Eur Radiol (2004) 14:2347–2356
DOI 10.1007/s00330-004-2462-6



**Walter Wiesner**
**Andreas Hauser**
**Wolfgang Steinbrich**

# Accuracy of multidetector row computed tomography for the diagnosis of acute bowel ischemia in a non-selected study population

Received: 21 April 2004
Revised: 9 July 2004
Accepted: 16 July 2004
Published online: 17 September 2004


W. Wiesner (✉) · A. Hauser
W. Steinbrich
Institute of Diagnostic Radiology,
University Hospital Basel,
Basel, Switzerland
e-mail: walter.wiesner@stephanshorn.ch
Tel.: +41-71-2827557
Fax: +41-71-2827561

W. Wiesner
Medical Radiology Center,
Clinic Stephanshorn,
St. Gallen, Switzerland

**Abstract** The diagnostic accuracy of multidetector row computed tomography for the prospective diagnosis of acute bowel ischemia in the daily clinical routine was analyzed. Two hundred ninety-one consecutive patients with an acute or subacute abdomen, examined by MDCT over a time period of 5 months, were included in the study. All original CT diagnoses made during the daily routine by radiological generalists were compared to the final diagnoses made by using all available medical information from endoscopies, surgical interventions, autopsies and follow-up. Finally, all CT examinations of patients with an initial CT diagnosis or a final diagnosis of bowel ischemia were reread by a radiologist specialized in abdominal imaging in order to analyze the CT findings and the reasons for initially false negative or false positive CT readings. Twenty-four patients out of 291 (8.2%) had acute bowel ischemia. The age of affected patients ranged from 50 to 94 years (mean age: 75.7 years). Eleven patients were male, and 13 female. Reasons for acute bowel ischemia were: arterio-occlusive (*n*=11), non-occlusive (*n*=5), strangulation (*n*=2), over-distension (*n*=3) and radiation (*n*=3). The prospective sensitivity, specificity, PPV and NPV of MDCT for the diagnosis of acute bowel ischemia in the daily routine were 79.17, 98.51, 90.48 and 98.15%. MDCT reaches a similarly high sensitivity in diagnosing acute bowel as angiography. Furthermore, it has the advantage of being helpful in most of its clinical differential diagnoses and of being less invasive with the consecutive possibility of being used earlier in the diagnostic process with all the resulting positive effects on the patients prognosis. Therefore, nowadays MDCT should probably be used as the first step imaging modality of choice in patients with suspected acute bowel ischemia.

**Keywords** Computed tomography · Bowel ischemia · Mesenteric infarction

## Introduction

Acute bowel ischemia is one of the most threatening abdominal emergencies in elderly patients, and this entity has not yet lost its ominous character since it is still associated with a mortality rate of more than 50% [1–5]. Furthermore, acute bowel ischemia is an often underestimated and not recognized reason for acute abdomen in our daily routine, and this especially since, according to the literature, it represents only about 1% of all cases of an acute abdomen [3]. However, in subspecialized fields of medicine, this percentage may be significantly higher, and with the increase of average life expectancy and the increasing prevalence of cardiovascular diseases in the western world, acute bowel ischemia is becoming more and more common [3, 4]. So, for instance, ischemic colitis is already known to be the most common type of colitis in patients older than 50 years, and acute bowel ischemia is responsible for about 5% of deaths in the USA year by year, causing more deaths than colonic cancer [3, 4].

Acute bowel ischemia has a wide range of possible clinical and pathological presentations since it can be caused by a variety of different conditions and presents with various clinical and radiological findings [1–5]. Therefore, it may easily be missed or misinterpreted initially, and the broad spectrum of acute bowel ischemia, which ranges from mild and generally transient, clinically often inapparent, superficial changes of the intestinal mucosa to more dangerous and potentially life-threatening, transmural necrosis of the bowel wall, may explain why the clinical diagnosis of acute bowel ischemia has remained quite challenging.

For these reasons, it is obvious why radiology has become so important since the 1960s and 70s, and the upcoming catheter angiography, a modality that has a sensitivity of up to 87% in diagnosing this disease, has evolved into the imaging modality of choice in acute bowel ischemia over the past 20 years [6].

However, angiography will usually not contribute to reaching the correct differential diagnoses of acute bowel ischemia, and furthermore, angiography is an invasive procedure that it is often performed quite late in the diagnostic process—at a time when other differential diagnoses are excluded and when clinical suspicion of acute bowel ischemia is supported by more specific clinical and laboratory findings. However, this delay in diagnosis and onset of appropriate treatment may result in a fatal decrease of the patient's chances to survive.

Therefore, there is an obvious need for a diagnostic tool that shows a comparably high sensitivity in the detection of acute bowel ischemia as angiography, but with the advantages of being able to diagnose potential differential diagnoses with a similar accuracy and of being used early in the diagnostic process in order to influence positively the patients prognosis. Multidetector row computed tomography (MDCT) has shown over the past years that it is able to provide very exact information about the parenchymatous organs of the abdomen, the intestinal structures and the mesenteric vasculature as well, and by combining all this information, MDCT might be the ideal first step imaging approach in patients with acute bowel ischemia.

For this reason, the present study was initiated in order to analyze the diagnostic accuracy of MDCT in the prospective diagnosis of acute bowel ischemia, to compare it to the results of angiography from the literature and to discuss if MDCT can be regarded nowadays as the first pass imaging modality of choice in patients with acute bowel ischemia.

## Patients and methods

Out of a total of 910 consecutive abdominal MDCT examinations performed over a time period of 5 months, all cases in which CT was performed for high suspicion for urolithiasis (urolith CT) and all CT examinations performed for already known diseases, follow-up examinations or reevaluation of formerly diagnosed illnesses ($n$=604) were excluded. The remaining 304 consecutive patients, who were all examined for an acute or subacute abdomen, were included into our study. In 15 cases the clinical or follow-up information was insufficient or impossible, and these patients had to be excluded. The remaining 291 built our final study population.

