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CT signs of diverticulum destruction in inflammatory complications of diverticular disease

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ABSTRACT *AIM: to evaluate diagnostic capabilities of computed tomography in identifying the destruction of the diverticulum wall in complicated diverticular disease.*

PATIENTS AND METHODS: the prospective cohort study included 70 patients (38 female and 32 male median age — 57 ± 13), which underwent elective surgery for complicated diverticular disease. The following assessment criteria for CT were used: signs of diverticulum destruction, thickness of the bowel wall, length of inflammatory changes of colonic wall, length of pericolonic inflammation. The data of preoperative CT were compared with the morphology of removed bowel specimen.

RESULTS: the sensitivity and specificity of CT were 96.8% and 97.4% in the detection of abscesses, 95% and 100% of colonic fistulas, and 100% and 97% pericolonic inflammation, respectively. Based on results of morphological studies of resected colon segment, two groups of patients were identified: with macroperforation (abscesses and fistulas) and microperforation (pericolic inflammatory mass). According to the ROC-analysis, colon wall thickness ⩾ 0.7 cm, length of inflammatory changes of colonic wall ⩾ 9.2 cm and the length of pericolonic inflammation ⩾ 3.1 cm highly likely show microperforation.

CONCLUSION: CT parameters of thickening of colon wall, length of inflammatory changes of colonic wall and the length of pericolonic inflammation seem to be significant for the possibility of predicting the presence of microperforation. New studies with a larger number of clinical cases are required.

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

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INTRODUCTION

More and more attention is being paid to the diagnosis of inflammatory complications of diverticular disease. This is due to the fact that the choice of optimal approach directly depends on the accuracy of the information obtained during the check-up.

The main methods of diagnosing inflammatory complications of diverticular disease are computed tomography (CT) and ultrasound, which allow to assess the nature of the inflammatory process (acute or chronic), its severity and extent. CT of the abdomen and pelvis in these patients has a number of advantages. Among them, should be noted the speed of the study, the absence of pain (arising from compression by an ultrasound sensor during transabdominal ultrasound), greater opportunities to exclude peritonitis, less operator-dependence, the possibility of reviewing the images obtained, which is especially important in the conditions of emergency care in acute case and the need for a quick choice of treatment method [1,2]. The undoubted advantage of the method is its high diagnostic efficiency. So, a meta-analysis of Laméris W., et al (2008), which included 684 patients with suspected acute inflammatory complications of diverticular disease, demonstrated high sensitivity — 94% (95% CI: 87–97%) and high specificity of computed tomography — 99% (95% CI:90–100%) [3]. A systematic review

by Andeweg C.S. and co-authors (2014), which included 588 patients with acute diverticulitis, revealed similar diagnostic indicators — CT sensitivity and specificity were 95% (95% CI:91–97%) and 96% (95% CI: 90–100%), respectively [4].

An extremely important diagnostic task is to determine the integrity of the wall of the inflamed diverticulum, which makes it possible to establish or exclude the diagnosis of perforated diverticulitis in acute inflammatory process. Depending on this criterion, a decision is made on the conditions of treatment (outpatient or inpatient), the specialty (therapist or surgeon), the nature of treatment (conservative, minimally invasive, emergency surgery). Conservative treatment is effective in 100% of cases with acute diverticulitis, acute abdominal mass and pericolic abscess up to 4 cm in size. Larger pericolic abscesses and distant abscesses are well cured by CT or US guided per cutaneous drainage in 85% [5].

Despite the effectiveness of conservative and minimally invasive approach, recurrent diverticulitis develops in 11.2–25.5% of patients [6,7], depending on the clinical form of acute inflammatory complications [1]. Despite the lesser danger to life of recurrent attacks, they have an extremely negative impact on its quality [8]. Many of these patients need elective surgery. An accurate prognosis of the disease will avoid a long period of observation and conservative treatment in this category of patients, if indications for elective laparoscopic resection are established in favorable conditions.

It is known that the ineffectiveness of conservative treatment and the high probability of recurrent attacks are higher in groups of patients who had diverticular destruction during an acute attack [9]. If with many acute complications, such as free perforation of the colon with the development of peritonitis, abscesses, fistulas and pericolic phlegmon, there are direct signs of destruction of the diverticulum, then with acute diverticulitis or acute abdominal mass, these symptoms are absent. In chronic inflammatory complications, it is even more difficult to identify signs of the diverticulum destruction for a number of reasons, among which it is necessary to indicate the small size of the affected diverticula, their thin wall, the presence of scar changes in pericolic tissues.

Thus, the resolving capabilities of the methods used today often do not allow to visualize the destroyed diverticulum. As a result, there is a need to rely on indirect signs, that is, the consequences of the diverticulum destruction.

The aim of the study was to evaluate the diagnostic capabilities of CT in detecting the diverticulum wall destructionin inflammatory complications of CDD based on comparisons with morphological data.

PATIENTS AND METHODS

The prospective cohort study included 70 patients who underwent elective surgery for diverticular disease in the period from February 2018 to July 2019. The criteria for inclusion of patients in the study were: the clinical picture of inflammatory complications of diverticular disease; the possibility of CT with intravenous contrast; the presence of written consent of the patient to participate in the study, resection of the affected bowel with subsequent morphological verification. The criterion of non-inclusion is patients with a diagnosis of IBD. The criteria for exclusion from the study were revealed by CT tumor diseases of the gastrointestinal tract, inflammatory changes of the colon of other etiology.

