatomy, appearance of the lumen,
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Fig. 1: Distal simple diverticulum. Transverse view, distal third – 1. anechoic nodule (3mm) – 2. Muscular layer.

Fig. 1 : Diverticule simple de la pointe. Coupe transversale, tiers distal – 1. nodule anéchogène de 3 mm – 2. musculeuse.

Fig. 2: Simple diverticulum. Transverse view, endovaginal view – 1. diverticulum – 2. Enlarged lumen filled with mucus – 3. iliac vessels.

Fig. 2 : Diverticule simple. Coupe transversale, voie endovaginale – 1. diverticule – 2. lumière distendue par du mucus, 3. vaisseau iliaque.

Fig. 3: Distal diverticulum. Transverse view, distal third – 1. thickened muscular layer – * disruption of the muscular layer.

Fig. 3 : Diverticule distal. Coupe transversale, tiers distal – 1. musculeuse hypertrophiée – * interruption de la musculeuse.

Fig. 4: Chronic appendicitis. Middle third, transverse view – 1. asymmetrical thickening of the sub-mucosa – 2. moderately thickened muscular layer.

Fig. 4 : Appendicite chronique. Tiers moyen, coupe transversale – 1. épaissement asymétrique de la sous-muqueuse – 2. épaississement modéré de la musculeuse.

Fig. 5: Obliterating chronic distal appendicitis. Longitudinal view of the distal appendix – 1. moderately thickened muscular layer – 2. psoas muscle – * absence of the lumen.

Fig. 5 : Appendicite chronique distale oblitérante. Coupe longitudinales de la pointe – 1. musculeuse discrètement hypertrophiée – 2. muscle psoas – * disparition de la lumière.

Fig. 6: Chronic appendicitis. Transverse view, middle third – 1 thickened sub-mucosa – 2. thickened muscular layer – reduced lumen (cf Fig. 9).

Fig. 6 : Appendicite chronique. Coupe transversale, tiers moyen – 1. hypertrophie de la sous-muqueuse – 2. musculeuse hypertrophiée – → lumière rétrécie (cf Fig. 9).
compressibility, echogenicity of the meso and vascularity at power Doppler. Then, features of the diverticulum: nodule attached to the muscularis, size of the nodule, echogenicity, number, location relative to the tip of the appendix, and when possible relative to the meso. Sixteen of the 21 patients underwent surgery. Pathological evaluation included macroscopic evaluation of the specimen followed by histological evaluation after trichrome staining (hemalum, phloxine, safran).

**Results**

A total of 21 patients were included, ten males and 11 females. The mean age of 11 patients with simple uncomplicated diverticulosis was 47.7 years and the mean age of 10 patients with complicated diverticulosis was 50.7 years. Patients with simple diverticulosis presented with recurrent episodes of right lower quadrant abdominal pain without detectable abnormality at the time of physical examination. One patient with diverticulosis presented with acute pain and sepsis due to appendicitis. Five patients were evaluated for unrelated indications and the appendiceal diverticulosis was incidental. On the other hand, 80% of patients with complicated appendiceal diverticulosis presented with a clinical syndrome suggestive of acute appendicitis with fever above 38°C, right lower quadrant abdominal pain, with or without guarding. Patients with abscess formation or perforation, contained or free, had more severe presenting symptoms.

A summary of the US features of simple diverticulosis is presented in Table I and a summary of the US features of complicated diverticulosis is presented in Table II. Simple diverticula usually present as a hypoechoic nodule along the distal appendix (91% of cases) (fig. 1-3). They abut the appendix and the appendiceal wall usually shows significant thickening of the muscular and submucosal layers (fig. 4-6). Diverticulitis (5 cases) is associated with characteristic inflammatory changes: hyperechoic meso (fig. 7), irregular thickening of the serosa (fig. 8), and increased flow is present at power Doppler (fig. 9). Abscesses (3 cases) are hypoechoic and contain low level echoes with increased through transmission (fig. 10). Peri-diverticular inflammatory changes are also more advanced: hypoechoic strands are present at the surface of the muscular layer and along the meso. At the stage of perforation (2 cases), US findings are consistent with peritonitis, focal or generalized.