All CTs were read in our normal daily clinical routine by a board-certified radiologist who was usually not subspecialized in abdominal radiology. No focused radiological search for bowel ischemia was performed, and the radiologists were not influenced at all because they did not know that the study was being performed. In a second step, the initial radiological CT diagnoses made during our daily routine by radiologists who were usually not specialized in abdominal imaging as well as the final diagnoses made by using all available medical information from patient follow-ups, endoscopies, surgical interventions or autopsies were compared in order to analyze the sensitivity and specificity and the positive and negative predictive value of MDCT for the prospective diagnosis of acute bowel ischemia in the daily routine.

All patients were examined in a four-row detector CT scanner (Volume Zoom, Siemens, Erlangen, Germany). The clinical constellation and the initially suspected clinical diagnosis were not uniform in our study population, and, therefore, the used examination protocols varied minimally from patient to patient. Not every patient could drink the same amount of positive oral contrast, for example, and only those patients received positive rectal contrast whose abdominal complaints were located in the lower abdomen. However, if abdominal symptoms were located more in other abdominal regions, rectal contrast administration was not performed regularly. Bolus tracking was not applied since in these routine cases the abdomen was scanned regularly during a portal venous phase, starting 70 s after the start of contrast injection. Intravenous contrast application was performed with a flow rate of 2 ml/s and with a total volume of 100–120 ml. Collimation/table feed was 4×2.5/10, and reconstructed slice thickness was 3 mm. Arterial phase scanning was not performed regularly in these routine cases if there was no more specific clinical demand for it. However, four patients additionally underwent prior unenhanced CT scanning and arterial phase CT scanning according to the fact that acute bowel ischemia was suspected clinically. Prospective CT reading was regularly performed by using soft tissue windows. However, because reading was done on work stations, the readers could also use other window settings, for example, lung windows in cases with pneumatosis and/or portal venous gas, and 2D reconstructions were therefore also used on a regular basis.

Based on all available medical information, the age distribution of patients with acute bowel ischemia in our study population, the most probable etiology of bowel ischemia in every patient, the mortality as well as the localization, the extent and the severity of bowel ischemia were analyzed. Finally, all CTs of patients with an initial CT diagnosis or a final diagnosis of bowel ischemia were reread by a radiologist specialized into abdominal imaging in order to analyze the CT findings and the main reasons for initially false negative or false positive CT readings.

## Results

Out of all 291 consecutive patients who underwent abdominal MDCT for an acute or subacute abdomen over a time period of 5 months, 24 (8.2%) turned out to have acute bowel ischemia. The final diagnoses made in the remaining 267 patients are listed in Tables 1, 2.

**Table 1** Schematic presentation of diagnoses among 291 patients with acute/subacute and/or unclear abdomen examined by MDCT over a time period of 5 months