Among the patients there were 38 (54.0%) women and 32 (46.0%) men aged 44–70 (57 ± 13) years. Sixty-four (91%) patients had a history of more than one acute attack. Upon admission to the hospital, 67 (95%) patients had complaints of diarrhea or liquid stools, fever up to 37.5–38.0°C. Sixty-one (87.0%) patients had an increase in the level of C-reactive protein more than 50 mg/l. In 32 (43.0%) patients, painful abdominal mass in the left iliac area was detected during palpation.

The study was carried out on a “CT Philips Brilliance 64” tomograph and included scanning with a 2 mm slice thickness of the abdominal cavity and pelvic organs after bolus injection of a nonionic contrast agent with a volume of

Table 1. *The severity of CT symptoms of inflammation in various complications of diverticular disease (n = 70)*

CT symptoms of inflammation*	Type of complication		
	Abscess (n = 31)**	Fistula (n = 23)	Abdominal mass (n = 16)***
Thickening of the intestinal wall	From 0.5 to 1.5 cm Δ0.9 cm ± 0.4 cm	From 0.4 to 0.9 cm Δ0.7 cm ± 0.2 cm	From 0.5 to 0.7 cm Δ0.6 cm ± 0.1 cm
Extent of intestinal wall changes	From 10.7 to 15.3 cm Δ12.6 cm ± 0.9 cm	From 9.4 to 12.5 cm Δ11,42 cm ± 1.6 cm	From 6.8 to 9.2 cm Δ7.3 cm ± 2.1 cm
Extent of infiltration of pericolic tissues: — up to 4 cm -over 4 cm	16 15	17 6	13 0
Involvement: -pelvic organs — peritoneum	5 16	19	8 6
The presence of fluid in the pericolic tissues	7	5	2
The presence of air in the pericolic tissues			2
The "centipede" symptom (pronounced vasa recta blood filling of the mesentery of the sigmoid colon)	18	3	5

**abscesses/cavities and fistulas are considered in this case as types of complications and are not included in the list of symptoms*
*** abscess/cavity on the background of chronic abdominal mass*
****chronic abdominal mass*

70–100 ml at a rate of 2.5–3 ml/s. The study was conducted without bowel cleansing or after liquid diet for 2 days.

When analyzing the data obtained, the following qualitative and quantitative parameters were evaluated: 1) the presence of diverticula and their condition (thickening of the wall, indirect signs of the diverticulum destruction); 2) thickening of the intestinal wall (thickness in cm, the nature of the accumulation of contrast agent, structure, spasm); 3) the extent of inflammatory changes in the intestinal wall; 4) the extent of infiltration of pericolic tissues; 5) the presence of abscesses (size and site); 6) the presence of free gas and free fluid in the abdominal cavity; 7) the presence of fistulas (length, site); 8) involvement of adjacent organs and structures in the inflammatory process.

The conclusion was formulated in accordance with the classification of diverticular disease adopted by the Russian Gastroenterological Association and the Association of Coloproctologists of Russia [1].

All the patients included in the study underwent resection of altered colon sections. The results of CT studies were compared with the morphology of resected specimens.

Statistics were carried out using the Microsoft Office Excel 2019 software package, Statistica12.

RESULTS

In all cases, the inflammatory complications of CDD detected by CT were in the sigmoid colon, in five of them spreading to the distal third of the descending colon, which coincided with the data of the intraoperative revision. The main and general signs of the inflammatory process for all described CT complications were thickening of the intestinal wall from 0.4 to 1.5 cm in length from 6.8 cm to 15.3 cm and cloud-shaped or heavy compaction of pericolic tissues (Table 1).

Abscesses/cavities on the background of chronic abdominal mass during CT were diagnosed in 31 (42.3%) patients, while in 25 (80.6%) cases their diameter did not exceed 4 cm, and in 6 (19.3%) cases it was more than 4 cm, reaching 6.5 cm in one patient (Fig.1,2). In most cases (29/93.5%), the abscess cavity was filled with liquid contents and gas bubbles (with the formation of liquid and gas levels) and in 2 (6.4%) observations contained only air. Pathological

cavities were delimited by a capsule from 2 to 4 mm thick (accumulating contrast agent) with the presence of infiltration and fibrosis in the pericolic tissues. In 5 (16.1%) cases, the boundaries of the abscess walls were the pelvic organs (uterus, left ovary, bladder) and/or the side walls of the pelvis with pelvic peritoneum involvement in 16 (51.6%) cases.

All abscesses were near the altered intestine (at a distance of no more than 5 cm), and almost two thirds of 19 (61.0%) of them were in the mesentery of the sigmoid colon. Morphology revealed a destroyed diverticulum, fragments of the cavity wall and fibrosis along the boundaries of the cavity in the mesentery of the sigmoid colon in the presence of an abscess. At the same time, according to the morphology, a false negative result was noted in one case, and a false positive result in the other (Table 2).

In the first case, a morphology revealed a small (0.9 × 0.4 cm) linear abscess between the affected sigmoid wall and the left ovary, the