All symptomatic patients underwent surgery. Follow-up was not available for the five patients where diverticulosis was an incidental finding (mean time interval of 4.5 years). Histological analysis of the surgical specimen showed:

- 6 cases of simple diverticulum (fig. 11, 12), one with incidental acute appendicitis.
- 10 cases of diverticulitis (fig. 13), 3 with abscess (fig. 14a) and 2 with perforation.

Changes of chronic appendicitis were noted in all cases (fig. 15-17). These features
are discussed later. The diverticulum was overlooked at surgery in most cases. It may also be overlooked at histology unless the US report is available for correlation. In three cases, the diverticulum was identified only upon further review of the histological material. The post-operative outcome was always favorable.

### Discussion

#### Histopathology

The gross and microscopic appearance of the normal appendix is first reviewed. At macroscopy, the appendix is blind ending, grayish pink, smooth and soft with a mean length of 8 cm (7) and thickness of 5 to 7 mm. The meso contains a variable amount of fat and is only a few mm thick. At histology, 4 main layers are identified (fig. 18):

- Colonic type mucosa with surface epithelium and crypts of Lieberkhun extending to the lamina propria. Lymphoid

### Table I

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<tr>
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<th>Diverticulum</th>
<th>Appendiceal wall</th>
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<td>Diverticulum</td>
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<td>hyperechoic nodule abutting the muscular layer</td>
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<td>mesenteric and antimesenteric: 9</td>
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<td></td>
<td>distension by mucus (%)</td>
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<td>thickening of the submucosal and muscular layers (%)</td>
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<td></td>
<td>loss of compressibility (%)</td>
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<td>irregular serosal thickening (%)</td>
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### Table II

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<th>Abscess</th>
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<td>Longitudinal location (%)</td>
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<td>location relative to the meso (%)</td>
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<td>antimesenteric: 20</td>
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<tr>
<td>Perforation</td>
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<td>distension by mucus (%)</td>
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<td>global thickening of the appendix (%)</td>
<td>100</td>
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<td>thickening of the submucosal and muscular layers (%)</td>
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<td>loss of compressibility (%)</td>
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<td>irregular serosal thickening (%)</td>
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<td>submucosal signal at power Doppler (%)</td>
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Fig. 9: Doppler energy of the distal appendix. Longitudinal view. doppler signal of the appendiceal and abscess wall.

Fig. 9 : Doppler énergie de la pointe. Coupe longitudinales. signal doppler de la paroi appendiculaire et de la coque de l’abcès.

Fig. 10: Abscessed distal diverticulitis.


Fig. 10 : Diverticulite abcédée de la pointe.
a échographie : Coupe transversale – 1. contenu finement échogène – 2. renforcement postérieur – 3. graisse inflammatoire hyper-échogène.

Fig. 11: Pseudo-diverticulum. Transverse view, distal third, low magnification – 1. atrophied diverticular mucosa – 2. submucosa – 3. thickened muscular layer – >< muscular layer disruption.

Fig. 11 : Diverticule acquis. Coupe transversale, tiers distal, faible grossissement – 1. muqueuse diverticulaire atrophiée – 2. sous-muqueuse – 3. musculeuse hypertrophiée – >< interruption de la musculeuse.

Nodules are present extending into the submucosa. These regress if not completely disappear in elderly subjects.
- Submucosa composed of loose connective-adipose tissue containing multiple vessels with a maximum thickness of 0.5 mm.
- Muscular layer composed of two distinct components: circular inner component and longitudinal outer component, with a thickness less than 1 mm.
- Serosa, thin and composed of connective-vascular tissue. The vascular supply is provided by the appendicular artery and vein. They supply a collateral network, with some perforating the muscular layer via vascular hiatus (fig. 19) partially filled with connective tissue.