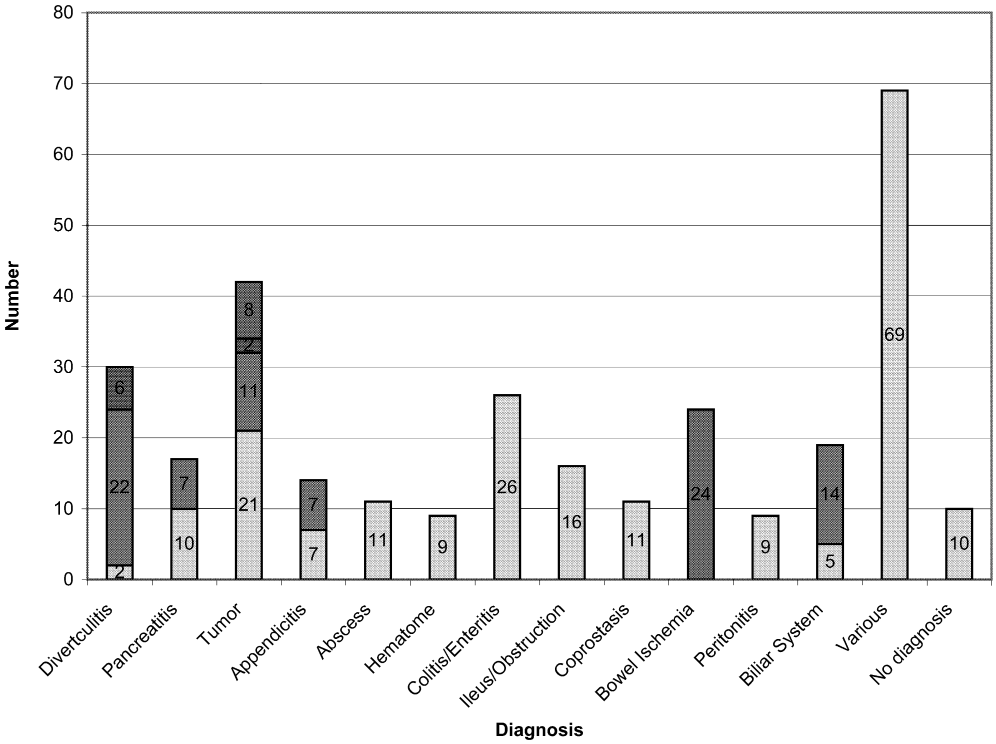


**Table 2** Distribution of diagnoses among 291 patients included into the study

| | | |
|---|---|---|
| Diverticulitis with abscess | 2 | |
| Diverticulitis without abscess | 22 | |
| Diverticulitis with perforation | 6 | |
| Acute pancreatitis | 10 | |
| Chronic pancreatitis | 7 | |
| Tumor (new) upper abdomen | 21 | |
| Tumor (new) lower abdomen | 11 | |
| Tumor recurrence | 2 | |
| Metastasis | 8 | |
| Appendicitis with perforation | 7 | |
| Appendicitis | 7 | |
| Haematoma | 9 | |
| Abscess | 11 | |
| Colitis/enteritis | 26 | (infectious, Crohn's disease, ulcerous colitis) |
| Coprostasis/meteorism | 11 | |
| Ileus/stenosis | 16 | |
| Bowel ischemia | 24 | |
| Peritonitis | 9 | |
| Cholelithiasis | 5 | |
| Cholangitis/cholecystitis | 14 | |
| Various | 69 | (cirrhosis, lympocele, pyelonephritis, hemorrhoids, hernia, diverticulosis, gastral erosions, ulcers, aneurysma, pneumonia, arteritis temporalis, thrombosis) |
| No diagnosis | 10 | |

The age of our patients with bowel ischemia ranged from 50 to 94 years with a mean age of 75.7 years. Eleven patients with bowel ischemia were male, 13 were female. Causes for acute bowel ischemia were: strangulation ($n$=2), arterio-occlusive factors ($n$=11), non-occlusive factors ($n$=5), distension ($n$=3) and radiation ($n$=3) [(compare to Table 3)].

Bowel ischemia was located in the small bowel in 11 cases, in the large bowel in 12 cases, in the cecum in 5 cases and in the rectum in 2 cases. In one patient, colon, cecum and small bowel were affected; in three cases there was involvement of the colon and cecum, and in another of small bowel and cecum, explaining why 30 regions were affected in 24 patients. In the small bowel four cases represented partial mural and seven cases transmural ischemia, whereas in the large bowel only two cases showed partial mural and ten cases transmural changes. Four out of five cases of cecal ischemia were transmural, whereas both cases of rectal ischemia were only partially mural. Seven patients died (29.2%), and although their overall health condition was often critical, their cause of death could mainly be attributed to bowel ischemia.

Imaging findings in these 24 patients with bowel ischemia consisted of wall thickening ($n$=21), mesenteric stranding and/or little mesenteric fluid ($n$=21), pneumatosis ($n$=8) and portal venous gas ($n$=2) [(Fig. 1, 2, 3, 4, 5, 6, 7). Occlusions of mesenteric arteries were found in 11 patients and consisted of five atherosclerotic occlu-

**Table 3** Findings in 24 patients with all different types of acute bowel ischemia

| Age | Sex | Ischemia | Extension | Radiological findings | Clinical context | Therapy/prognosis | Pathogenesis |
|---|---|---|---|---|---|---|---|
| 45 | M | Small bowel | PM | Pneumatosis, portal venous gas, ascites (due to cirrhosis) | Hemodynamic instability, clin. confirmation (shock bowel) | Conservative | Non-occlusive |
| 72 | F | Sigmoid colon | TM | Wall thickening, mes. stranding | Surgical confirmation | Laparotomy, resection | Non-occlusive |
| 50 | M | Cecum, colon | TM | Wall thickening, mes. stranding, bowel dilatation | Surgical confirmation | Ileocoecal resection | Non-occlusive |
| 86 | M | Small bowel | PM | Wall thickening, mes. stranding, pathological cm-enhancement | Surgical confirmation | Laparatomy, resection | Non-occlusive |
| 90 | F | Descending colon | PM | Mild wall thickening, contraction, mild stranding missed due to contraction | Recurrence of ischemic colitis | Conservative | Non-occlusive |
| 82 | F | Cecum | PM | Very mild but significant wall thickening in massive dilatation missed due to minimal wall thickening | Surgical confirmation (secondary to stenosing sigmoid diverticulitis) | Sigmoid resection | Distension |
| 77 | F | Sigmoid colon | TM | Wall thickening, mesenteric stranding | Surgical confirmation | Left hemicolectomy | Arterio occlusive |
| 74 | M | Sigmoid colon | TM + Perf. | Wall thickening, mes. stranding, pneumatosis misinterpreted as infectious despite pneumatosis | Inflammatory parameters high, surgical confirmation | Total colectomy deceased | Arterio occlusive |
| 73 | M | Small bowel | TM | Dilatation, no wall thickening, no stranding, missed due to absence of bowel wall thickening | Acute abdomen following coro-narography, surgical confirmation | Small bowel resection deceased | Arterio occlusive |
| 78 | M | Small bowel | PM | Enhancement, wall thickening, stranding, fluid | Radiation | Conservative | Radiation |
| 72 | F | Colon and cecum | TM | Pneumatosis, wall thickening, stranding, Ileus | Postmortem histological confirmation | Conservative due to bad state, *deceased* | Arterio occlusive |
| 92 | F | Small bowel | TM | Dilatation, wall thickening | Postmortem histological confirmation | Conservative, *deceased* | Arterio occlusive |
| 81 | F | Colon | TM | Pneumatosis, wall thickening, stranding | Surgical confirmation | Right hemicolectomy | Arterio occlusive |
| 55 | M | Cecum and ascending colon | TM | Dilatation, pneumatosis, strangulated transverse colon | Surgical confirmation (secondary to herniation of transverse colon) | Right hemicolectomy | Distension |
| 68 | F | Small bowel | PM | Herniation of small bowel loop, wall thickening | Surgical confirmation | Surgical intervention due to incarcerated hernia | Strangulation |
| 72 | F | Small bowel and colon | TM + Perf. | Dilatation (sb), pneumatosis, wall thick (lb) | Surgical confirmation | Small bowel and large bowel resection | Arterio occlusive |