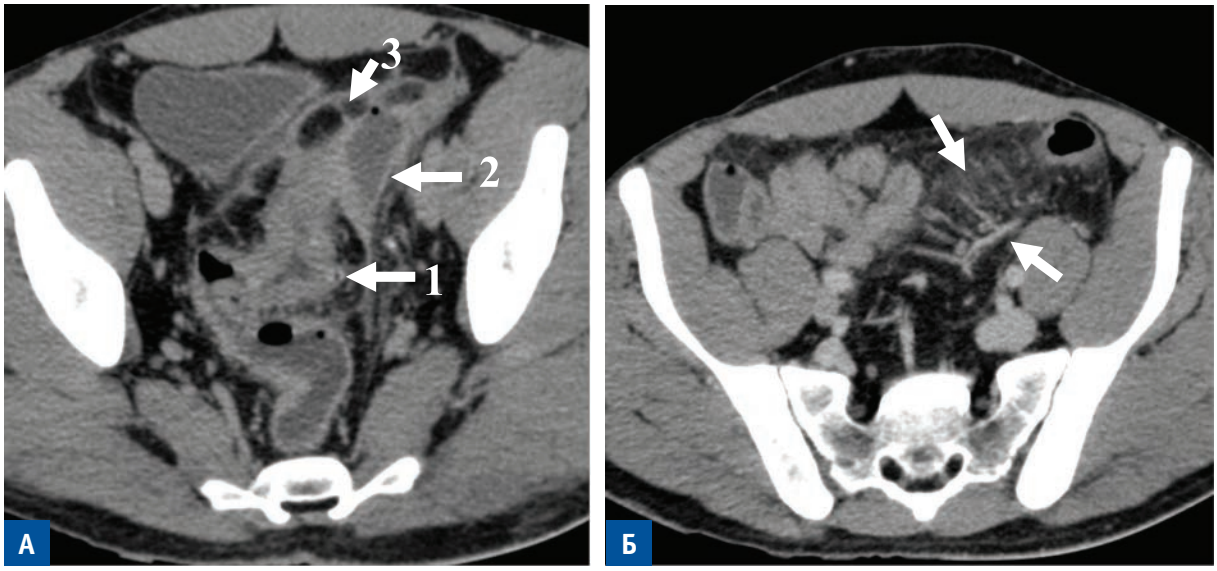


Figure 1. *A. CT with intravenous contrast, axial projection. Thickening of the sigmoid colon wall up to 1.1 cm (arrow 1); an abscess up to 4.2 cm in size with a gas bubble and unevenly thickened walls (arrow 2); inflammatory infiltration of pericolic fat (arrow 3); Б. The «centipede» symptom is a pronounced blood filling of the vasa recta of the mesentery of the sigmoid colon (arrows).*

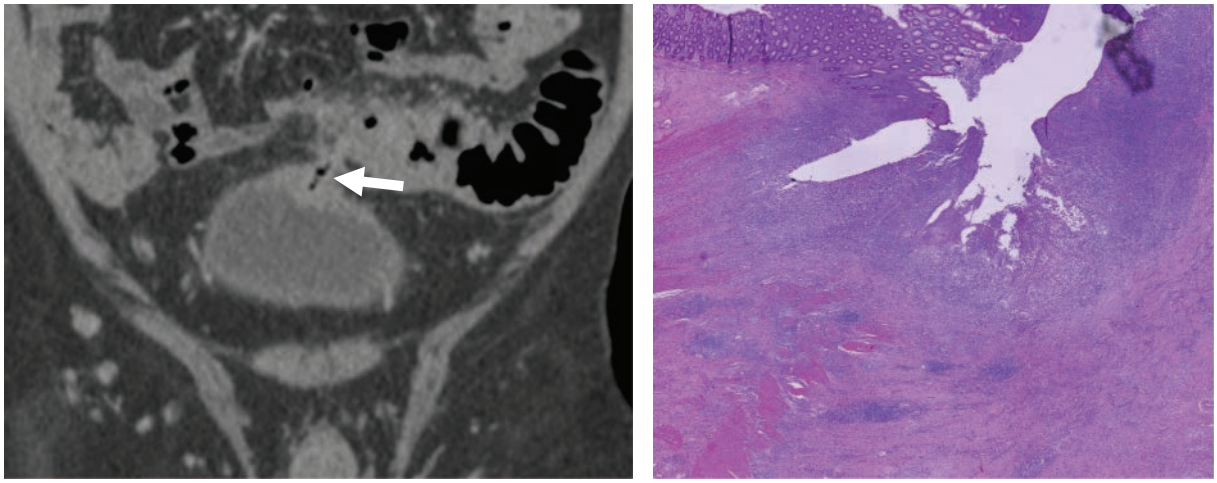


Figure 2. *A. CT with intravenous contrast, frontal projection. On the background of inflammatory thickening of the sigmoid colon wall and inflammatory infiltration pericolic fat, a sigmovesical fistulous tract with gas bubbles in the lumen is visualized (arrow); Б. Diverticulum with pronounced inflammatory infiltration, complete destruction of the wall and the presence of fistulous passages. Micropreparation ×40, staining with hematoxylin and eosin*

Table 2. *Diagnostic efficiency of CT in various inflammatory complications of diverticular disease (n = 70)*

Complication type	TP	FP	TN	FN	*n*	Sensitivity	Specificity	PPV	NPV	Accuracy
Chronicabdominal mass	16	1	53	0	70	100%	97%	94.1%	100%	98.5%
Chronic abdominal mass with abscess/cavity	30	1	38	1	70	96.8%	97.4%	96.7%	97.4%	97.1%
Colon fistula	22	0	47	1	70	95%	100%	100%	97.9%	98.5%

Note: TP — true positive results; TN — true negative; FP-false positive; FN–false negative; PPV — positive predictive value; NPV — negative predictive value

visualization of which during computed tomography against the background of inflammatory infiltration was difficult. The false positive result was associated with a fragment of a partially obliterated fistula, mistaken for a small abscess.

Fistulas were detected by CT in 22 (31.4%) patients: 20 sigmovesical and 2 external sigmoid fistulas. With sigmovesical fistulas, a thickening of the bladder wall from 0.6 to 1.1 cm was noted in the area of fistula track, with the presence of air bubbles in its lumen in 21 cases (Fig.2). In 4 (18.1%) patients, sigmovesical fistulas were accompanied by the formation of small (up to 2–2.5 cm) abscesses involving the bladder wall. The morphological verification of the fistula included visualization of the fistula track and the internal fistula opening (the area of the destroyed diverticulum) in the sigmoid colon.

