

Ischemic colitis: spectrum of CT findings, sites of involvement and severity

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Abstract To summarize the frequency of findings on IV contrast, enhanced computer tomography (CT) in 335 patients with pathologically proven ischemic colitis (IC) determine the most frequent locations and patterns of involvement and establish the correlation of these findings with the severity of IC. 231 patients were excluded for not having a concomitant CT or for having underlying comorbidities. 104 cases were analyzed. Scans were evaluated for abnormal wall enhancement (AE), bowel wall thickening (BWT), bowel dilatation (DIL), mesenteric fat stranding (FS), venous engorgement (VE), pericolonic free fluid (FF), and pneumatosis (PN) and portomesenteric venous gas. Segmental versus pancolonic involvement was noted. Severity was determined by histopathology criteria. Data obtained are as follows: female to male incidence, 69 % (70) vs. 31 % (34); average age, 64.5; and positive CT, 102/104 (98.1 %). The most frequent findings include FS (88 %), BWT (88 %), and AE (82 %) regardless of severity of involvement. Statistically significant increased risk ratio and likelihood of severe ischemia for PN, DIL, and FF individually. BWT, DIL, FS, FF, VE, and PN together have a probability for severe IC of 91.8 %. A correlation between fewer findings and milder IC was found ($R^2=0.6771$). The most frequently involved segments: descending (64 %) and sigmoid colon (54 %). Splenic flexure (SF) was infrequently involved ($n=8$, 7.84 %). Females had two times higher incidence of IC. The most frequent CT findings in IC are FS, BWT, and AE regardless of the severity. PN is suggestive of

severe IC. Segmental involvement is the predominant pattern. The distal colon is more frequently involved. SF contrary to the conventional literature is not disproportionately involved in IC.

Keywords Ischemic colitis · CT · Patterns · Location · Severity · Colon · Ischemia · Contrast enhanced

Introduction

Ischemic colitis is the most frequent form of intestinal ischemia (70 %) [1] and results from an insufficient blood supply to the colon rather than vascular obstruction, often causing subsequent inflammation and damage which may rarely progress to necrosis and become fatal [2]. It mostly occurs in elderly patients (80 %) that present with abdominal pain, rectal bleeding, and/or diarrhea [3].

The diagnosis of ischemic colitis is challenging since its clinical presentation may be similar to that of other abdominal diseases and conditions such as diverticulitis, appendicitis, bowel obstruction ulcerative colitis, and Crohn's disease [4]. Computed tomography (CT) is widely accepted as the primary screening modality for the evaluation of abdominal pain [3, 5], but while CT imaging has become a mainstay of clinical diagnostic decision making, the definitive diagnosis of ischemic colitis still requires histopathological analysis [6]. Pathological changes vary with the duration and severity of ischemic colitis allowing different degrees of involvement to be defined [2]. CT appearance has also been linked to the evolutionary phase of this condition [3], and certain colonic segments known as “watershed areas” have been identified as sites of high susceptibility to ischemic colitis.

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The purpose of this work is to summarize the frequency of the different imaging features of ischemic colitis on intravenous (IV) contrast CT examinations, in a substantial series of patients with pathologically proven cases of ischemic colitis, to determine the most frequently involved segmental locations and patterns of involvement, and to establish whether there are correlations between the CT findings and the severity of ischemia assessed by histopathology.

Materials and methods

This is an IRB, HIPAA-compliant retrospective review of CT examinations acquired using intravenous (IV) contrast on patients with an established pathological diagnosis of ischemic colitis. Subjects were identified by searching the database of the pathology laboratory of our institution for “ischemic colitis” including cases diagnosed between 2007 and 2010.

A total of 335 patients with a final diagnosis of ischemic colitis were found. 231 patients were excluded for not having a concurrent oral and IV contrast enhanced CT or for having a history of recent abdominal surgery or trauma and/or concomitant chronic inflammatory bowel disease.