**Table 3** (continued)

| Age | Sex | Ischemia | Extension | Radiological findings | Clinical context | Therapy/prognosis | Pathogenesis |
|---|---|---|---|---|---|---|---|
| 65 | M | Rectum | PM | Wall thickening, stranding | Rectoscopic confirmation | Conservative | Radiation |
| 72 | M | Cecum | PM | Pneumatosis intestinalis | Surgical confirmation (sec. to stenos. pseudotumor of the sigmoid) | Sigmoidectomy | Distension |
| 79 | F | Rectosigmoid | PM | Wall thickening, stranding | Radiation | Conservative | Radiation |
| 86 | F | Small bowel | TM | Dilatation, wall thickening, stranding, signs of volvulus | Surgical confirmation (strangulation) | Resection, *deceased* | Strangulation |
| 94 | F | Small bowel | TM | Stranding, mesenteric fluid, no wall thickening | Surgical confirmation | Resection | Arterio occlusive |
| 77 | M | Transverse and sigmoid colon | TM | Mesenteric venous gas, no pneumatosis, wall thickening | Surgical confirmation | Left hemicolectomy, deceased | Arterio occlusive |
| 64 | F | Cecum | TM | Strong cecal wall thickening, stranding misinterpreted as cecal tumor | Surgical confirmation | Right hemicolectomy | Arterio occlusive |
| 82 | M | Sigmoid colon | TM | Wall thickening, stranding, pneumatosis, splenic infarctions | | Due to bad state no surgical intervention, deceased | Arterio occlusive |

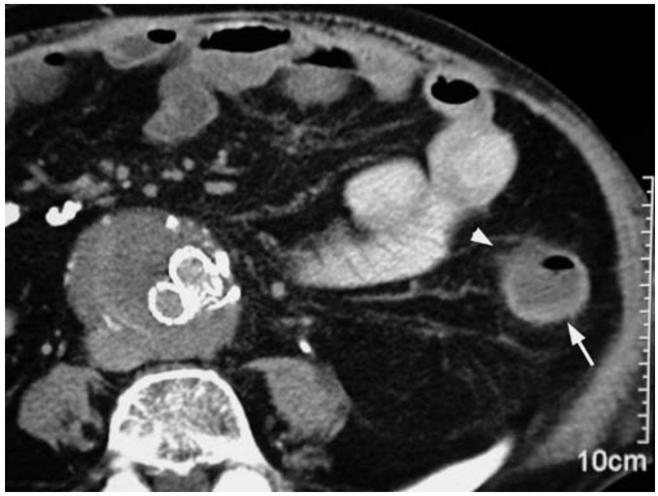


**Fig. 1** Ischemic colitis of the descending colon following aortoiliac stent implantation. CT shows mild wall thickening of the descending colon (*arrow*) with minimal paracolic stranding (*arrowhead*)—a finding that might be missed in contracted colonic segments

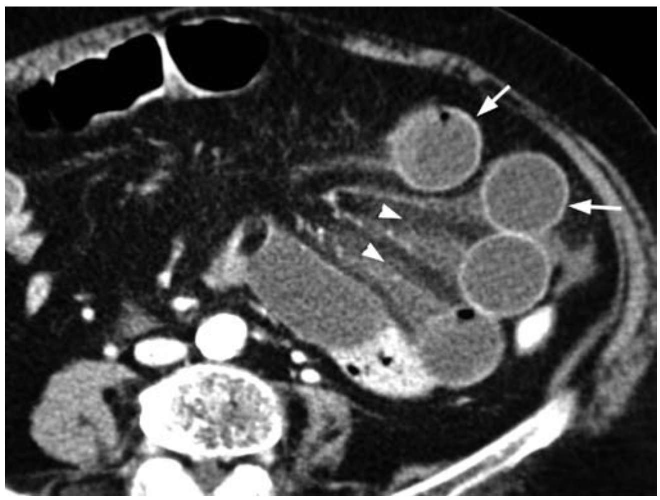

**Fig. 2** Strangulation ischemia of the small bowel due to adhesions. CT shows mild wall thickening (*arrows*) and mesenteric fat stranding (*arrowheads*). However, these findings are not absolutely specific for ischemia since they may be observed already in cases in which they represent only bowel wall edema resulting from venous congestion

sions or high grade stenoses, two proximal thrombotic occlusions, two embolic vascular occlusions (one with associated splenic infarction) and two iatrogenic occlusion of the inferior mesenteric artery following aortic y-graft and bilateral aortoiliacal stent implantation, respectively (Figs. 1, 8, 9).

The sensitivity of MDCT for the diagnosis of acute bowel ischemia was 79.17% if only the first prospective radiological diagnosis was counted. However, if the first

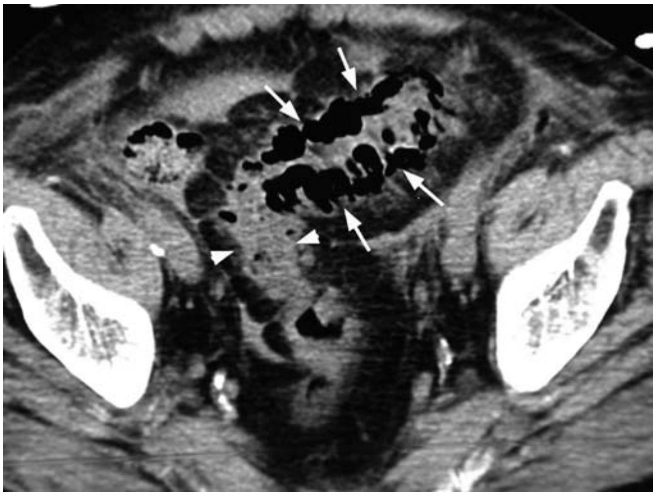

**Fig. 3** Sigmoid infarction. CT shows only mild wall thickening (*arrowheads*), but pronounced pneumatosis of the sigmoid colon (*arrows*)—a finding that must raise the suspicion of ischemia or infarction