In 17 patients, computed tomography revealed a thickening of the intestinal wall from 0.5 cm to 0.7 cm in length from 6.8 cm to 9.2 cm with cloud-shaped or heavy compaction of pericolic tissues without CT symptoms of abscesses or fistulas. Only in two cases on the mesenteric edge of the intestine against the background of inflammatory infiltration of pericolic tissues, single air bubbles were detected (CT symptom of microperforation of the diverticulum) (Fig.3). Changes in this group of patients were regarded by us as aabdominal mass. In 8 cases, adjacent organs (uterus, left ovary) and in 6 cases the pelvic peritoneums were involved in the inflammatory process. The morphology of the resected specimens revealed in 16 cases the diverticulum destruction in the form of microperforation only in microscopic study. And only in one case, the diverticulum destruction was noted both in macro- and microscopic study and was

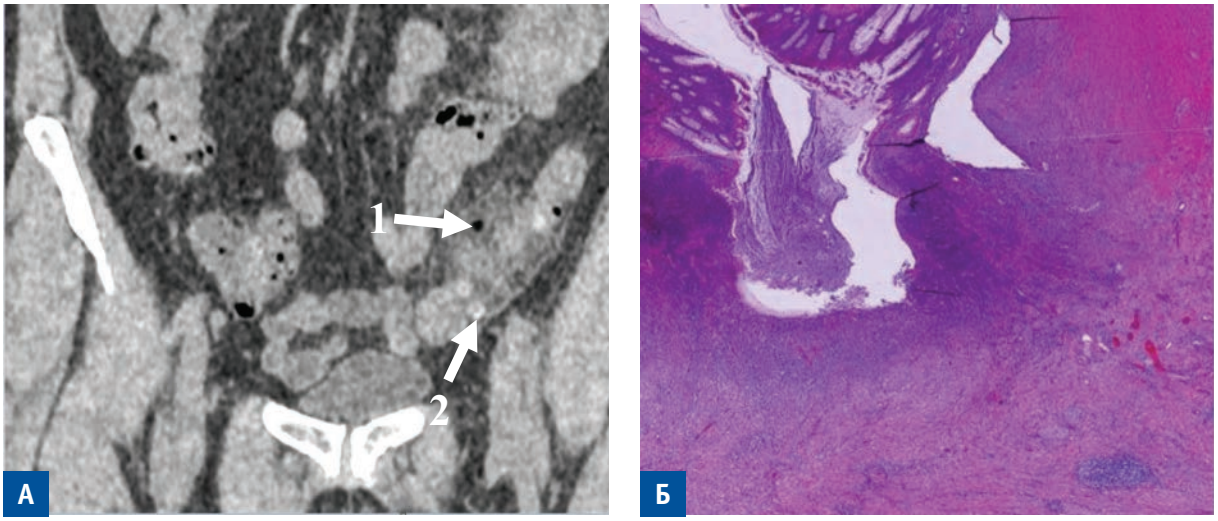


Figure 3. *A. CT with intravenous contrast, frontal projection. Limited infiltration of pericolic fat with the presence of a single gas bubble on this background is visualized (arrow 1). Diverticula with contrasting content are identified (arrow 2); Б. Diverticulum with severe inflammatory infiltration and wall destruction. Micropreparation ×40, staining with hematoxylin and eosin*

Table 3. *Splitting the sample objects into two clusters and comparing them**

CT-parameter/symptom	The first cluster** (*n* = 16)	The second cluster*** (*n* = 54)	Threshold value	*p*
Intestinal wall thickness, CT (cm) Me (Q_1 — Q_3)	0.60 (0.50–0.70)	0.70 (0.60–0.90)	0.80	0.002****
Extent of intestinal wall changes, CT (cm) M ± SD Me (Q_1 — Q_3)	8.11 ± 0.72	10.5 (9.80-12.23)	9.20	< 0.001****
Extent of inflammatory infiltration of pericolic tissues, CT (cm) Me (Q_1 — Q_3)	2.50 (2.30–2.75)	4,18 (2.9–5.73)	3.30	< 0.001****
The "centipede" symptom	5 (19.2%)	21 (80.8%)	–	0.579
Involvement of adjacent organs	8 (23.5%)	24 (76.5%)	–	0.826
Pelvic peritoneum involvement	6 (21.2%)	16 (78.8%)	–	0.564

** The silhouette measure of connectivity and separation was 0.4, which corresponds to the average quality of clusters*
***Microperforation ***Macroperforation ****Differences in indicators are significant (p < 0.05, method used: Pearson Chi-squared)*

accompanied by the small cavity that was not detected by CT (that patient was assigned to the group of complications with abscesses). The CT sensitivity of the microperforation symptom