There were 104 subjects that met the inclusion criteria. All of the pathological specimens were obtained through endoscopic biopsy. The CT scans and endoscopic biopsies were acquired within 8–12 h of each other. Patients presented to the emergency department with histories of acute diffuse abdominal pain with a range of accompanying symptoms such as diarrhea, bloating, nausea, vomiting, bright red blood per rectum, and syncope. None of the patients required surgery.

Scans were performed using the standard CT imaging protocol for abdominal pain in the emergency department of our institution (http://www.mghradrounds.org/index.php?src=gendocs&link=nov_dec_2007#Anchor-CT-47857). A 64-row detector CT scanner was used and patients received 900–1,150 ml of diluted oral contrast material and 500–1,000 ml of water or a positive contrast agent as a rectal contrast, administered 30–45 min before the examination. IV-iodinated contrast material was administered at a rate of 3 ml/s up to 150 ml according to patients’ weights. A portal venous phase was obtained in every case. Thin section slices between 2 and 3 mm were obtained extending from the diaphragm to the symphysis pubis, acquiring coronal and sagittal reformations.

The examinations were analyzed by a general radiologist, an emergency radiologist and a gastrointestinal radiologist with 1, 12, and 20 years of experience, respectively.

The CT exams were evaluated for the presence of the following criteria: abnormal wall enhancement (AE), bowel wall thickening (BWT), bowel dilatation, mesenteric fat stranding (FS), venous engorgement (VE), presence of

fluid or ascites, pneumatosis-portomesenteric venous gas, and infarcts of other organs.

Abnormal wall enhancement (AE) was considered present when increased attenuation, decreased attenuation, or stratification [7] of the wall in comparison to the rest of the colon was noted. Bowel wall thickening (BWT) was considered to be present when the wall measured over 3 mm in well-distended bowel and more than 5 mm in partially distended colon [7]. The criterion for diagnosis of large bowel dilatation was a diameter that exceeded 8 cm, 9 cm for the cecum [3, 5]. The presence of adjacent stranding in the mesenteric fat and/or pericolonic fluid was recorded. Pneumatosis (PN) was diagnosed when round, linear, or curvilinear gas was present within the bowel wall [3, 5].

Extent of involvement was recorded first as either pancolonic or segmental, and for assessment of cases with segmental involvement, the colon was divided into the cecum, ascending colon, hepatic flexure, transverse colon, splenic flexure (SF), descending colon, sigmoid colon, and rectum. Involvement of the proximal (right) or distal (left) colon based on the WHO 2010 classification criteria [8] was also recorded to assess the relative involvement of the superior and inferior mesenteric artery watersheds. In the WHO system, the right or proximal colon is taken as the cecum, ascending colon, hepatic flexure, and the proximal two thirds of the transverse colon; and the left or distal colon is taken as the distal third of the transverse colon, splenic flexure, descending colon, sigmoid colon, and rectum.

The contiguity or intermittency of the injured colon segments was noted.

Consensus agreement about the CT findings and location of injuries was reached through consultation between observers.

Pathology reports included a classification of ischemic severity from mild to severe. The mildest injury by pathology criteria is mucosal and submucosal hemorrhage and edema, with or without partial necrosis and ulceration of the mucosa. With moderate injury, chronic ulcerations, crypt abscesses, and pseudopolyps develop. The most severe form of ischemic damage causes transmural infarction and potential for rupture. The cases were classified according to their pathological features as mild, moderate, and severe [9].

Two-proportion *Z* tests were utilized to determine the significance of the difference between the subsets of CT features manifested by patients with severe involvement versus lower degrees of involvement. The risk of having severe ischemia based on the presence of each of the analyzed CT findings was quantified by calculating its odds ratio in the group with severe ischemia [10].

A logistic regression model was used to predict the severity of ischemia based on associations between CT findings, and a

correlation analysis was performed in an attempt to associate the number of tomographic features and the severity of ischemic colitis [10]. The cases with severe ischemia were further evaluated for the presence of each of the CT features, then divided as “with the feature” or “without the feature” accordingly; these were compared as proportions to the remaining set of cases with lower severity (mild and moderate cases).