In all 16 cases where surgery was performed, and as previously reported by Jean,
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the appendix was involved by scarring, either local or diffuse. The lumen is narrowed, if not completely obliterated, by fibrous tissue leading some authors to use the term chronic obliterating appendicitis (fig. 15-17). The mucosa is atrophied and the lymphoid layer is atrophied or absent. The submucosa and muscular layers are thickened. As a result, the wall may be more than 3 mm thick, and be as thick as 5-6 mm. The size of the clefts containing the vasa recta in the muscular layer widens. The combination of these features is considered by some as chronic appendicitis whereas others consider this physiologic involution. The goal here is not to open a debate on this subject but merely to be aware of these changes in order to understand the US features to follow.

Two types of diverticulum can occur: congenital diverticulum and acquired diverticulum or pseudo-diverticulum. The congenital type, rare, is composed of all bowel wall layers. An example is the Meckel’s diverticulum. We have not encountered any congenital diverticulum in our series nor found any reported case in the literature. All patients included in our series had an acquired or false diverticulum consisting of mucosa and submucosa herniated through the muscular layer (fig. 11). They are typically small, less than 5 mm in size, sometimes multiple, and typically located in the distal third of the appendix along the meso (fig. 12). The lumen contains fecal material, mucus, or even pus when complicated by suppuration. The mucosa often is atrophied and may become ulcerated when complicated by diverticulitis or replaced by a fibrous shell when complicated by suppuration (fig. 14a). The pa-
Theogenesis of appendiceal diverticula is not completely elucidated. Several theories have been proposed, some contradictory. One, based on mechanical principles, seems more attractive. It suggests a mechanism of increased pressure against a focus of weakness. The widened vascular cleft in the muscular layer is the site of weakness. Herniation of mucosa through the cleft could be the result of increased intraluminal pressure secondary to obstruction or excessive contraction of a hypertrophied muscular layer. The appendix would be presented as a structure composed of two concentric tubes: inner tube (mucosal and submucosal layers) and outer (muscular and serosal layers). Contractions of the muscular layer would cause the inner tube, now relatively too long, to herniate through the abnormally widened vascular cleft. This theory share similarities with the theory explaining colonic diverticulosis. Some authors suggest that the site of weakness in the muscular layer would be the result of a past episode of appendicitis (17). Chronic appendicitis, cystic fibrosis, male gender, and age above 30 years are risks factors described in the literature (4, 12).

When the diverticulum is detected at the stage of inflammation or complications, additional abnormalities involve the appendiceal wall. Eosinophils infiltrate the submucosa indicating a chronic inflammatory process. The serosa is thickened in association with an inflammatory
Vascular hiatus. Longitudinal view, distal third, low magnification.

Hiatus vasculaire. Coupe longitudinale, tiers distal, faible grossissement.

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Ultrasound

The appendix is attached to the cecal pole, about 2 cm below the level of the ileocecal valve, a reliable landmark at US. It is tubular on longitudinal images and rounded on transverse images and characterized by its well-defined layered appearance. It is soft and compressible (fig. 21) and blind ending. Peristalsis is not perceptible. The lumen may be virtual and correspond to a thin echogenic line (serosal interface). The latter may be thicker due to lymphoid hyperplasia. The latter may be thicker due to lymphoid hyperplasia. The lumen may be narrowed or absent due to replacement of the mucosa (fig. 5, 6) by fibrosis (obliterating chronic appendicitis). The lumen may also be distended by hypoechoic retained secretions (fig. 23) to an obstruction. The wall may be focally or diffusely thickened, sometimes 4 to 6 mm in thickness. The thickening mainly involves the submucosal and muscular layers, with atrophied mucosa and frequently absent lymphoid tissue (fig. 4). The firm and rigid nature of the appendix is illustrated by the indentation of adjacent structures, best displayed with compression (fig. 24). Generally, no signal is present in the submucosa at power Doppler. The similarity of findings with low power microscopy confirms the excellent spatial resolution of US. Knowledge of these US features is useful since their identification facilitates the detection of the diverticulum. Usually, evaluation of the appendix begins at its proximal end, with a single wall thickness to describe the lumen – 4. peri-appendicitis – < vessels.

Diverticulum. Longitudinal view, distal third, low magnification.

Distal diverticulum. Longitudinal view, distal third, low magnification.

