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Value of computed tomography and abdominal ultrasound for chronic inflammatory complications of diverticular disease

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ABSTRACT *AIM: to evaluate the diagnostic value of computed tomography (CT) and abdominal ultrasound (US) for chronic inflammatory complications in patients with diverticular disease (DD).*

PATIENTS AND METHODS: the prospective cohort study included 50 patients with complicated DD. All patients underwent preoperative abdominal CT with intravenous contrast and abdominal US, with further elective bowel resection. The results of CT and ultrasound were compared with morphology of the removed specimens.

RESULTS: the sensitivity and specificity for chronic diverticulitis was 66.7% and 95.7% for CT and 100.0% and 95.7% for US. For chronic pericolic abdominal mass it was 94.8% and 90.9% for CT, 94.8% and 100.0% for US; for abdominal abscesses/cavities it was 87.5% and 96.2% for CT and 91.6% and 100.0% for US; for diverticular fistulas it was 87.5% and 100.0% for CT and 87.5% and 100.0% for US. No significant differences were obtained between two diagnostic modalities. A high level of consistency (κ-coefficient 0.71) of CT and US for the diagnosis of inflammatory complications of DD was found.

CONCLUSION: CT and US have a similar high diagnostic value for chronic inflammatory complications of DD. Each of them can be used as a single diagnostic modality or both depending on the clinical case.

KEYWORDS: *inflammatory complications of diverticular disease, computed tomography, ultrasound*

CONFLICT OF INTEREST: *the authors declare no conflict of interest*

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INTRODUCTION

Recent diagnostic modalities (CT, ultrasound) are crucial in identifying and assessing the severity of inflammatory complications of diverticular disease (DD). It is important to note the fact that it is the results of CT and ultrasound (US) allow clinicians to correlate a clinical situation with international classification systems and their modifications (Hinchey, modified Hinchey, Klarenbeck, Kaiser, Wasvary, Neff, HS classification) [1–10], and with the Russian classification [11]. The type and severity of the identified inflammatory changes determine the strategy of treatment, which can vary from conservative treatment (antibiotics and/or anti-inflammatory drugs) to surgical intervention [11,12]. According to the literature, both methods have similar high diagnostic value in identifying inflammatory complications of DD: the sensitivity and specificity of CT are 86–94% and 88–99% [13,14], the sensitivity and specificity of US are 84–92% and 85–98% [13,14].

Despite the comparable diagnostic capabilities of CT and US for complicated DD in the medical community, there is still no consensus on the algorithm for each method [15–23]. Thus, the Association of Surgeons of the Netherlands recommends using ultrasound as the first line, and prescribing CT only if ultrasound results

are inconclusive [15]. According to the Danish Surgical Society, CT should be used for inflammatory complications of DD in all patients, with the exception of pregnant, for whom ultrasound is indicated [15]. The guidelines of the American Society of Colorectal Surgeons consider CT as the most appropriate diagnostic option for complicated DD, and US or MRI is recommended to be performed only if there are contraindications to CT [15,17]. According to the clinical guidelines of the Russian Association of Coloproctologists, for inflammatory complications of DD, it is better to use both methods, especially when deciding on the choice between conservative and surgical approach [11].

It should be emphasized that the main attention in all publications is on acute inflammatory complications of DD, and diagnostic options for chronic inflammatory process are not fully covered [23–29]. In this regard, the goal of the study was to assess the diagnostic value of CT and US in identifying of chronic inflammatory complications of DD.

PATIENTS AND METHODS

The prospective cohort study included 50 patients who underwent elective surgery for chronic inflammatory complications of DD in 2020–2022. There were 32 females, aged 62 ± 8 (46–74) years.

The criteria for inclusion in the study were the presence of clinical manifestations of inflammatory complications of DD, preoperative abdominal CT with intravenous contrast and transabdominal ultrasound. Patients who did not undergo surgical intervention with resection of altered parts of the colon, as well as patients with inflammatory diseases of the gastrointestinal tract of other etiologies were excluded from the study. All patients gave written consent to participate in the study.

At the time of admission, patients complained of irregular stool or diarrhea (46/50, 92%), pain in the left iliac region (41/50, 82%), fever 37.5–38 °C (38/50, 76%), periodic discharge of gas or gas and feces from the vagina (3/50, 6%), urethra (5/50, 10%). Clinically, a painful abdominal mass was palpated in the left iliac region (38/50, 76%). C-reactive protein was increased up to 30–72 ml/g (45/50, 90%). Forty-three (86.0%) patients had a previous history of at least two attacks of acute inflammation, seven (14.0%) patients had one attack. The time from the first manifestation of acute inflammation to admission for elective surgery was 3.5–48 months. All patients underwent preoperative conservative treatment. The surgical procedure included resection of left colon.