Results

A more than twofold greater incidence of ischemic colitis was found in females ($n=72$, 69 %) than males ($n=32$, 31 %) in this study. The mean age of the subjects was 64.5 years of age with a standard deviation (SD) of 15.04-year-old. Average age for female patients was higher (66 years old) than males (61.7 years old) with no statistical difference found ($p=0.087$).

Out of 104 cases, two (1.9 %) did not show any radiological changes in the bowel and/or adjacent structures. CT scans were positive in 102 of 104 (98.1 %) of the cases, demonstrating one or more abnormal findings (Figs. 1, 2 and 3).

Imaging findings

The most frequently observed findings in our cohort ($n=102$) were colonic wall thickening and mesenteric fat stranding (Table 1) present in 90 cases each (87 %). Abnormal colonic wall enhancement was detected in 85 of 102 cases (82 %), with increased enhancement as the most commonly observed pattern in 63 of 85 cases (74 %).

No infarcts of other organs or vascular occlusions were observed.

The findings that were observed more frequently together were: bowel wall thickening and fat stranding 81 % (83/102),

fat stranding and abnormal wall enhancement 76 % (78/102), bowel wall thickening and abnormal wall enhancement 75 % (76/102), bowel wall thickening and venous engorgement 45 % (46/102), and abnormal wall enhancement and venous engorgement 43 % (44/102), with other combinations of findings seen less frequently.

Distribution

Involvement of ischemic injury is depicted in Fig. 4. Pancolonic involvement was seen in 6 of the 102 CT positive cases. Multisegmental involvement was more common than single segment involvement, 76 versus 20 cases, and a pattern of contiguous multisegment involvement was more common than a pattern of skipped segments. Overall, the left colon—splenic flexure to rectum—was involved more than three times as often than the right colon: 74 cases (77 %) versus 22 cases (22.9 %).

The segments most frequently involved individually and in combination with others (Fig. 5) were the descending 62.7 % (64/102) and sigmoid colon 60 % (58/102).

Histopathological severity and correlation with CT findings

Out of 102 positive cases, 24 were described histopathologically as severe (23.5 %), 6 were described as moderate to severe (5.8 %), 37 were described as moderate (36.2 %), 15 showed mild to moderate ischemic changes (14.7 %), and 20 cases were diagnosed as mild ischemia (19.6 %). The most frequently involved segments in severe ischemic colitis ($n=24$) are the descending colon (15/24) followed by the sigmoid colon (12/24) and the cecum (9/24).

The most frequent CT findings in patients with severe ischemic colitis were fat stranding, bowel wall thickening, and abnormal wall enhancement in descending order (Fig. 6).



Fig. 1 **a** 80-year-old male with diagnosis of full thickness severe ischemic colitis. Coronal view showed pneumatisis coli in visualized portions of the ascending colon and splenic flexure (white arrows), thickened wall with abnormal wall enhancement (white arrow heads), and trace free fluid and fat stranding in the adjacent mesentery (black arrows). **b** Coronal view of contrast enhanced CT of a 65-year-old female with ischemic colitis showing bowel wall thickening and

abnormal wall enhancement involving the left colon (white arrows). Axial image of 74-year-old female diagnosed with ischemic colitis (c) shows moderately dilated bowel (*), bowel wall thickening and abnormal enhancement of the left colon (white arrows) and mesenteric fat stranding (black arrows) surrounding the bowel in the left flank. Patients were followed up and medically treated