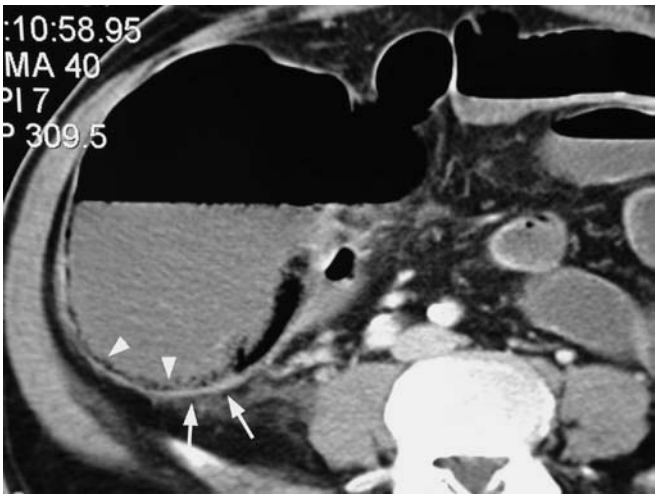


**Fig. 4** Distension colitis of the cecum in distal large bowel obstruction. CT shows only minimal, but according to the degree of distension clearly pathological, wall thickening (*arrows*) that may be missed if the wall thickness of the cecum is not set into relation to the local luminal distension. Note also minimal pneumatosis along the posterior cecal wall (*arrowheads*)

reading led to radiological differential diagnoses and if up to three of these radiological differential diagnoses were also included in our analysis, the sensitivity of MDCT was raised to 83.33%. If only the first radiological diagnosis was taken into account, specificity was 98.51%, PPV was 90.48% and NPV was 98.15%. If there were radiological differential diagnoses and if up to three of them were included in our analysis, specificity was 96.66%, PPV 68.97% and NPV 98.47% (compare to Table 4).

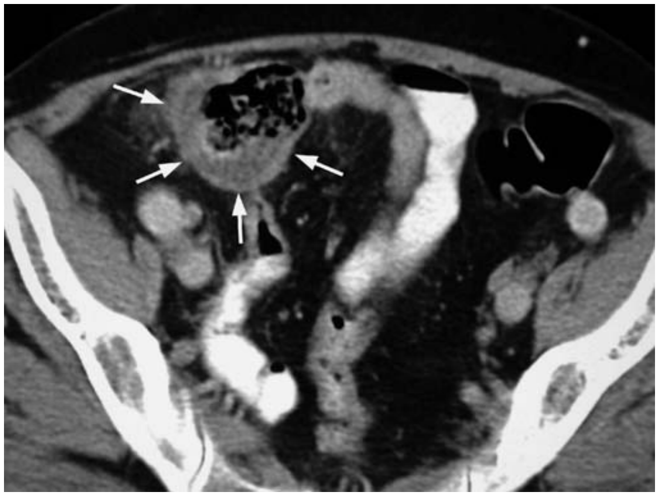

**Fig. 5** Isolated cecal infarction. CT shows pronounced eccentric cecal wall thickening (*arrows*) that may easily be misinterpreted as a neoplastic pathology if ignoring the clinical constellation

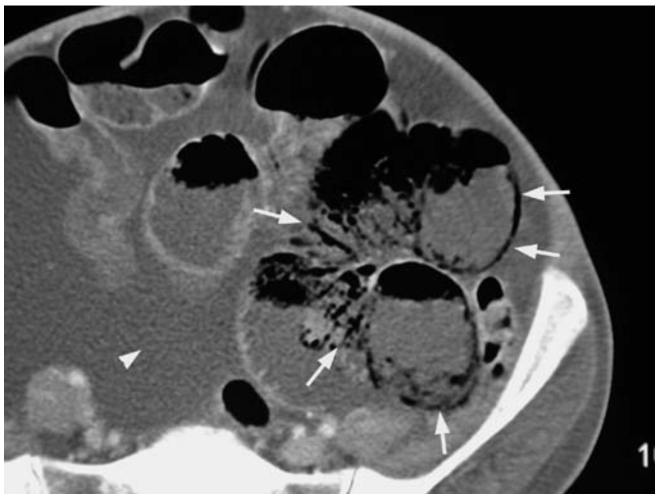

**Fig. 6** Pneumatosis in small bowel infarction. CT shows multiple linear gaseous inclusions in the wall of multiple small bowel loops (*arrows*). A highly specific finding in bowel ischemia. Note: ascites (*arrowhead*) were related to severe liver cirrhosis in this particular case

**Table 4** Results regarding sensitivity, specificity, NPV and PPV of 1st and 2nd MDCT reading by board-certified radiologist not specialized in abdominal imaging

| | Only one dg. | | Up to three DDs | |
|---|---|---|---|---|
| | No BI | BI | No BI | BI |
| Radiological positive | 2 | 19 | 9 | 20 |
| Radiological negative | 265 | 5 | 258 | 4 |
| Sensitivity/specificity | 79.17/98.51% | | 83.33/96.66% | |
| PPV/NPV | 90.48/98.15% | | 68.97 /98.47% | |


**Fig. 7** Isolated arterio-occlusive small bowel infarction. CT shows no or only minimal wall thickening of the infarcted and consecutively dilated small bowel loops with air-fluid levels. Cases like this may easily be misinterpreted as mechanical small bowel obstruction by CT if ignoring the clinical constellation and as long as there are not more specific CT findings

**Fig. 9** Sclerotic stenoses of the superior mesenteric artery. Sagittal reconstruction of MDCT (maximum intensity projection) nicely shows several sclerotic plaques at the origin and along the proximal superior mesenteric artery (*arrows*) and a severely calcified infrarenal aorta