CT was performed without bowel cleansing or after fiber-free diet 2–3 days before. The large intestine was contrasted antegrade: the patient drunk 1000–1500 ml of water at room temperature orally in fractions one and a half hours before the CT. If a sigmo-vaginal fistula was suspected, 100–200 ml of a 3% solution of a water-soluble contrast agent was injected into the rectum. CT was carried out on a 160-slice Aquilion Prime tomograph with a slice thickness of 2 mm. Scanning was performed before intravenous contrast and in the portovenous phase after intravenous administration using an automatic injector of a non-ionic contrast agent in a volume of 80–100 ml at a speed of 2.5–3 ml/s.

US was performed on iU 22 device (Philips) using a convex sensor with specified frequency parameters of 1–5 MHz, an intracavital convex sensor (3–10 MHz), as well as a linear sensor (5–12 MHz). The device used was ProFocus 2202 (B-K Medical A/S) using a convex transducer (2–6 MHz), an intracavital convex transducer (4–9 MHz) and a linear transducer with a frequency of 6–12 MHz.

The interval between CT and ultrasound examinations did not exceed 3 days.

The assessment of inflammatory changes detected by both CT and ultrasound was carried out according to the Russian classification of DD [4].

The CT and US protocols included general parameters used to assess the identified changes:

1) the presence of diverticula, their condition (wall thickness, signs of diverticulum destruction);
2) the thickness of the intestinal wall and its structure;
3) the extent of inflammatory changes in the intestinal wall;
4) the state of pericolic tissue (infiltration, collection of fluid and gas, abscesses, cavities);
5) the presence of intestinal fistulas;
6) involvement of adjacent organs in the inflammatory process.

The results of CT and US were compared to morphology of the resected specimens.

Statistical analysis was carried out using SPSS and the Microsoft Office 2022 application package.

RESULTS

In all cases, both CT and ultrasound revealed left-sided diverticula. All inflammatory changes were located in the sigmoid colon. A common symptom of inflammatory complications of DD in all 50 patients, was thickening of the intestinal wall: from 0.4 to 1.5 cm (0.7 ± 0.5 cm) over 4–11 cm (6.8 ± 3.5 cm) on CT and from