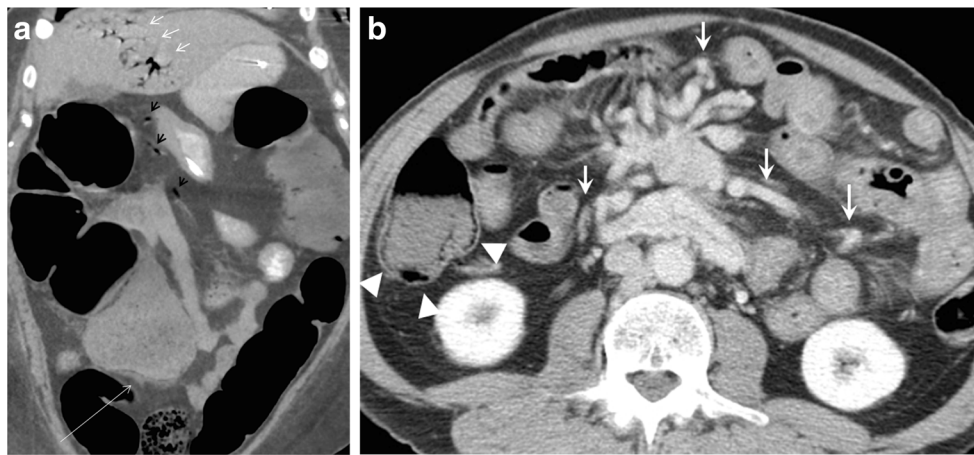


Fig. 2 Coronal reconstruction of a 59-year-old female patient with severe ischemic colitis demonstrated presence of portal venous gas (*white short arrows*), mesenteric gas (*black arrows*), and inflammatory changes surrounding the ascending colon (*white long arrow*). **b** 66-year-

old female with striking venous engorgement in the central mesenteric veins (*white arrows*) and pneumatosis of the ascending colon (*white arrow heads*) in a contrast enhanced CT axial plane. Patients required hospitalization and antibiotic treatment

However, these findings were present in the majority of cases and were also the most frequent findings in lower degrees of involvement.

The odds ratio for three specific findings showed a statistically significant increased risk of severe ischemia when seen on CT. The findings were: pneumatosis, free fluid, and dilatation (DIL). Their quantified risk ratios relative to severe ischemic colitis given a 95 % confidence interval are: 4.3382, 3.878, and 2.5702, respectively. The odds ratios relative to severe ischemia for all other individual findings were below 1.

Table 2 shows the likelihood of the CT findings to correspond to severe ischemia. The three findings that showed a

higher likelihood of indicating severe ischemia in descending order of probability are: pneumatosis, dilatation, and free fluid with $p < 0.05$. The number of cases for pneumatosis was not sufficient for statistical validation [8].

When different groupings of CT findings were tested as indicators of level of severity, we found that if *BWT*, *DIL*, *FS*, *FF*, *VE*, and *PN* are seen together, the probability for severe ischemic colitis equals 91.8 % by logistic regression. No other combinations were found to have a high correlation with severe ischemia. On the other hand, linear regression indicated there was a correlation between fewer total findings per case and milder ischemic colitis (Fig. 7) with $R = 0.6771$.