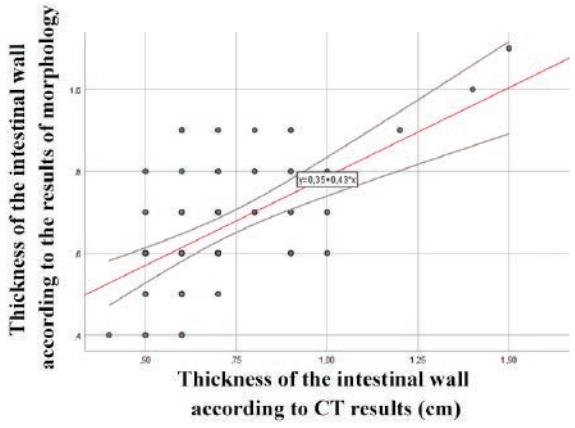


Figure 4. *Regression function graph (colon wall thickness)*

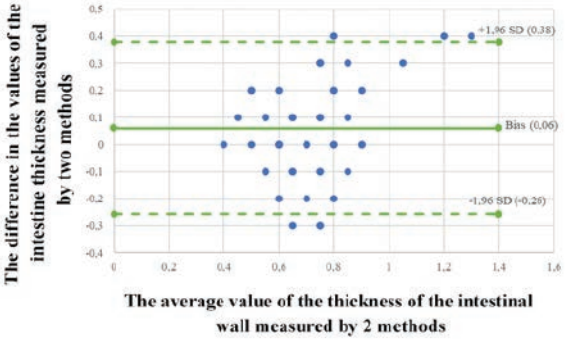


Figure 6. *Blend-Altman diagram in assessing the consistency of the intestinal wall thickness measured by CT and morphological examination*

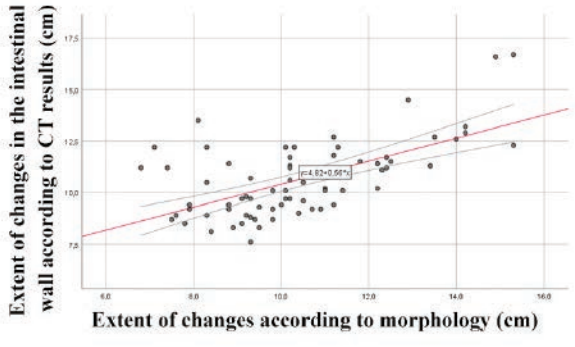


Figure 5. *Regression function graph (length of the colon wall)*

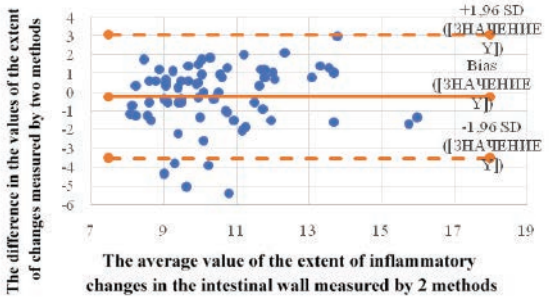


Figure 7. *Blend-Altman diagram in assessing the consistency of the values of the extent of inflammatory changes in the intestinal wall, measured by CT and morphological examination*

(gas in pericolic tissues) in our study was only 12.5% with a high specificity of the symptom (100.0%).

A comparative analysis of the numerical values of the thickness of the intestinal wall and the extent of inflammatory changes in the intestinal wall obtained by CT and morphology was carried out. According to the results of the analysis, were obtained the data indicating a significant direct correlation estimated using the Spearman correlation coefficient both with respect to thickening of the intestinal wall (r_{xy} = 0.486; p < 0.001) and with respect to the extent of changes in the intestinal wall (r_{xy} = 0.555; p < 0.001) (Fig.4,5).

The consistency of values of the thickness of the intestinal wall and the extent of inflammatory changes in the intestinal wall obtained by CT and morphology using the Blend-Altman method was analyzed. The results of the analysis demonstrate high consistency of the data obtained by different diagnostic methods (Fig.6,7).

According to the morphological analysis of the removed specimens, the diverticulum destruction in the form of macroperforation (abscesses and fistulas) was found in 54 patients (a group of patients with macroperforation) and in the

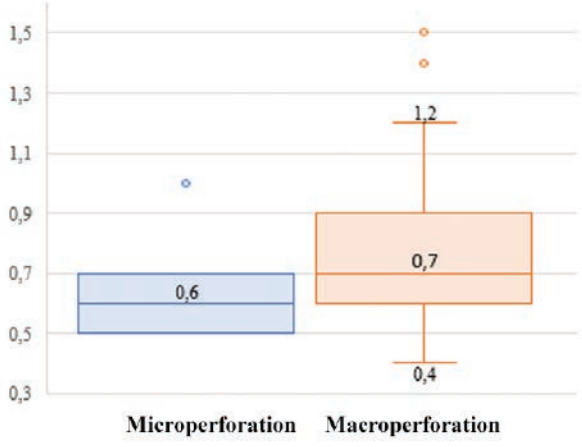


Figure 8. *Distribution of values of colon wall thickness measured by CT in groups of patients with microperforation and macroperforation (according to the results of pathomorphological examination)*

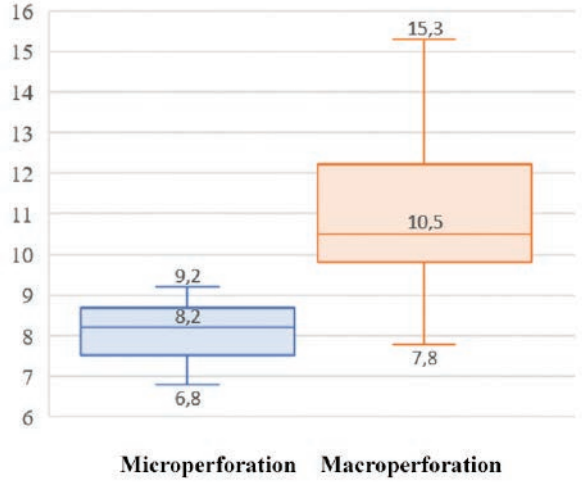


Figure 9. *Distribution of values of the extent of changes in the colon wall, measured by CT, in groups of patients with microperforation and macroperforation (according to the results of pathomorphological examination)*