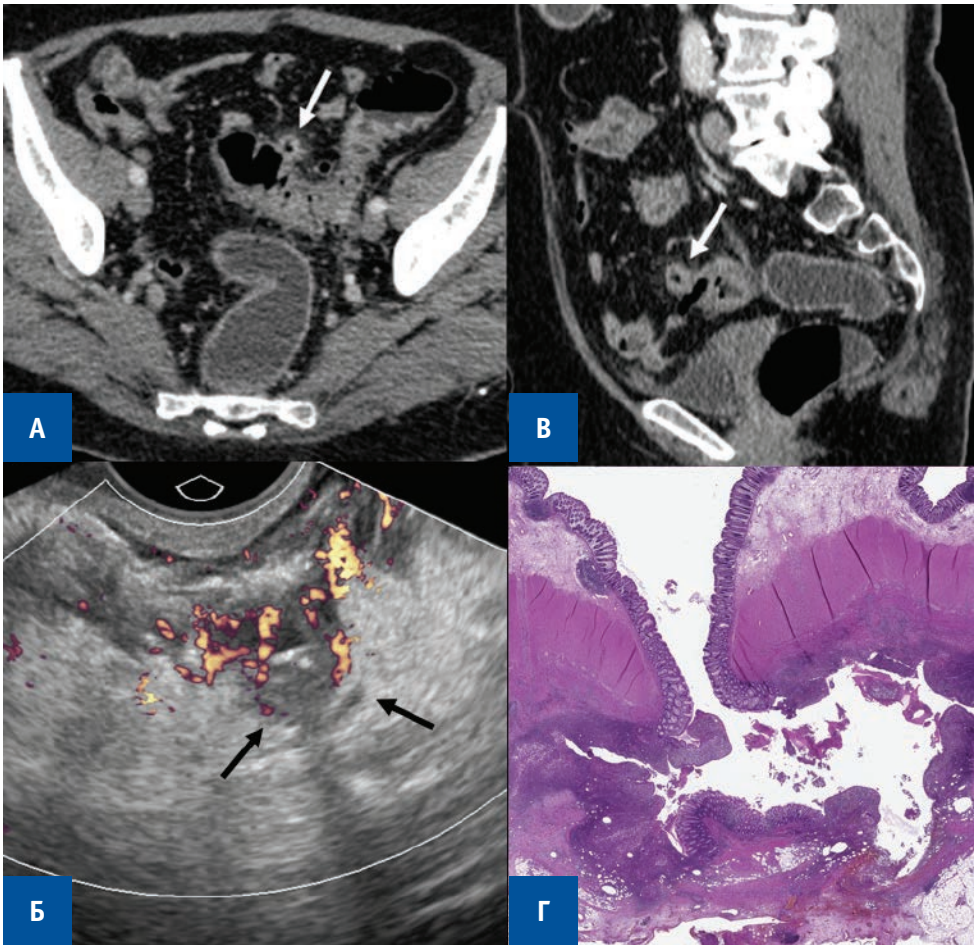

Figure 1. *Diverticulitis. А, Б — CT of pelvic with intravenous contrast in axial (А) and sagittal (Б) projections. In the middle third of the sigmoid colon, a diverticulum with thickened uneven walls is detected, surrounded by local infiltration (white arrows). В — ultrasound of the sigmoid colon. In the middle third of the sigmoid colon, an inflamed diverticulum with hyperechoic contents is detected along the outer contour, its contours are blurred, the tissues around it are inflamingly altered (black arrows). Г — Histology × 40, staining hematoxylin and eosin. Pseudodiverticulum with dense polymorphocellular inflammatory infiltration and destruction of the wall.*

Table 1. *Diagnostic efficacy of CT in various types of chronic inflammatory complications of DD.*

Complication	TP	FP	TN	FN	*n*	Sensitivity	Specificity	PPV	NPV	Accuracy
Diverticulitis	2	2	45	1	50	66.7%	95,7%	50.0%	97.8%	94.0%
Pericolic inflammatory mass including abscess/perocolic cavity	37 21	1 1	10 25	2 3	50 50	94.87% 87.5%	90.91% 96.2%	97.4% 95.4%	83.3% 89.3%	94.0% 92.0%
Fistula	7	0	42	1	50	87.5%	100.0%	100.0%	97.7%	98.0%

Note: TP — true positive; TP — true negative; FP — false positive; FN — false negative; PPV — positive prognostic value; NPV — negative prognostic value

Table 2. *Diagnostic efficacy of ultrasound in various types of chronic inflammatory complications of DD*

Complication	TP	FP	TN	FN	*n*	Sensitivity	Specificity	PPV	NPV	Accuracy
Diverticulitis	3	2	45	0	50	100.0%	95.7%	60.0%	100.0%	96.0%
Pericolic inflammatory mass including abscess/perocolic cavity	37 22	0 0	11 26	2 2	50 50	94.8% 91.6%	100.0% 100.0%	100.0% 100.0%	84.6% 92.8%	96.0% 96.0%
Fistula	7	0	42	1	50	87.5%	100.0%	100.0%	97.7%	98.0%

Note: TP — true positive; TP — true negative; FP — false positive; FN — false negative; PPV — positive prognostic value; NPV — negative prognostic value

0.4 to 1.1 cm (0.6 ± 0.4 cm) over 5–15 cm on ultrasound (7.2 ± 4.6 cm). These parameters varied depending on the type of complication and reached the highest values with pericolic inflammatory mass. According to ultrasound, thickening of the intestinal wall occurred mainly due to the muscle layer. With CT, we could not visualize the layers of the intestinal wall due to limitations in the capabilities of the method.

Diverticulitis on CT was diagnosed in 2 (2/50, 4%) patients and was manifested by thickening of the walls of one of the diverticula with local infiltration (Fig. 1А,Б). Ultrasound revealed diverticulitis in 3 (3/50, 6%) cases and was characterized by unevenness and blurring of the outer contour of the diverticula, the presence of faecalits and gas bubbles in the lumen of the diverticula, and increased echogenicity of the pericolic tissue (Fig. 1В).

Morphology revealed in the intestinal wall against the background of fibrosis of the submucosal and muscular layers an area of granulation tissue with a dense polymorphic inflammatory infiltration extending to the mesenteric tissue, clusters of giant multinucleated cells, without a clearly defined diverticulum wall in a limited area (Fig. 1Г).

When comparing CT data with the results of a morphology of removed specimens, three discrepancies were noted. In one case, diverticulitis was incorrectly assessed as a pericolic inflammatory mass (false negative result), and in two cases, the inflammatory mass was incorrectly assessed as diverticulitis (false positive results) (Table 1). During ultrasound, in two cases, a pericolic mass was mistaken for diverticulitis (false positive results) (Table 1, 2).

Pericolic inflammatory masses on CT were detected in 37 (37/50.74%) patients and were characterized by thickening of the intestinal wall from 0.6 to 1.5 cm over a distance of 6 to 11 cm, cloud-like or stringy infiltration of tissue, accumulation of fluid in pericolic tissue or pelvis, increased blood supply to the vasa recta of the mesentery of the sigmoid colon, involvement of adjacent organs and structures (bladder, uterus, ovaries, pelvic peritoneum) in the inflammatory process (Fig. 2А).