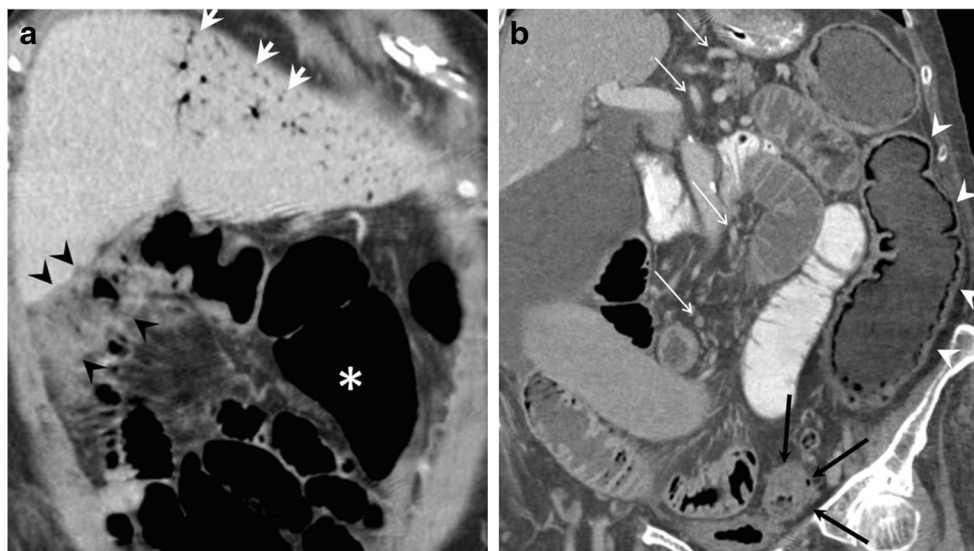


Fig. 3 **a** 69-year-old male diagnosed with moderate ischemic colitis, underwent contrast enhanced ct. Coronal view demonstrating portal venous gas (*white arrows*) in the left hepatic lobe, colonic dilatation (*star*), and mucosal enhancement and wall thickening of the hepatic flexure (*black arrow heads*). **b** 77-year-old female: coronal view showing a left colon moderately distended with low density fluid, thin

air line surrounding the bowel content, shaping the inner mucosa (*white arrow heads*) corresponding with pneumatosis, the wall is heterogeneously enhancing and sigmoid colon is thickened and inflamed (*black arrows*); there is diffuse venous engorgement (*white arrows*). Patients were hospitalized and required strict monitoring, and medical treatment

Table 1 Frequency of CT findings on ischemic colitis

	Number of cases	Percentage
Bowel wall thickening (BWT)	90/102	88 %
Fat stranding (FS)	90/102	88 %
Abnormal wall enhancement (AE)	85/102	82 %
Venous engorgement (VE)	52/102	51 %
Fluid or Ascites (F)	36/102	35 %
Dilatation (DIL)	20/102	20 %
Pneumatosis (PN)	10/102	9.8 %
Portomesenteric gas (MG)	2/102	1.9 %

Splenic flexure

The splenic flexure (SF) was not disproportionately involved than any other segment at 8/102 cases (7.84 %). In 7/8 of these cases (88 %), the SF was affected along with other segments of the colon, and 5/8 of the cases involving the SF were diagnosed with mild ischemia (63 %), with just one case of severe ischemic colitis (1/8, 13 %).

Discussion

We found a female predominance of ischemic colitis—69 % of cases—for unknown reasons. There was a predominant segmental pattern of involvement, mainly involving the distal colon. Wall thickening, fat stranding, and abnormal wall enhancement were the most frequent findings on CT. Patterns of findings with regard to number and type did not correlate with severity of involvement with the exception of an infrequently seen combination of BWT, DIL, FS, FF, VE, and PN in severe colitis. Contrary to conventional teachings about increased risk of ischemia in the watershed between the superior and inferior mesenteric artery circulations, the splenic flexure was not found to be a site of disproportionate risk for ischemic colitis.

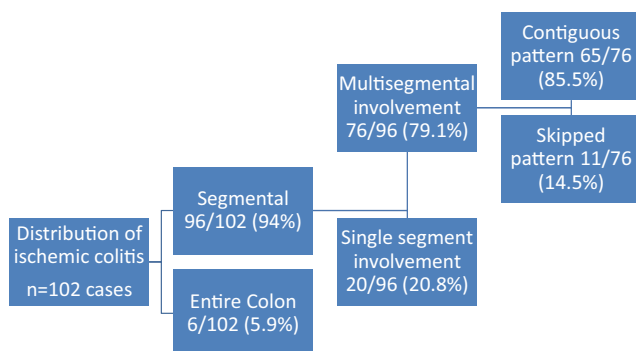


Fig. 4 Distribution of involvement of ischemic colitis. Diagram shows the distribution of involvement of ischemic colitis

Female predominance has been described in previous publications with large cohorts [11–14], some of which include only subjects with pathologically proven cases of IC. There is no known reason for ischemic colitis to predominantly affect women; we suggest a relatively higher susceptibility to local and systemic hypotension due to smaller vessel size on average compared with men that could lead to intestinal hypoperfusion. Males have a higher incidence of atherosclerotic disease and probably present more frequently with occlusive ischemia than ischemic colitis. Our study showed female predominance in 69 % of the cases.