Normal compressible appendix in a child. Transverse view. * prominent mucosal and lymphoid layers – 1 psoas muscle – 2 oblique muscles.

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Fig. 22: Normal tip of the appendix. Sagittal view. 1 mucosa – 2 submucosa – 3 muscular layer – effusion – * meso.

Fig. 22 : Pointe appendiculaire normale. Coupe sagittale. 1 muqueuse – 2 sous-muqueuse – 3 musculueuse – 4 épanchement liquide – * méso.

Fig. 23: Mucocele. Distal third, endovaginal view – 1. enlarged mucus-filled appendicular lumen – 2. obstruction.

Fig. 23 : Mucocèle. Tiers distal, voie endovaginale – 1. lumière appendiculaire distendue : mucus – 2. obstruction.

Fig. 24: Firm non-compressible appendix. Transverse view, middle third – 1. thickened muscular layer. – 2. thickened sub-mucosa – 3. mass effect on the psoas muscle – 4. mass effect on the oblique muscles.

Fig. 24 : Paroi ferme. Coupe transversale, tiers moyen – 1. musculeuse hypertrophiée – 2. sous-muqueuse épaisse – 3. empreinte sur le muscle psaos – 4. Refoulement des muscles obliques.

Fig. 25: Obliterating chronic appendicitis. Transverse view – distal third – > hyperechoic nodule – * disruption of the muscular layer (cf fig. 2).

Fig. 25 : Appendicite chronique oblitérante. Coupe transversale, tiers distal – > nodule hyperéchogène – * interruption de la musculueuse (cf fig. 2).

Fig. 26: Multiple diverticulum. Longitudinal view, distal third. * two hypoechoic diverticula – < one distal hyperechoic diverticulum.

Fig. 26 : Diverticules multiples. Coupe longitudinale de la pointe. * deux diverticules hypoéchogènes – < un diverticule distal hyper-échogène.

Diverticula of the appendix, site of most diverticula in our series, is frequently visible only during graded compression. The presence of luminal obliteration at the base or mid portion of the appendix should raise the suspicion of distal diverticulum.

The imaging diagnosis of diverticulum of the appendix was first described at barium enema in 1926 (15). This technique did not provide any understanding of the underlying pathophysiology nor could it suggest its pathological nature. Publications on the features of appendiceal diverticula at cross sectional imaging are rare and mainly limited to case reports. The US features were first reported 15 years ago by Skaane et al. (16) and described as a target lesion with hypoechoic center and echogenic periphery, a non-specific appearance given the limited spatial resolution of US units available at that time. Some authors report that preoperative diagnosis cannot be achieved with US and CT (10). However, the US imaging features of 4 cases were described by Rioux (14) in 1995. Our results, with pathological correlation, further support that US diagnosis can be achieved.

The diverticulum usually presents as a well-defined hypoechoic (fig. 1) rounded (fig. 2) or oval-shaped nodular lesion abutting the muscular layer of the appendix. Rarely, in patients with chronic appendicitis, the diverticulum may be echogenic (fig. 25) due to its echogenic submucosa component (9). Under optimal imaging conditions, the neck of the diverticulum, echogenic and thin, may be identified at the level of the vascular cleft. The diverticulum is usually small, less
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than 5 mm in size, typically distal in location (fig. 3). Frequently, only a single diverticulum is present, but the absence of additional ones (fig. 26) should be confirmed to not underestimate the risk of potential complications. In our experience, in the absence of inflammatory complication, it may be difficult to ascertain the relationship of the diverticulum with the meso-appendix. Finally, no signal is present at power Doppler imaging.