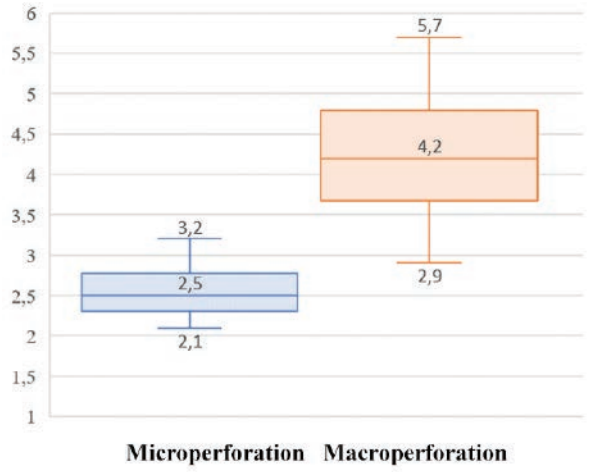


Figure 10. *Distribution of the length of the pericolonic inflammation, measured by CT, in the groups of patients with microperforation and macroperforation (according to the results of pathomorphological examination)*

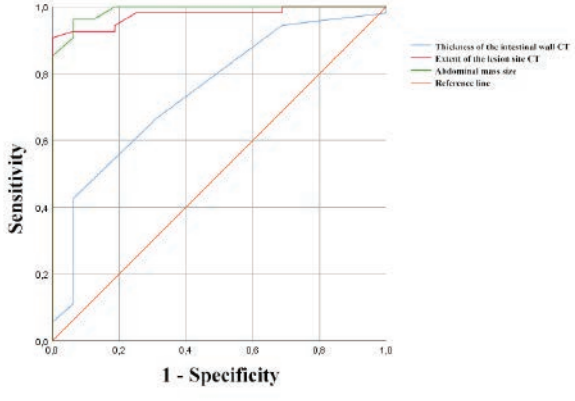
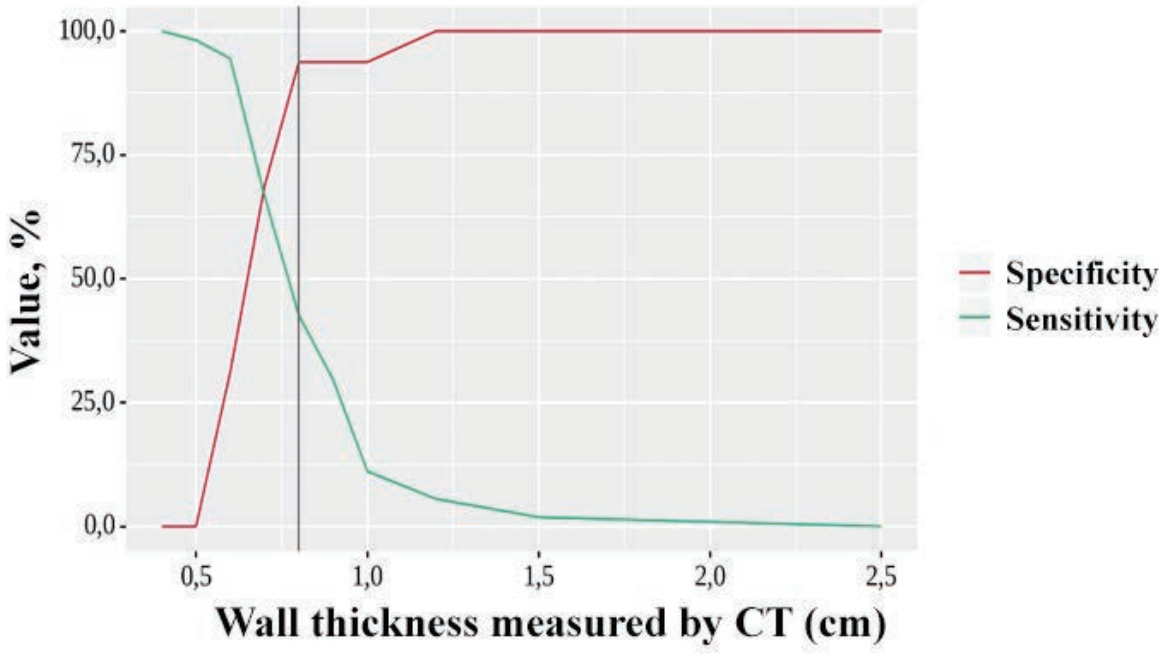