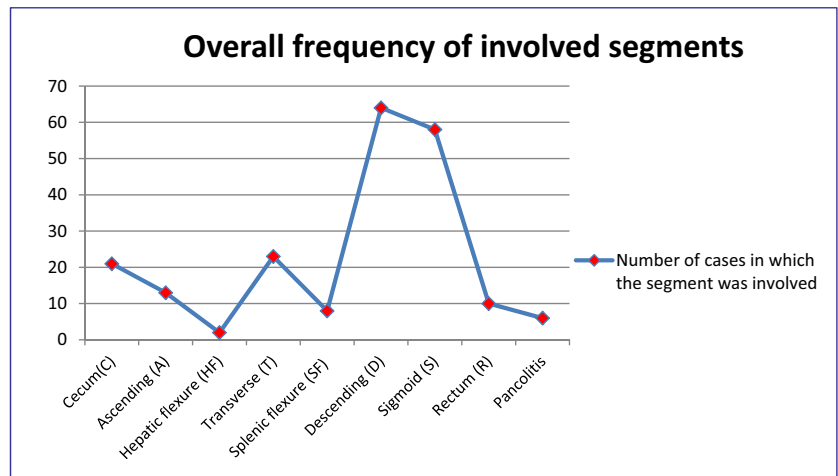
The most frequent CT findings in our series correspond with those found by Balthazar et al. [15] in merely 54 cases. Bowel wall thickening (BWT) was the most frequent CT finding in this series and in other reports in the literature regarding ischemic colitis [3, 5, 15–17]. The ischemia induced inflammatory process initially causes injury to the mucosa as a consequence of local hypoperfusion and reperfusion, through congestion, edema and hemorrhage [7, 14], producing a thicker aspect of the wall. This pattern of BWT cannot be distinguished from other etiologies, such as inflammatory bowel disease, pancreatitis and peritonitis, among others. BWT alone does not point to ischemic colitis and, as with other individual findings, is not specific for ischemic colitis [5, 18, 19]. No association between the severity of colitis and the degree of wall thickening was found.

Hyperenhancement of the wall is likely attributed to two events: the redistribution of blood with vasodilatation during very early stages of recovery from ischemia and/or the injury to intramural vessels causing interstitial leakage or intramural hemorrhage in more advanced or severe cases of ischemia [1]. Hypoenhancement of the wall can be seen in more advanced ischemia as well [20]; hence, no assessment of stage or severity of ischemia can be done. Comparing the enhancement of the wall to that of the adjacent vessels and remaining bowel is the most common, least subjective, and most reliable practice amongst radiologists [15]. The enhancement pattern has been proved to provide no direct correlation to the pathogenesis and severity of ischemia [8, 11, 12, 18].

The presence of pericolonic fluid as well as mesenteric fat stranding may result as part of the inflammatory response, probably due to congestion, intravascular redistribution, migration of inflammatory cells, and the chemical response of colonic fat to the oxidative stress during ischemia. Fat stranding has been reported in superficial mild and transmural severe colonic ischemia [19]. It may also result from superinfection [5, 21] and therefore is not specific. Correlation between these findings and the pathogenesis and the severity of ischemia has been described in previous reports [3, 22]. In our series, the presence or amount of fat stranding and/or free fluid showed no correlation with the severity of ischemia.

Venous engorgement (VE) represents blood stasis, and it presents with augmented diameter of the venous vessels some

Fig. 5 Segmental involvement distribution of ischemic colitis. Graphic and chart demonstrate the segmental involvement distribution of ischemic colitis



# of segments involved	Total of cases out of multisegmental sample	Most frequent combination of involved segments	Frequency	%
2	42/76 (55.26%)	D-S	18/42	42.85
3	31/76 (40.78%)	T-D-S	7/31	22.58
4	2/76 (2.63%)	D-S-R-C	2/2	100
5	1/76 (1.31%)	HFT-D-S-R	1/1	100

of which demonstrate tortuosity, indicating volume redistribution with a lack of returning blood flow [3]. Venous engorgement does not correlate with the subjacent cause and/or severity of ischemia and can be present before the ischemic process begins. It has been reported to occur along with bowel wall thickening [3], but this was not the case in our series.