With transabdominal ultrasound, pericolic inflammatory masses were detected in 37 (37/50,

74%) cases and were of irregular shape, mixed structure, consisting of an inflammatory-changed part of the colon with hyperechoic fiber, adjacent organs fixed to the intestine (bladder, uterus, ovaries, abdominal wall), as well as fluid collections between them. The length of pericolic inflammatory masses ranged from 9 to 15 cm (12.3 ± 1.3 cm) (Fig. 2Б).

Morphology in the area of inflammatory mass revealed infiltration of mesenteric tissue with polymorphonuclear leukocytes of varying severity, in some cases with focal collections of giant cells such as foreign bodies, congestion of mesenteric vessels, signs of vasculitis in small vessels. With long-term inflammatory masses, a perifocal desmoplastic reaction and fibrosis of the adjacent peritoneum were noted. As a rule, elements of the pseudodiverticulum wall with inflammatory infiltration and signs of partial or subtotal destruction due to severe inflammation were found in the thickness of the mass.

When comparing the CT results with the data of intraoperative revision and morphology of removed specimens, three discrepancies were noted (Table 1). In one of them (false-positive result), the altered area of the sigmoid colon was closely adjacent to the left ovary, which was regarded as its involvement in the inflammatory process. However, intraoperative revision revealed no signs of fixation between the organs, and a morphology revealed signs