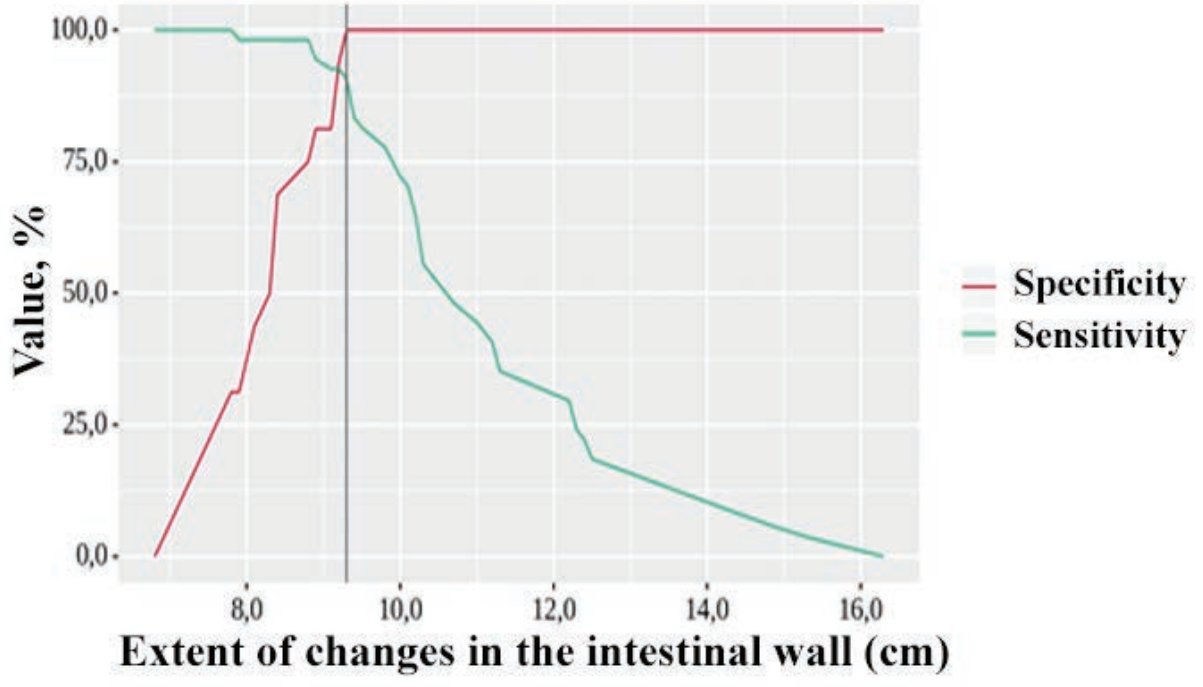
Figure 11. *ROC-curve, the probability of detecting microperforation depending on the thickness of the intestinal wall, the length of changes in the colon wall, the lenght of pericolonic inflammation revealed by CT.*



Пороговое значение при КТ, (см)	Чувствительность (Se), %	Специфичность (Sp), %
0,7	66,7	68,8

Threshold values of wall thickness (cm) based on CT results. Microperforation was predicted at CT wall thickness greater than or equal to this value.

Figure 12. *The area under the ROC-curve of the CT colonic wall thickness was 0.75 ± 0.06 with 95% CI: 0.62–0.87. The resulting model was statistically significant (p = 0.002).*



Пороговое значение при КТ, (см)	Чувствительность (Se), %	Специфичность (Sp), %
9,2	92,6	93,8

Threshold values of the extent of bowel wall changes (cm) based on CT results. Microperforation was predicted when the value of changes in the colonic wall, measured on CT, was greater than or equal to this value.

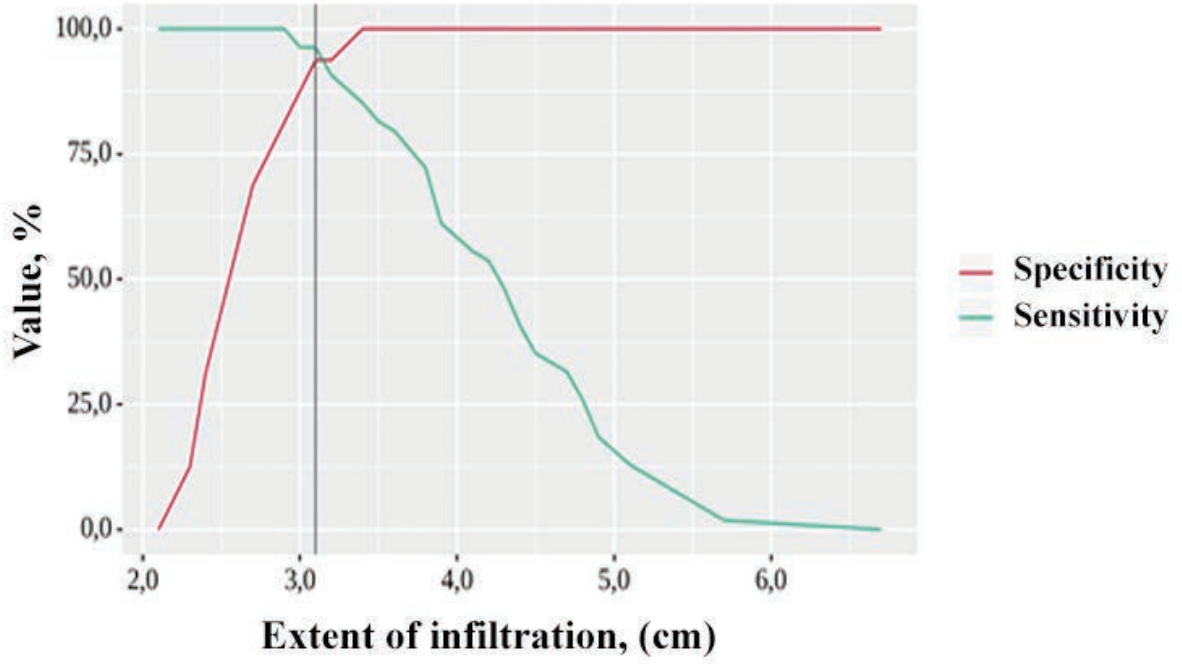
Figure 13. *The area under the ROC-curve of the length of changes in the colonic wall according to CT was 0.975 ± 0.016 with 95% CI: 0.943–1.000. The resulting model was statistically significant (p < 0.001).*

form of microperforation (abdominal mass) — in 16 cases (a group of patients with microperforation). Statistical analysis of computed tomography data in each of those groups to identify CT symptoms, which, firstly, could with a high degree of probability allow us to judge the presence of the diverticulum destructionin the absence of obvious CT symptoms of its destruction (abscesses, fistulas, air in pericolic tissues); secondly, would provide better differentiation of patients with macro- and microperforationin CT. In the above analysis, data on abscesses and fistulas were not used to achieve the necessary cross-validation.