Pneumatosis (PN) may manifest with small isolated gas within the wall or have the typical rim aspect. Even though previous studies have shown a high specificity for ischemic colitis, there are many other conditions that can present with pneumatosis, with or without accompanying portal gas, such as infection and inflammation, neoplastic damage, and

overdistension [3, 23, 24]. Intestinal pneumatosis can be an incidental finding in asymptomatic patients and considered a benign condition, but it can also present as a life-threatening emergency with bowel necrosis and obstruction requiring surgical management, most often in the context of an underlying neoplasia, hereby known as malignant pneumatosis. Pneumatosis and portomesenteric venous gas are not only the least common findings in most previous researches on ischemic colitis but also the most specific features for acute bowel ischemia, approaching reported specificities of almost 100 % [22, 24–34]. In our series, pneumatosis was the least frequent CT finding, but the feature with the highest

Fig. 6 Incidence of CT findings in severe ischemic colitis (n=24). Incidence of CT findings in severe ischemic colitis

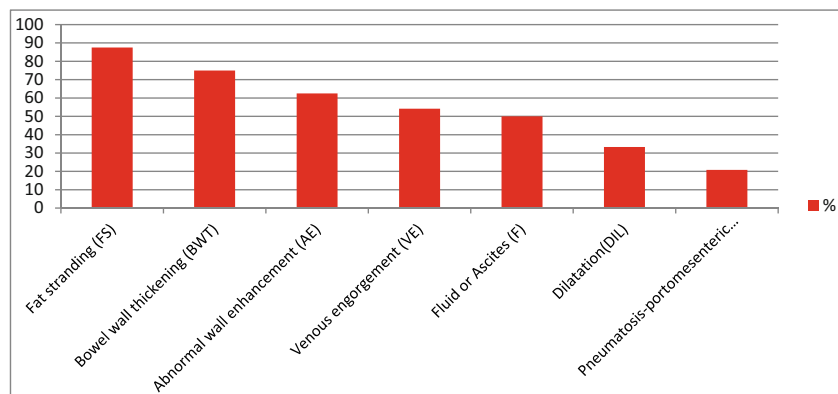


Table 2 Likelihood to correspond with severe ischemia

	Bowel thickening	Dilatation	Abnormal enhancement	Fat stranding	Fluid	Venous engorgement	Pneumatosis
With the characteristic and severe damage	20.88 % (19/91)	45.00 % (9/20)	20.00 % (17/85)	23.33 % (21/90)	38.89 % (14/36)	23.08 % (12/52)	62.50 % (5/8)
Without the characteristic and severe damage	45.45 % (5/11)	18.29 % (15/82)	41.18 % (7/17)	25.00 % (3/12)	15.15 % (10/66)	24.00 % (12/50)	20.21 % (19/94)
Test validity	Not Valid	Valid	Valid	Not Valid	Valid	Valid	Not Valid
<i>p</i> Value	0.0696	0.0116	0.0602	0.8981	0.0069	0.9128	0.0068
Result	Not significant	Significant	Not significant	Not Significant	Significant	Not Significant	Significant

significant probability (62.5 %), and a four times higher risk than the other analyzed findings, of being present in cases of severe ischemic colitis.