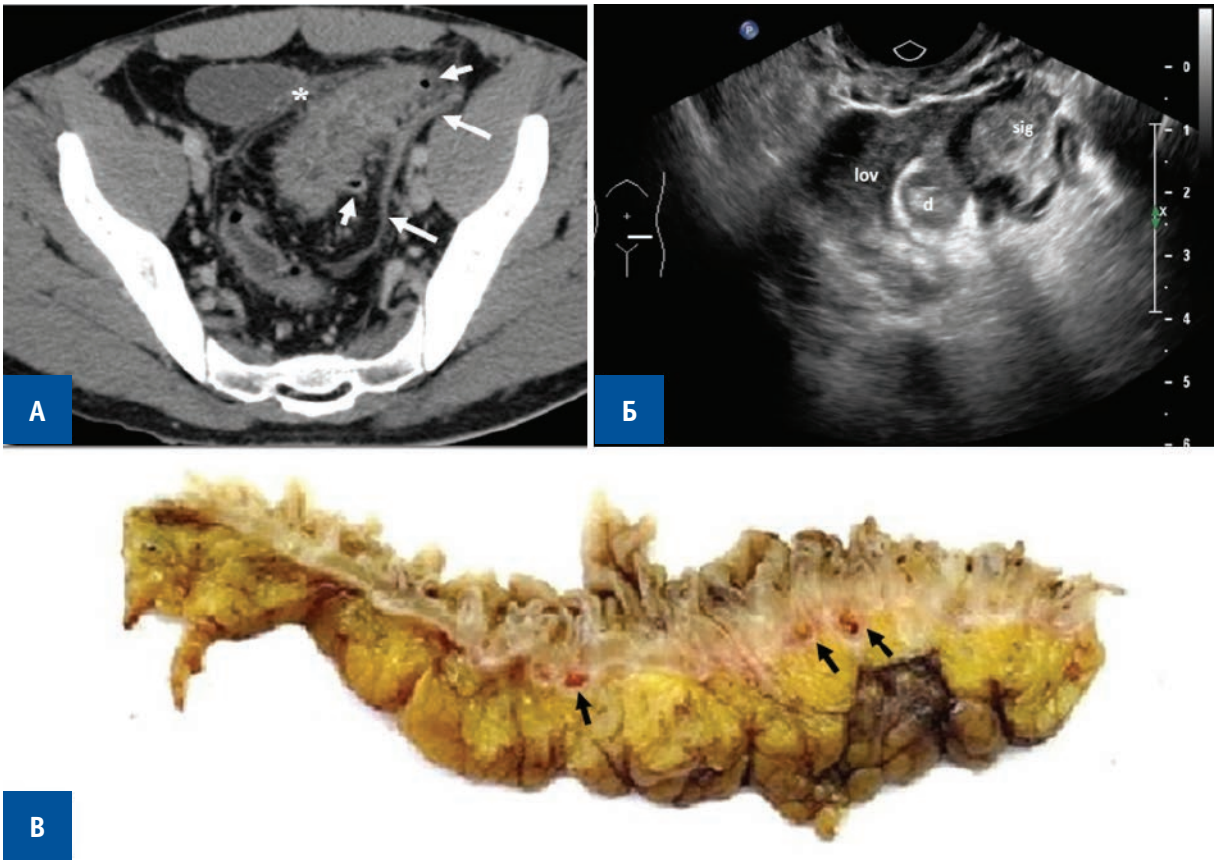

Figure 2. *Pericolic inflammatory masses. А — CT of the pelvis with intravenous contrast in axial projection. In the distal third of the sigmoid colon, a thickening of the intestinal wall up to 1.5 cm is detected for 7 cm due to inflammatory changes with infiltration of pericolic fat, involvement of the pelvic peritoneum (long arrows) and the bladder wall (*). Single diverticula (short arrows) are determined. Б — ultrasound of the sigmoid colon. For 7.5 cm, the intestinal wall is thickened to 1.1 cm (*), low echogenicity, the layers of the intestinal wall are fuzzy, the muscle layer is thickened, the fat is increased echogenicity with the presence of narrow fluid collections (arrows). В — Removed specimen of the sigmoid colon. The intestinal wall is thickened, the muscle layer is fragmented, pseudodiverticula (arrows) are revealed. There is a pronounced inflammatory infiltration with perifocal fibrosis in the mesentery tissue.*

of diverticulitis with microperforation. In two more patients with low body weight, the lack of expression of adipose tissue made it difficult to adequately assess the extent of inflammatory changes and the involvement of adjacent organs and tissues in the process. According to the CT data, a conclusion was made about the presence of diverticulitis (false-negative results). During intraoperative revision in the area of the sigmoid colon, an inflammatory masses were detected involving the uterus and pelvic peritoneum in one case and the pelvic peritoneum and left ovary in another.

At ultrasound, two false-negative results were due to underestimation of inflammatory changes due to pneumatized loops of the small intestine (Table 2).

According to CT data, in 20 (20/50, 40%) patients with pericolic inflammatory mass, the process was accompanied by the formation of an abscess/cavity, which was determined near the altered segment of the intestine, usually in the mesentery of the sigmoid colon. The dimensions of the cavity formations varied from 1.5 to 5 cm, their contents were represented by fluid and gas or only gas; the formations were surrounded