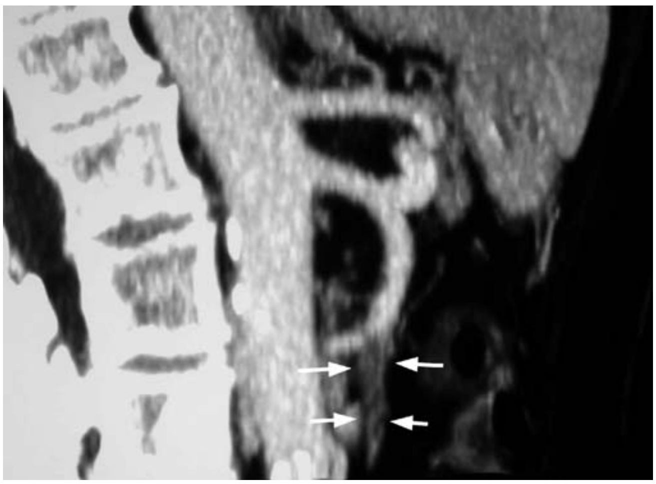

**Fig. 8** Thrombembolic occlusion of the superior mesenteric artery. Sagittal reconstruction by MDCT (maximum intensity projection) nicely shows the intraluminal filling defect (*arrows*)

The initial CT diagnosis was false negative in five cases if only the first diagnosis of the reader was counted. Two of these cases represented ischemic colitis, and one of them was missed in the initial reading mainly according to the fact that the ischemic colonic segment was contracted and wall thickening therefore not perceived. In the second case, CT findings were misinterpreted as infectious colitis in the first diagnosis, and ischemic colitis was only included among the radiological differential diagnoses despite the presence of pneumatosis (Fig. 3). The third false negative case represented ischemic distension colitis of the cecum (caused by a distal high grade stenosis of the sigmoid colon) and was missed in the initial reading since the wall of the massively distended cecum measured only 4 mm (Fig. 4). The fourth false negative case represented an acute isolated small bowel infarction that presented with several distended small bowel loops with only minimal bowel wall thickening and without visible changes at the mesenteric vessels (Fig. 7). The fifth false negative case represented isolated cecal infarction, and here the findings were not missed, but misinterpreted since CT showed pronounced eccentric wall thickening of the cecum. The findings were therefore thought to be caused by neoplastic changes (Fig. 5).

False positive CT diagnoses included the following: in two patients CT findings were consistent with a colitis, and in both cases the localization (descending colon) as well as the advanced age of the patient were the most important factors why ischemic colitis was mentioned as first radiological diagnosis. However, finally both cases turned out to represent ulcerous and infectious colitis, respectively. In four additional patients in whom CT showed large bowel wall thickening as well, ulcerous/infectious colitis was correctly diagnosed by CT although ischemic colitis had been included in the radiological differential diagnosis in these four cases.

In three patients with mechanical small bowel obstruction who showed some edema of their small bowel walls and some mesenteric stranding, small bowel ischemia was included in the radiological differential diagnosis as a potential coexisting finding, but surgery revealed only bowel wall edema resulting from venous congestion and no signs of bowel ischemia.

## Discussion

Since the mid 1980s a quite impressive number of publications have appeared on the role of CT in bowel ischemia and infarction [7–21]. While the sensitivity of CT was still poor in the late 1980s, ranging around 39%, it increased significantly over the following years, and the only study we are aware of that compared the sensitivity of CT and angiography directly showed that the sensitivity of CT (82%) had almost reached the sensitivity of angiography (87%) already in 1995 [6]. However, this particular study included a control group that was even smaller than the group of patients with bowel ischemia, and furthermore, all studies on CT and bowel ischemia that have been published until the present have been conducted as retrospective reviews of patients with known bowel ischemia. Therefore, the diagnostic accuracy of CT, and especially of MDCT, including not only sensitivity but also specificity, as well as positive and negative predictive values, have not yet been evaluated in the prospective diagnosis of acute bowel ischemia in the daily routine and especially in a non-preselected study population.

The etiologies of acute bowel ischemia are diverse and range from occlusion of arteries or veins to low flow states and intestinal over-distension. Although occlusive conditions still account for the majority of cases of acute bowel ischemia, non-occlusive bowel ischemia has become more and more common with the increasing life expectancy in the western world and probably also because of better monitoring of intensive care patients. Nevertheless, although major progress has been made in the therapy of patients with acute bowel ischemia regarding early corrections of hemodynamic abnormalities and electrolyte imbalances, prophylactic antibioc treatment or protection of reperfusion injury, the basic therapy of bowel infarction—surgical resection—has not changed over the past decades. This, together with the fact that most prognostic factors of bowel ischemia cannot be influenced may explain why the mortality of acute bowel ischemia has not dropped significantly over the past decades. The prognosis of acute bowel ischemia depends on the cause, severity and extension of the intestinal damage as well as on the presence of certain complications. However, these factors are given, and the only factor that may influence the prognosis of affected patients is the early onset of the correct diagnosis and therapy.

Until the present, angiography has been regarded as the imaging modality of choice and gold standard in clinically suspected acute bowel ischemia. However, angiography is not helpful in diagnosing or excluding other reasons for an acute abdomen, and according to this and the fact that it is an invasive procedure, it is usually used quite late in the diagnostic process. This often leads to a potentially fatal delay in diagnosis and therapy for the patients, whereas CT has the advantage of being able to cover a much broader spectrum of potential differential diagnoses of an acute abdomen and to diagnose ischemic and non-ischemic reasons for an acute abdomen with a similarly high accuracy early in the diagnostic process.