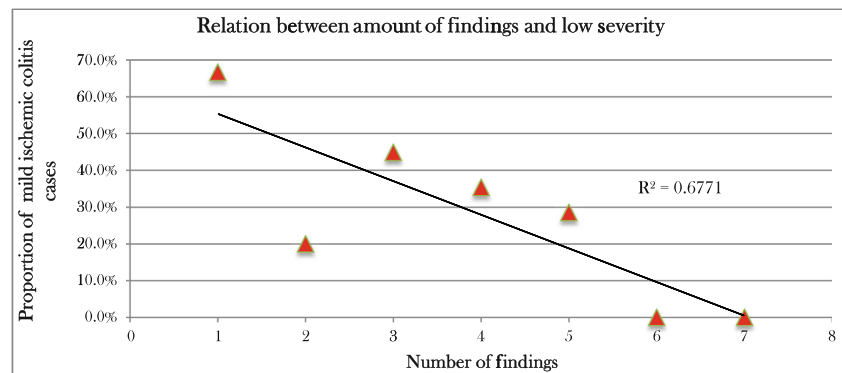
Our findings of segmental over pancolonic involvement in ischemic colitis and predominant involvement of the left colon dominated by the descending and sigmoid segments, support previous reports in the literature [11–13]. The left colon was more frequently involved independent of the severity of ischemia. The large retrospective study of Feuerstadt and Brandt [11] without image correlation of patients with biopsy-proven ischemic colitis showed that a segmental pattern of involvement was seen most commonly [11, 12] and that the sigmoid was affected most often followed by the descending-to-sigmoid colon segment, the cecum-to-hepatic flexure segment, the descending colon alone, and a pancolonic pattern [2, 11].

Rectal involvement is reported to be relatively less frequent than other left-sided segments presumably due to the abundant collateral blood supply found in the pelvis and perineum [3]. Our finding of involvement of the rectum in only 9.8 % of the cases is in keeping with this.

There are two putatively high-risk areas for IC known as “watersheds” in the literature; the sigmoid-rectal junction at

the distal limit of inferior mesenteric artery perfusion, and Griffith’s point at the splenic flexure, representing the junction between blood supplies, from the superior mesenteric artery and the inferior mesenteric artery [13]. We found a high incidence of ischemic findings at the sigmoid-rectal junction with 58 cases (56.9 %) which is consistent with the literature and conventional wisdom [14, 17]. However, we found only 8 out of 102 cases (7.84 %) showing splenic flexure involvement, suggesting that this area is not at risk, perhaps due to good collateral circulation at the junction of the two major arterial supplies, through the marginal artery and its branches. This speaks against the traditional literature and teaching that cite the vulnerability of the blood supply at the splenic flexure. Moreover, there are no previous studies in the literature that report a high incidence of ischemic colitis involvement of the splenic flexure over other segments, either through imaging or through pathological observation [1, 18]. Most of our cases with involvement of SF showed mild injury. A higher incidence of ischemia involving the splenic flexure over other segments has not yet been demonstrated, and medical literature and education should now reflect this observation.

Fig. 7 Correlation between severity and number of findings. Distribution chart shows a correlation between a lower number of findings and mild ischemic colitis



The present study is limited by its retrospective nature and inclusive criteria that do not allow for determination of the specificity and sensitivity of the CT scans for detecting or excluding ischemic colitis. Moreover, the failure to find strong positive or negative correlations between CT findings and severity of involvement by histopathological criteria, with the exception of BWT, DIL, FF, VE, and PN occurring together in a small number of patients, highlights the limited use of CT in trying to segment patients into higher- versus lower-risk groups for ischemic colitis.

The consensus among readers and the nonrandomized selection of the study group limits the generalization of the results. Due to study design and the inclusion criteria, diagnostic accuracy was not assessed. Because consensus among reviewers was used to adjudicate reviewer differences, we were not able to assess interobserver variability in detecting the respective types of findings encountered.

In conclusion, this study showed a female predominance of ischemic colitis. The most frequently observed CT findings in ischemic colitis in our series were fat stranding, wall thickening, and abnormal enhancement seen in colitis of all severity levels. Pneumatosis was a finding suggestive of severe ischemic colitis. Even in the presence of numerous and striking findings, the clinicopathological severity of ischemic colitis cannot be predicted by CT.

A segmental pattern of involvement was shown to be far more common than pancolitis, as well as involvement of the distal colon relative to the proximal colon. Splenic flexure contrary to the conventional literature is not disproportionately involved in ischemic colitis.

Conflict of Interest The authors declare that they have no conflict of interest.

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