In the setting of diverticulitis, additional imaging findings, indirect signs of the inflammatory reaction, can be identified. The adjacent fat becomes echogenic with ground glass appearance (fig. 7). This is most apparent at the level of the meso in the peri-diverticular region (fig. 8). The adjacent peri-cecal, peri-ileo, mesenteric and omental fat is less involved. It is important to recognize the presence of abnormal fat since it is this finding that firsts attracts the attention of the sonographer (18). The wall of the appendix next to the inflamed diverticulum becomes thickened and the normal hypoechoic muscular layer is replaced by irregular hypoechoic bands of variable thickness that may extend into the meso (fig. 27). This appearance is similar to the appearance in acute sigmoid diverticulitis. When acute appendicitis is also present, histological data show that it most typically involves the distal third of the appendix, near the site of diverticulitis. The base of the appendix may appear nearly normal except for thickening of the submucosal and muscular layers. The normal layered appearance of the appendix is lost at the site of acute inflammation. Power Doppler shows increased vascularity in the submucosa. Signs of peri-appendicitis are also more advanced. Abscesses usually form within the meso (fig. 4b). Generally, the abscess is larger than the original diverticulum. The abscess is slightly hyperechoic with increased through transmission (fig. 10). The wall of the diverticulum has been replaced by an inflammatory fibrous cap with irregular margins that is sometimes visible at power Doppler (fig. 9). The signs of inflammation are advanced with extension to the base of the diverticulum even if the adjacent mucosa is intact. Hypoechoic stranding secondary to the inflammatory exudate and fat necrosis involves the surrounding echogenic fat.

In our experience, a complicated diverticulum is no longer visible at the stage of perforation. The appearance is thus similar to severe appendicitis. Two scenarios are possible: free and contained perforation. Free perforation leads to generalized peritonitis with small amount of echogenic ascites and ileus. The appendix is not always visible. Contained perforation leads to focal peritonitis; pus is contained by peritoneal fat and isolated from the remainder of the peritoneal cavity. The collection may be echogenic and contain fecaliths.

Treatment and Complications

The suggested management varies between authors. Early appendectomy is recommended for symptomatic patients, i.e. patients with appendiceal diverticulitis (1). Some authors recommend elective appendectomy, even for asymptomatic patients, since 2 out of 3 patients will experience an acute episode (2, 13). Others, less aggressive (5), only recommend elective appendectomy when a diverticulum is incidentally discovered at the time of an unrelated surgical procedure. This approach is restrictive since only large diverticula are easily visible. Jean (6) reports that the peroperative detection rate is only 12.5%.

It is not our purpose here to make recommendations with regards to management, but it would seem appropriate that symptomatic patients with acute abdomen or recurrent atypical right lower quadrant abdominal pain should undergo surgery. In our series, patients with recurrent atypical right lower quadrant abdominal pain were pain free after surgery. Four out of 5 asymptomatic patients in our series did not undergo surgery. It is not possible to draw any conclusion with regards to the value of prophylactic appendectomy in this subgroup of patients because of the small number of subjects in our series, insufficient follow-up, and unavailable follow-up in two cases. A few facts must nonetheless be remembered. Diverticula develop on abnormal appendices. They develop through weakness points of the muscular layer. Usually, US is unable to establish the relationship between the diverticulum and meso. The patient should be informed of the increased

Fig. 27: Peri-appendicitis.


Fig. 27 : Péri-appendicite.
a échographie : Coupe transversale, tiers moyen – 1. méso hyperéchogène – 2. travées hypo-échogène – 3. contours appendiculaires irréguliers.
risk of perforation, a complication well described in the literature. Lipton et al. (11) state that perforation, with an increased mortality rate, would be more frequent than in cases of acute appendicitis. These facts might favor elective appendectomy.

**Conclusion**

We agree with Rioux (14) that appendiceal diverticula are acquired. Its incidence is underestimated due to three main factors: not well known by sonographers, too small for peroperative detection, and sometimes overlooked at histology. It most frequently involves the distal third of the appendix. It is always associated with changes of chronic appendicitis, such that we believe that it may be due to chronic appendicitis. Its presentation shares similarities with colonic diverticulosis. Surgery is required in patients with acutely complicated appendiceal diverticulosis and probably preferable otherwise. It is associated with recurrent episodes of acute abdominal pain and with a four-fold increase in the risk of perforation. Because of its excellent spatial resolution, US seems most appropriate for diagnosis. US allows detection of the diverticulum, its complications and associated abnormalities of the appendix. US also contributes to the differential diagnosis and may prevent necessary surgical management.

**References**