Acute bowel ischemia is quite common in the western world, and while it is said to be responsible for about 1% of all acute abdomens, its relative frequency in subspecialized fields of medicine may be significantly higher [1–5]. This is again shown by our study in which 8.2% of all our patients had some type of acute bowel ischemia. This high number might be explained partially by the fact that our clinic is a major diagnostic health center with a relatively high percentage of severe cases. On the other hand, in our clinic there is a strong gastroenterology department, and this prevented many patients with only mild and superficial ischemic colitis to be examined by CT. This also explains why the relative number of cases with partial mural large bowel ischemia (superficial and reversible ischemic colitis) was relatively small in our study population compared to those cases with transmural colonic ischemia (large bowel infarction).

Our results indicate that the overall sensitivity of CT in the detection of acute bowel ischemia is comparable to that of angiography, although it suggests that CT will not have the same sensitivity in detecting distal vascular occlusions of the very small mesenteric arteries. However, this seems to be well compensated by the fact that—in contrast to angiography—CT is able to show the pathologic changes at the intestine as well as possible complications of bowel ischemia directly and that CT is additionally able to diagnose various non-occlusive types of bowel ischemia as, for example, transient ischemic colitis and distension colitis with a similarly high accuracy as, for example, more rare types of bowel ischemia such as ischemic proctosigmoiditis or isolated cecal infarction [19, 20].

Nevertheless, false negative or false positive diagnoses are certainly possible using CT, and here one should differentiate between cases that are missed and cases that are primarily misinterpreted.

False positive cases typically occur as a result of misinterpretation of other types of colitis (for example, infectious or ulcerous colitis)—especially when affecting the left colon in elderly patients and also in patients with complicated small bowel obstruction since in the latter bowel wall thickening and mesenteric stranding are typically found already in cases with venous congestion and not only in strangulation-related bowel ischemia. They therefore do not allow CT differentiation as long as more specific findings such pneumatosis or portal venous gas are absent [22, 23].

Another quite typical example of a false negative CT diagnosis is to miss ischemic colitis in contracted colonic segments and, therefore, rectal instillation of water or contrast prior to the CT examination is generally recommended [18]. Furthermore, ischemic distension colitis of the cecum (caused by a distal high grade colonic stenosis) may also be missed at first sight because the wall of the dilated cecum usually measures less than 5 mm under such circumstances—a measure that is generally accepted as the upper limit of a normal colonic wall thickness at CT. However, it is well known that the wall thickness of the colon at CT stays in clear relation to the luminal distension and, therefore, such cases will usually be correctly interpreted if the reader sets the wall thickness of the cecum in relation to its luminal distension [24].

A false negative CT diagnosis in isolated cecal infarction on the other hand quite typically results from misinterpretation and not from missing the CT findings since the pronounced cecal wall thickening may often resemble tumorous or infectious wall thickening in these cases. However, under such circumstances, knowledge of this entity and proper clinical information about acute right lower abdominal quadrant pain will usually allow the radiologist to make the correct diagnosis [19].

Another very important example of a potentially false negative CT diagnosis is found in patients with peracute isolated arterio-occlusive small bowel infarction. This entity typically shows no or only minimal bowel wall thickening at CT. Therefore, it may easily be missed by CT as long as more specific findings such as pneumatosis or portal venous gas are absent and as long the mesenteric arterial occlusions are located too far distally to be detected by CT [18, 21]. In such cases, the absence of bowel wall enhancement may be the only characteristic early CT finding.

However, as shown by one of our cases with large bowel infarction that was missed despite the presence of pneumatosis, the limiting factor may also be the radiologist, who sometimes just does not perceive characteristic CT findings that would allow making the right diagnosis.

In our false positive cases (where seven out of nine cases were only included in the differential diagnosis), endoscopy or surgery finally could exclude ischemic colitis and complicated small bowel obstruction, respectively. Although the initial CT diagnosis was false positive for bowel ischemia in these cases, CT was nevertheless helpful for decision making regarding the further patient management and did not negatively influence the diagnostic or therapeutic approach or the patient's clinical course.

In three of our five false negative cases, the patient's clinical course was not negatively influenced by the CT diagnosis either, since one case of ischemic colitis that was missed initially by CT was finally found during endoscopy, and distension ischemia of the cecum as well as isolated cecal infarction were both found during laparotomy, which both were initiated by the CT findings. Nevertheless, in one patient in whom the characteristic CT findings of colonic infarction (pneumatosis) were missed and in another patient with small bowel infarction in whom CT showed no abnormal findings, the false negative CT diagnoses contributed to a fatal follow-up. Both patients died several days later, although the correct diagnosis was finally made intraoperatively and by angiography, respectively, and in these two cases the most important negative prognostic factor was presumably the time delay that was mainly caused by an initial false negative CT reading.

Our results show that MDCT has a prospective sensitivity of 80% in diagnosing acute bowel ischemia in the daily routine and that its overall sensitivity is therefore comparable to that of angiography. Furthermore, MDCT has an overall very high diagnostic accuracy for acute bowel ischemia and its clinical differential diagnoses together with the advantage of being a non-invasive examination that may be used early in the diagnostic process with all its positive effects on the patient's prognosis.

One may speculate if the results of our study would have been even a little bit better if we had included CT angiographies in our regular CT examination protocol because probably more vascular pathologies would have been detected [25]. Furthermore, one may argue that the diagnostic accuracy of MDCT might have been even higher in our study if the initial CT reading had been performed by radiologists subspecialized in abdominal radiology since at least one of the two cases with an initially missed ischemic colitis as well as the case with a missed distension colitis of the cecum and finally also the case with a misinterpreted cecal infarction most probably would have been correctly interpreted by a reader who is more familiar with these entities. Therefore, one may ask why we chose this particular study design, why our cases were not preselected, examined by a more optimal CT protocol, and why our cases were not just read retrospectively in a blinded fashion. However, in many European countries, subspecialization of radiologists is not as common as in the United States, and results from the daily routine of radiological generalists surely provide much more useful information regarding the true diagnostic value of a method than retrospective studies in which subspecialized readers know exactly what to focus on, even if blinded. However, this question must be answered by future studies.