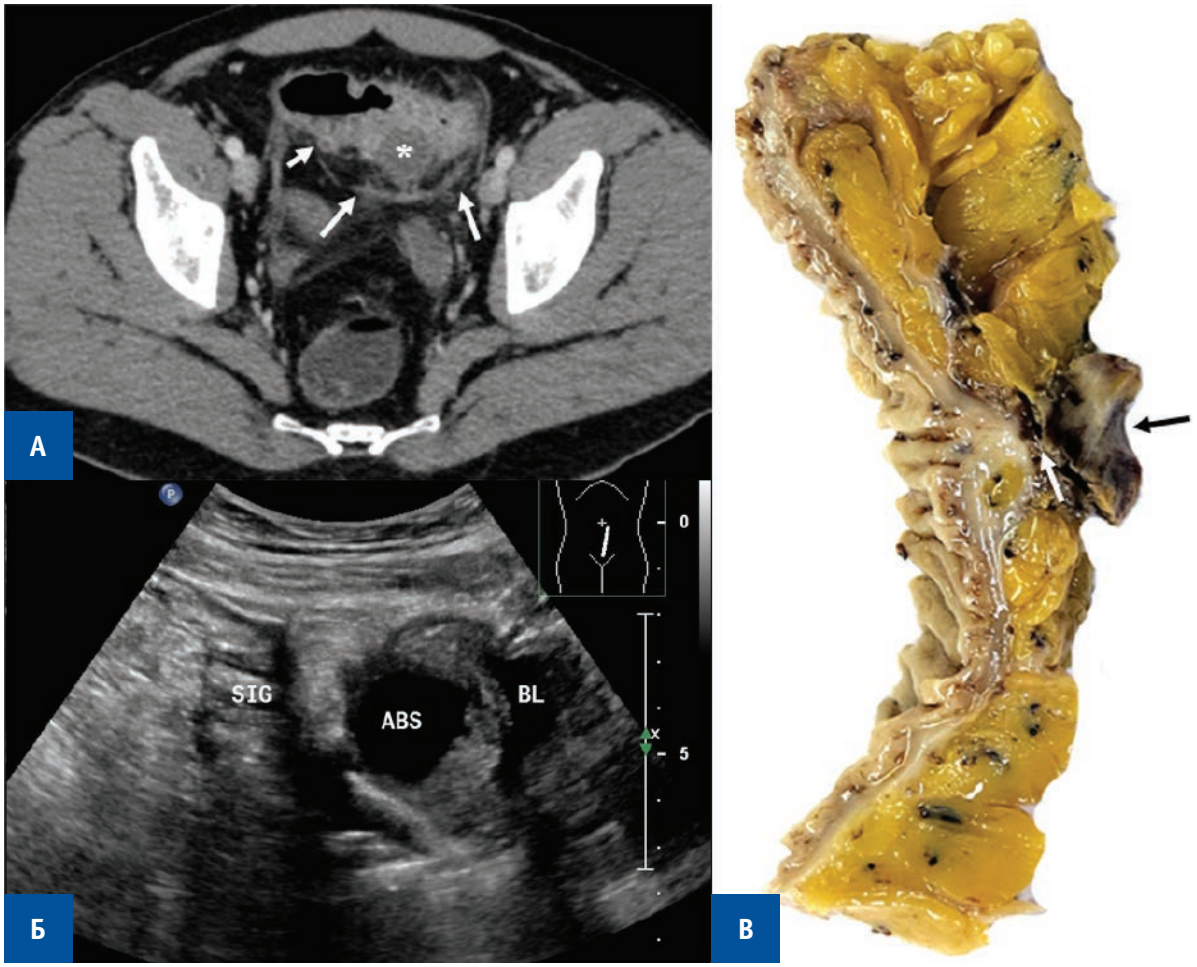

Figure 3. *Pericolic inflammatory mass with abscess. A — CT of the pelvis with intravenous contrast in axial projection. In the middle third of the sigmoid colon, a fluid collection is detected, surrounded by a thin capsule, measuring 2,2 × 2,4 cm — an abscess (*). The intestinal wall is thickened, the pericolic fat is infiltrated with the involvement of the pelvic peritoneum (long arrows). A single diverticulum is visible (short arrow). Б — ultrasound of the sigmoid colon. An irregular, predominantly anechoic fluid collection with hyperechoic inclusions, measuring 2.6 × 2.4 cm (asterisk), is revealed. The wall of the intestine is thickened (arrow). B — Macro specimen of the removed sigmoid colon. Along the mesenteric edge of the intestine, a destroyed diverticulum (white arrow) with a purulent cavity (black arrow) is revealed. The intestinal wall is thickened, the muscle layer is fragmented, pseudodiverticula are detected, the mesentery is sclerosed.*

by a capsule 2–4 mm thick, which accumulated the contrast agent when administered intravenously (Fig. 3А).

Ultrasound in 22 (22/50, 44%) patients with pericolic inflammatory masses revealed irregularly shaped anechoic fluid collections or cavities from 1.2 to 4.5 cm in diameter with a heterogeneous internal structure, the presence of fine suspension and hyperechoic inclusions, surrounded by hyperechoic capsule (Fig. 3Б). In 10 out of 22 patients with abscesses/cavities, ultrasound was able to visualize the destroyed diverticulum, which was the cause of the complication.

According to a morphology, in pericolic inflammatory masses with pronounced infiltration, foci of abscesses were found in the mesentery of the sigmoid colon, some of them small in size, determined only by histology, without connection with the intestinal wall. In a number of cases, foci of abscesses were determined macroscopically with purulent exudate in the