As a result of a two-stage cluster analysis, two optimal clusters were identified (Table 3). The share of the first cluster in the total structure was 22.9%, of the second — 77.1%. The first and second clusters were significantly separated.

Significant differences between the groups with macro- and microperforation were not established in relation to CT symptoms of adjacent organ involvement (p = 0.826), pelvic peritoneum involvement (p = 0.564), and the "centipede" symptom (p = 0.579). Significant differences were found for three CT symptoms: the thickness of the intestinal wall (p = 0.002), the extent of inflammatory changes in the intestinal wall (p < 0.001), and the extent of inflammatory infiltration of pericolic tissues (p < 0.001) (Table3; Fig.8,9,10). These CT symptoms were evaluated using ROC analysis to determine the threshold values at which it is possible to judge the presence of microperforation with a high degree of probability (Fig.11).

The threshold values were 0.7 cm for the intestinal wall thickness (sensitivity — 66.7%, specificity — 68.8%), 9.2 cm for the extent of changes in the intestinal wall (sensitivity — 92.6%, specificity — 93.8%), 3.1 cm for the extent of infiltration (sensitivity — 96.3%, specificity — 93.8%) (Fig. 11,12,13,14).



Пороговое значение при КТ (см)	Чувствительность (Se), %	Специфичность (Sp), %
3,1	96,3	93,8

Threshold values of the extent of the infiltrate according to the results of CT. Microperforation was predicted when the length of the infiltrate was greater than or equal to this value.

Figure 14. *The area under the ROC-curve of pericolonic inflammation length according to the CT results was 0.989 ± 0.011 with 95% CI: 0.968–1.000. The resulting model was statistically significant (p < 0.001).*

DISCUSSION

The expediency of using CT to detect inflammatory complications of CDD is a generally recognized fact, which is due to the high diagnostic accuracy of the method. According to the literature, computed tomography has a high sensitivity (94–99.1%) and specificity (99–99.8%) in the diagnosis of acute diverticulitis, complications such as perforation, abscesses, fistulas [3,10,11]. The values of informativity of CT obtained in our study are consistent with the data of publications by other authors. Thus, when compared with the morphology of the resected specimen, the sensitivity and specificity of CT scans were 96.8% and 97.4%, respectively, when detecting abscesses; colon fistulas– 95% and 100%; and abdominal mass–100% and 97%.

In the last decade, the authors of publications have been paying more and more attention to the search for CT predictors of the recurrence of the inflammatory process in CDD. Ambrosetti, P. et al. proposed a classification of acute diverticulitis based on CT symptoms, according to which moderate diverticulitis is distinguished (thickening of the intestinal wall to 5 mm or more with infiltration of pericolic tissues) and severe diverticulitis (perforation, abscess, extra-intestinal gas) [12]. As further research has shown, the proposed classification makes it possible to assess the likelihood of recurrent complications after drug treatment of the first episode of inflammation. When observed for 5 years after conservative treatment of the first attack of acute diverticulitis in 429 patients, recurrences of the inflammatory process most often (49.0%) occurred in patients with CT symptoms of severe diverticulitis and twice as rarely (22%) in patients with a CT picture of moderate diverticulitis [13].

A study by Hall, J.F. et al. revealed that the extent of inflammatory changes in the intestinal wall and the presence of an abscess increase the risk of diverticulitis recurrence, and the study by Dickerson, E.C. et al. demonstrated that the maximal thickness of the intestinal wall and the grade of severity of inflammatory changes in pericolic tissues make it possible to predict the recurrence [2,14].

In the study we compared data obtained by CT and morphology of resected bowel in order to search for additional capabilities of computed tomography in detecting the diverticulum wall destruction in inflammatory complications of CDD. To date, the resolving CT capabilities do not allow to visualize the destructed diverticulum itself; and we can only judge the presence of perforation by changes that are the consequences of the diverticulum destruction(abscesses, fistulas, gas in pericolic tissues, free gas in the abdominal cavity). The detection of abscesses and fistulas in CT indicates the diverticulum destruction (macroperforation), the presence of gas bubbles in the pericolic tissues is considered as a CT symptom of microperforation [15,16]. In our study, the latter symptom was detected in only two out of 16 patients with morphological picture of microperforation and, with high specificity (100%), demonstrated extremely low sensitivity (12.5%). We have not found any data in the literature on the sensitivity of this highly specific CT symptom. Thus, in 14 (87.5%) of 16 patients with morphological picture of microperforation we were unable to diagnose it by CT, based on the known CT symptoms. As shown by our ROC analysis, the thickness of the intestinal wall, the extent of inflammatory changes in the intestinal wall, and the extent of inflammatory infiltration of pericolic tissues assessed by CT make it more likely to judge the presence of micro- or macroperforation of the diverticulum. Each of these CT symptoms allowed us to find a threshold value of the parameter at which it is possible to predict the presence of microperforation with a high degree of reliability.

It can be assumed that the presence of an unrevealed microperforation of the diverticulum is one of the causes of recurrences in CDD.

The use of the proposed system of CT symptoms will expand the diagnostic capabilities of computed tomography in identifying patients with microperforation of the diverticulum and will help in stratification of patients when planning elective surgery.

CONCLUSION

CT parameters of thickening of the intestinal wall, the extent of inflammatory changes in the intestinal wall, and the extent of infiltration of pericolic tissues are significant for the possibility of predicting the presence of microperforation. It is advisable to conduct further research in order to determine the CT capabilities in the prognostic assessment of the severity of inflammatory changes, which will provide a more differentiated approach when choosing treatment approach for patients with inflammatory complications of CDD.

AUTHORS CONTRIBUTION
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