Nevertheless, abdominal specialists and radiological generalists must be aware of the potential pitfalls of CT. Although radiological subspecialization into abdominal imaging might prevent false negative CT readings in many cases, it is obvious that especially those patients with an acute or even peracute isolated arterio-occlusive small bowel ischemia, in whom bowel wall thickening, mesenteric stranding, pneumatosis or portal venous gas are absent, and in whom the occlusions of mesenteric arteries are located too far distally to be detected by CT, may easily be missed by this modality and therefore still require angiography.

Nevertheless, in the vast majority of cases of acute bowel ischemia, there are fortunately enough additional CT findings that allow even radiological generalists to suspect the correct diagnosis prospectively. Therefore, MDCT should probably be used as the first step imaging modality of choice in cases with clinical suspicion of acute bowel ischemia in order to provide an early radiological one-step diagnosis for various ischemic and non-ischemic acute abdominal conditions. Only this can avoid an unnecessary delay in diagnosis and therapy of those patients with acute bowel ischemia in whom MDCT would already provide the correct diagnosis.

## References


1. Jrven O, Laurika J, Salenius JP, Tarkka M (1994) Acute intestinal ischemia. A review of 214 cases. Ann Chir Gynaecol 83:22–25
2. Bastidas J, Reilly PM, Bulkley GB (1995) Mesenteric vascular insufficiency. In: Yamada T (ed) Textbook of gastroenterology, 2nd edn. Lippincott, Philadelphia, pp 2490–2523
3. 3. Levine JS, Jacobson ED (1995) Intestinal ischemic disorders. Dig Dis 13:3–24
4. Brandt LJ, Boley SJ (1993) Ischemic and vascular lesions of the bowel. In: Sleisenger M, Fordtran J (eds) Gastrointestinal disease, 5th edn, vol 2. Saunders, Philadelphia, pp 1927–1961
5. Ruotolo RA, Evans SRT (1999) Mesenteric ischemia in the elderly. Gastroenterology 15:527–557
6. Klein HM, Lensing R, Klosterhalfen B, Toens C, Guenther RW (1995) Diagnostic imaging of mesenteric infarction. Radiology 197:79–82
7. Federle MP, Chun G, Jeffrey RB, Rayor R (1984) Computed tomographic findings in bowel infarction. Am J Roentgenol 142:91–95
8. Clark RA (1987) Computed tomography of bowel infarction. J Comput Assist Tomogr 11:757
9. Balthazar EJ, Hulnick D, Megibow AJ, Opulencia JF (1987) Computed tomography of intestinal hemorrhage and bowel ischemia. J Comput Assist Tomogr 11:67–72
10. Alpern MB, Glazer G, Francis IR (1988) Ischemic or infarcted bowel: CT findings. Radiology 166:149–152
11. Lund EC, Han SY, Holley HC et al (1988) Intestinal ischemia: comparison of plain radiographic and computed tomographic findings. Radiographics 8:1083
12. Perez C, Lauger J, Puig J et al (1989) Computed tomographic findings in bowel ischemia. Gastrointest Radiol 14:241
13. Smerud MJ, Johnson CD, Stephens DH (1990) Diagnosis of bowel infarction: a comparison of plain films and CT scans in 23 cases. Am J Roentgenol 154:99–103
14. Taourel PG, Deneuville M, Pradel JA, Regent D, Bruel JM (1996) Acute mesenteric ischemia: diagnosis with contrast enhanced CT. Radiology 199:632–636
15. Bartnicke BJ, Balfe DM (1994) CT appearance of intstinal ischemia and intramural hemorrhage. Radiol Clin North Am 32:845–860
16. Ha HK, Rha SE, Kim AY, Auh YH (2000) CT and MR diagnosis of intestinal ischemia. Semin Ultrasound CT MR 21:40–55
17. Balthazar EJ, Yen BC, Gordon RB (1999) Ischemic colitis: CT evaluation of 54 cases. Radiology 211:381–388
18. Wiesner W, Khurana B, Ji H, Ros PR (2003) CT of acute bowel ischemia. Radiology. 226:635–650
19. Wiesner W, Khurana B, Glickman J, Ji H, Ros PR (2002) “Cecal gangrene”: a rare cause of right-sided inferior abdominal quadrant pain, fever and lecokocytosis. Emerg Radiol 9:292–295
20. Wiesner W, Mortele KJ, Glickman JN, Ji H, Khurana B, Ros PR (2002) CT findings in isolated ischemic proctosigmoiditis. Eur Radiol 12:1762–1767
21. Wiesner W, Mortele KJ, Glickman J, Ji H, Ros PR (2001) Pneumatosis intestinalis and portomesenteric venous gas in mesenteric ischemia: correlation of CT findings with severity of ischemia and clinical outcome. Am J Roentgenol 177:1319–1323
22. Horton KM, Corl FM, Fishman EK (2000) CT evaluation of the colon: inflammatory disease. Radiographics 20:399–418
23. Zalcman M, Sy M, Donckier V, Closset J, Van Gansbeke D (2000) Helical CT signs in the diagnosis of intestinal ischemia in small bowel obstruction. Am J Roentgenol 175:1601–1607
24. Wiesner W, Mortele KJ, Ji H, Ros PR (2002) Normal colonic wall thickness at CT and its relation to colonic distension. J Comput Assist Tomogr 26:102–106
25. Fleischmann (2004) MDCT of renal and mesenteric vessels. Eur Rad 13(Suppl 5):94–1001