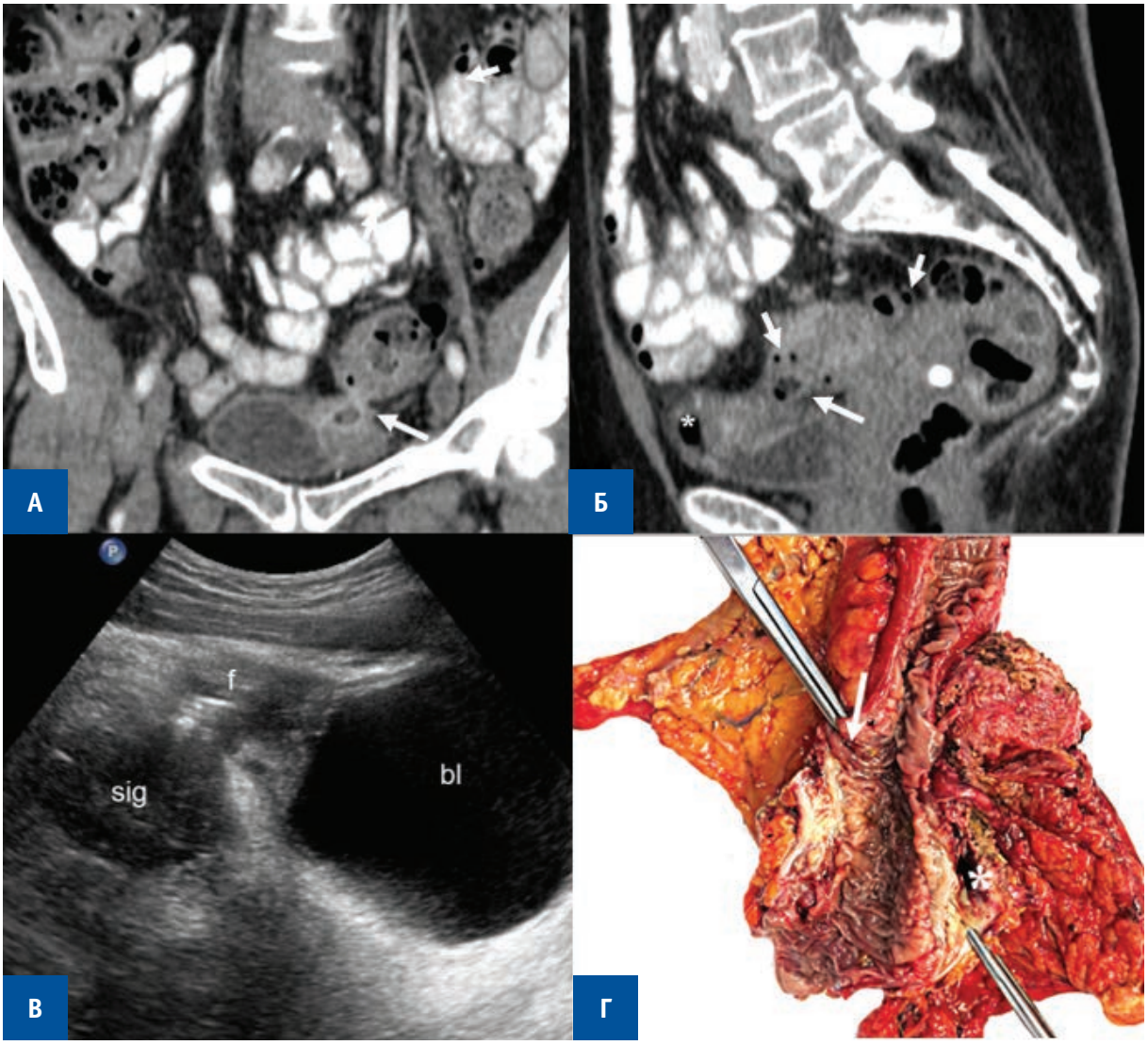

Figure 4. *Sigmovesical fistula. А, Б — CT with intravenous contrast in axial (A) and sagittal (B) projections. Between the distal third of the sigmoid colon and the tip of the bladder, a fistula with a cavity is revealed (arrow). The walls of the sigmoid colon and bladder are thickened. There is gas (*) in the lumen of the bladder. Single diverticula (short arrows) are determined. В — ultrasound of the sigmoid colon and bladder. A hyperechoic fistula with anechoic contents (long arrow) is detected between the wall of the sigmoid colon (short arrow) and the bladder (*). Г — Macro specimen of the removed sigmoid colon with a fragment of the bladder wall. A fistulous passage is detected between the sigmoid colon wall (arrow) and the bladder (*).*

Table 3. *Comparison of the diagnostic effectiveness of CT and ultrasound in detecting various types of chronic inflammatory complications of DD.*

Complication	Sensitivity CT vs US	Specificity CT vs US	Accuracy CT vs US	*p**
Diverticulitis	66.7%/100.0%	95.7%/95.7%	94.0%/96.0%	$p > 0.05$
Pericolic inflammatory mass, including abscess/perocolic cavity	94.8%/94.8% 87.5%/91.6%	90.9%/100.0% 96.2%/100.0%	94.0%/96.0% 92.0%/96.0%	$p > 0.05$ $p > 0.05$
Свищ ободочной кишки	87.5%/87.5%	100.0%/100.0%	98.0%/98.0%	$p > 0.05$

*Note: * χ^2-test*

lumen and, upon histology, had formed walls represented by granulation tissue of varying degrees of maturity with inflammatory leukocyte infiltration.

Discrepancies with the results of morphology on CT were noted in 4 cases (Table 1). One false-positive result was due to the fact that we mistook a deformed diverticulum with thickened walls for a small cavity. In three cases (false-negative results), we were unable to visualize small cavities that had no connection with the intestinal lumen and were detected only by morphology of the resected colon.

Ultrasound in two cases (false-negative results) failed to identify small cavities that contained tissue debris of the same density as the surrounding inflammatory tissue (Table 2).

Colon fistulas were detected by both CT and ultrasound in 7 patients: five sigmovesical and two sigmovaginal (with a vaginal stump). CT semiotics of sigmovesical fistulas included local thickening of the wall of the sigmoid colon and bladder in the area of the presumed fistula opening, the presence of gas bubbles in the lumen of the bladder (Fig. 4 А, Б). In identifying sigmo-vaginal fistulas, the injection of a water-soluble contrast agent into the vaginal lumen during retrograde filling of the distal colon was important.

Transabdominal ultrasound (transvaginal in women) made it possible to visualize the pathological track between the colon and the adjacent organ. From the destroyed diverticulum in the altered segment of the intestine, a fistulous tract was traced in the form of a hypoechoic stringy structure with heterogeneous contents, 1–2 cm in length, communicating with the bladder or vaginal stump (Fig. 4В).

