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 imaging and histological findings of 21 cases of diverticulitis of the appendix are reviewed.

Materials and methods. Sonography, because of its high spatial resolution, is an ideal imaging technique to diagnose diverticulitis of the appendix.

Results. Similar to diverticulosis of the large bowel, diverticula of the appendix correspond to pseudo-diverticula composed of mucosa and submu cosa herniating through the muscular layer. Chronic inflammatory changes affect the surrounding appendicular wall, as confirmed by histological examination. Clinical symptoms range from chronic right lower quadrant abdominal pain to acute appendicitis and even peritonitis.

Conclusion. Based on this retrospective analysis of 21 cases, it is possible to describe the specific and sensitive imaging findings for diagnosis of simple and complicated forms of diverticulitis of the appendix. Surgery is the treatment of choice because of the high risk of perforation.

Key words: Diverticulum. Appendix. Ultrasound.

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,

D
erviculosis of the appendix and its complications are infrequent. The first case was described in 1893 by Kelynack (8). The incidence based on surgical series is between 0.2 and 2.6% (3, 6, 9). It most frequently corresponds to a pseudodiverticulosis 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”.

Résumé

Ruptures hyperéchogènes de la coiffe des rotateurs

J Radiol 2005;86:299-309

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 ritérative 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.

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

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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. épaississement 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 evaluation. 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 diverticulitis is presented in Table I and a summary of the US features of complicated diverticulitis 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...
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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 Lieberkühn extending to the lamina propria. Lymphoid...
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,
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 (fig. 13) or replaced by a fibrous shell when complicated by suppuration (fig. 14a). The pa-
Therogenesis 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
infiltrate. This appearance is described as granulomatous peri-appendicitis (fig. 20) secondary to repeated episodes of peri-diverticulitis. Pseudo-membranes may be present. In spite of the extent of peri-appendiceal inflammatory changes, very little changes are present at the mucosal level. The fibrosis and peri-appendicitis cause the appendix to appear firm and rigid. This appearance is different from that of the garden-variety acute appendicitis where most changes involve the mucosa and submucosa. Diverticular pathology of the appendix has been classified by many into four morphological types (11, 16): Type 1 is characterized by diverticulitis and normal appendix, type 2 by diverticulitis and appendicitis, type 3 by simple uncomplicated diverticulum and acute appendicitis, and type 4 by a normal appendix and incidental simple uncomplicated diverticulum. Only types 2 and 3 were noted in our series. The appendiceal wall was never normal and always appeared thickened.

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). It may be thicker due to lymphoid hyperplasia. The latter may increase the overall diameter of the appendix. This is why it is preferable to use the single wall thickness to describe the appendix (normal < 3 mm). The normal layered appearance of the appendix should be visible on both longitudinal and transverse images. From inside out, four separate layers are visible (fig. 22):

- The mucosa and lymphoid tissue form a hypoechoic layer, usually less than 1 mm thick except in children where it may be thicker due to lymphoid hyperplasia.
- The submucosa corresponds to a homogeneous echogenic band, usually less than 1 mm thick.
- The muscular layer corresponds to a thin and regular hypoechoic line, 0.5 to 0.7 mm thick.
- The serosa and adjacent fat interface form a regular echogenic line. It may not always be visible. The meso-appendix, similar to the greater omentum, can be recognized in obese patients as a relatively hypoechoic band of tissue surrounded by a thin echogenic line (serosal interface).

In our series, similar to findings at histology, diverticula were always associated with an abnormal appearing appendix. 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) distal 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...
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Fig. 22: Normal tip of the appendix. Sagittal view. 1 mucosa – 2 sub-mucosa – 3 muscular layer – effusion – * meso.

Fig. 22 : Pointe appendiculaire normale. Coupe sagittale. 1 muqueuse – 2 sous-muqueuse – 3 musculeuse – 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. 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 musculeuse (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 hypéchoigènes – < un diverticule distal hyper-échogène.

Base after identification of the ileocecal valve. The tip 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
than 5 mm in size, typically distal in loca-
tion (fig. 3). Frequently, only a single di-
verticulum is present, but the absence of additional ones (fig. 26) should be con-
firmed to not underestimate the risk of po-
tential complications. In our experience, in the absence of inflammatory complica-
tion, it may be difficult to ascertain the re-
lation of the diverticulum with the meso-appendix. Finally, no signal is pre-
ent at power Doppler imaging.
In the setting of diverticulitis, additional imaging findings, indirect signs of the in-
flammatory 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-ileal, mesenteric and omental fat is less involved. It is im-
portant to recognize the presence of ab-
normal fat since it is this finding that firsts attracts the attention of the sonogra-
pher (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 appear-
ance in acute sigmoid diverticulitis. When acute appendicitis is also present, histological data show that it most typi-
cally involves the distal third of the ap-
pendix, near the site of diverticulitis. The base of the appendix may appear nearly normal except for thickening of the sub-
mucosal and muscular layers. The nor-
mal 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 abs-
cess is slightly hypechoic with increased through transmission (fig. 10). The wall of the diverticulum has been replaced by an inflammatory fibrous cap with ir-
regular margins that is sometimes visible at power Doppler (fig. 9). The signs of in-
flammation 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 sur-
rounding echogenic fat.
In our experience, a complicated diverticu-

lum is no longer visible at the stage of perforation. The appearance is thus simi-
lar to severe appendicitis. Two scenarios are possible: free and contained perfora-
tion. Free perforation leads to general-
ized peritonitis with small amount of echogenic ascites and ileus. The appendix is not always visible. Contained perfora-
tion leads to focal peritonitis; pus is con-
tained by peritoneal fat and isolated from the remainder of the peritoneal ca-
vity. The collection may be echogenic and contain fecaliths.

Treatment and Complications
The suggested management varies between authors. Early appendectomy is recom-
mended for symptomatic patients, i.e. pa-
tients with appendical diverticulitis (1). Some authors recommend elective ap-
 pendectomy, even for asymptomatic pa-
tients, since 2 out of 3 patients will expe-
rience 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 ap-
proach is restrictive since only large di-
verticula are easily visible. Jean (6) reports that the peroperative detection rate is only 12.5%.
It is not our purpose here to make recom-
mendations with regards to manage-
ment, but it would seem appropriate that symptomatic patients with acute abdo-
men or recurrent atypical right lower quadrant abdominal pain should under-
go surgery. In our series, patients with recurrent atypical right lower quadrant abdominal pain were pain free after sur-
gery. 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 app-
pendectomy 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 append-
dices. They develop through weakness points of the muscular layer. Usually, US is unable to establish the relationship between the diverticulum and meso. The pa-
tient should be informed of the increased
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**