Morphologically, in cases of fistula, an internal opening with perifocal inflammatory infiltration, fibrosis of the intestinal wall of varying severity was determined; in the adjacent removed tissues (mesentery, walls of the bladder and vagina), pronounced inflammatory infiltration was also noted. Fragments of the fistula tract were revealed with the presence of granulation tissue in the wall and accumulations of tissue and cellular detritus in the lumen of the fistula. In one case, both CT and ultrasound (false-negative results) failed to visualize a fistula between the sigmoid colon and the vaginal stump, but signs of fixation between these organs were revealed (Tables 1, 2).

When comparing CT and ultrasound data, no significant differences in the diagnostic effectiveness of the methods were identified for any of the indicators (Table 3).

A high level of agreement (Kappa Coefficient 0.71) was revealed between the results of CT and ultrasound in the assessment of inflammatory complications of DD.

DISCUSSION

CT and ultrasound of chronic inflammatory complications of BD is based on the assessment of the same basic parameters as the diagnosis of acute inflammatory complications: the presence of diverticula and signs of their destruction, the thickness of the intestinal wall, the

state of pericolic tissue (infiltration, collection of fluid and gas, increased vascularization) etc. [20–24]. At the same time, semiotics of the chronic inflammatory process has its own characteristics, largely due to the development of fibrotic changes both in the intestinal wall and in the surrounding tissue, which to a certain extent can limit the spread of inflammation during recurrent attacks [30,31]. Here there was no patients with the first episode of acute inflammation, and the majority (43/50, 86%) of them at the time of check up had underwent at least two attacks of acute inflammatory process. Neither CT nor ultrasound revealed any signs of pericolic phlegmon and peritonitis in any of the patients; all identified abscesses/cavities were located in pericolic tissue (most often in the mesentery of the sigmoid colon), no pelvic or distant collections of fluid and gas were detected. The main group of the included patients were patients with pericolic inflammatory masses, which in two thirds of cases were accompanied by abscesses/cavities. In the presence of communication with the intestinal lumen, identification of cavity formations was not difficult for both CT and ultrasound. The main diagnostic difficulties arose when cavities were detected that were not connected with the intestinal lumen, since in these cases the difference in the density and structure of the pathological cavity and surrounding tissue could be largely leveled out. We did not identify statistically significant differences between the two methods in the diagnosis of either pericolic inflammatory masses or abscesses/cavities in BD, but it should be emphasized that ultrasound has greater resolving power in detailing structural changes. Thus, only the ultrasound made it possible to visualize destroyed diverticula in patients with pericolic inflammatory masses. Due to the limitations of the CT method, it cannot provide such fine visualization, and we can detect the presence of diverticulum destruction only by gas and fluid in the pericolic tissue and abdominal cavity, abscesses/cavities, and fistulas.

Colon fistulas (8/50, 16%) and diverticulitis (3/50, 6%) were represented by a small number of cases in this study. Statistical analysis did not reveal differences in the diagnostic value of CT and ultrasound for each of these complications. CT and ultrasound demonstrated similar high overall accuracy (over 92%) for each of the identified chronic inflammatory complications of HD, as well as a high level of agreement (Kappa Coefficient 0.71) between the results of the two methods.

Despite the obtained similar diagnostic information values of CT and ultrasound, the advantages and disadvantages of each method should be taken into account. The advantages of CT are the speed of the study, the absence of pain in the patient that can occur during compression with an ultrasound sensor, less operator dependence compared to ultrasound, and the ability to repeatedly view multiplanar reconstructions of the obtained images [15,19,20,23]. The advantages of ultrasound include wide availability, safety (the absence of ionizing radiation, unlike CT), and the possibility of multiple studies for the control [19,20,23].

In addition to identifying inflammatory complications of DD, there is another aspect of radiodiagnosis, which we did not touch upon in our study. According to a number of publications, criteria for predicting the course of complicated DD are currently being developed based on CT data in order to stratify patients for planned surgical treatment [24,32].

The study had limitations. One of them is associated with a small number of cases and an uneven distribution of various complications with a predominance of pericolic inflammatory masses in the sample. We consider it advisable to continue the study with further collection of clinical cases and inclusion of both operated patients and patients who received conservative treatment for various inflammatory complications of DD. We think it is relevant to study the prognostic capabilities of CT and ultrasound in the chronic form of the inflammatory process

with a complicated DD, which may in the future be one of the factors in the selection of patients for elective surgery.

CONCLUSION

The study revealed similar high accuracy of CT and ultrasound (over 92%) for chronic inflammatory complications of BD, as well as a high level of agreement (Kappa Coefficient 0.71) between the results of the two methods. Taking into account the advantages and disadvantages of the methods under consideration, each of them can be used both as a single diagnostic method and in a complex manner, depending on the clinical situation.

AUTHORS CONTRIBUTION

Concept and design of the study: *Denis M. Belov, Irina V. Zarodnyuk, Yuliya L. Trubacheva, Alexey I. Moskalev Olga A. Maynovskaya*
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