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ORIGINAL ARTICLE

Diagnosis of Acute Bowel Ischaemia: Which Computed Tomography Finding Should We Trust?

VYK To[1], WL Poon[2], CY Lee[1], WS Wan[1]

[1]Department of Radiology, Tuen Mun Hospital, Tuen Mun, Hong Kong; and [2]Department of Radiology, Queen Elizabeth Hospital, Jordan, Hong Kong

ABSTRACT

Objective: *To determine which computed tomography (CT) findings correlate most with acute bowel ischaemia.*

Methods: *This cross-sectional study included patients attending the Tuen Mun Hospital, Hong Kong between July 2005 and July 2011 who fulfilled one of the following criteria: (1) had undergone CT abdomen for clinical suspicion of bowel ischaemia, (2) CT showed evidence of bowel ischaemia with or without clinical suspicion, or (3) had operative findings of bowel ischaemia and had undergone CT previously. All CT images were reviewed independently by three radiologists who were blinded to the clinical outcome. Six specific CT findings including mural thickness, bowel dilatation, mural enhancement, pneumatosis intestinalis, portal or mesenteric venous gas, and superior mesenteric artery or venous (SMA/SMV) occlusion were documented. Binary logistic regression and adjusted odds ratio were used for statistical analysis. Intraclass correlation coefficient was calculated to determine the interobserver agreement among the three radiologists. The sensitivity, specificity, and positive predictive values were determined.*

Results: *A total of 148 patients were included, of whom 28 were excluded due to death without confirmed operative findings within the same admission. The remaining 120 patients were included for review. A combined feature of bowel dilatation with mural thinning was found to be the strongest CT indicator of acute bowel ischaemia with an odds ratio of 30.3 ($p < 0.001$; sensitivity, 73%; specificity, 94%; positive predictive value, 88%). The other significant CT indicator was mural hypoenhancement with an odds ratio of 6.3 ($p = 0.001$; sensitivity, 63%; specificity, 80%; positive predictive value, 68%). The intraclass correlation coefficient was 0.85 ($p < 0.001$), indicating a high degree of interobserver agreement in assessing the CT signs of acute bowel ischaemia.*

Conclusion: *A combined feature of dilatation with mural thinning and mural hypoenhancement are the strongest indicators for diagnosing acute bowel ischaemia.*

Key Words: *Abdomen, acute; Intestinal diseases; Ischemia; Tomography, X-ray computed*

中文摘要

急性腸缺血的診斷：應相信哪些CT徵象？

杜婉筠、潘偉麟、李芷茵、溫詠雪

目的：確定哪些電腦斷層掃描（CT）徵象與急性腸道缺血最為相關。

Correspondence: *Dr Victoria YK To, Department of Radiology, Tuen Mun Hospital, Tuen Mun, Hong Kong.*
Tel: (852) 2468 5175; Email: vykto911@gmail.com

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方法：本橫斷面研究包括2005年7月至2011年7月期間到香港屯門醫院求診並符合以下其中一項標準的病人：（1）因臨床懷疑腸道缺血而接受腹部CT掃描；（2）不論是否臨床懷疑，CT徵象提示腸道缺血；或（3）手術發現腸道缺血，並有腹部CT掃描記錄。所有CT圖像分別由三名放射科醫生在未知臨床結果的情況下獨立審閱然後記錄以下六項CT徵象：腸壁的厚度、腸道擴張、腸壁強化、腸壁內積氣、門靜脈或腸系膜靜脈氣體，以及腸系膜上動脈或靜脈（SMA/SMV）閉塞。利用二元logistic迴歸和校正比值比進行統計分析。計算組內相關係數以確定三名放射科醫生之間的觀察者間一致性。判定CT徵象的敏感性、特異性和陽性預測值。

結果：148個腸道缺血病例中，28個無該次入院的手術結果確診的死亡病例而不被列入研究範圍。餘下的120例列入回顧分析。結果發現腸道擴張伴有腸壁變薄為急性腸道缺血的最強CT診斷指標，其比值比為30.3（$p < 0.001$；敏感性73%、特異性94%、陽性預測值88%）。另一項指標為腸壁低強化，比值比為6.3（$p = 0.001$；敏感性63%、特異性80%、陽性預測值68%）。組內相關係數為0.85（$p < 0.001$），顯示三名放射科醫生在判斷急性腸道缺血的CT特徵具高度一致性。

結論：腸道擴張伴有腸壁變薄，以及腸壁低強化為診斷急性腸缺血的最強CT指標。

INTRODUCTION

Acute bowel ischaemia has become an increasingly recognised entity with the availability of multidetector computed tomography (MDCT). Acute bowel ischaemia often occurs in the elderly, with a significant mortality rate of up to 80%.[1,2] Despite its severity, it remains one of the most difficult and challenging acute abdominal conditions to diagnose radiologically. The aetiology of bowel ischaemia could be broadly categorised under arterial or venous occlusion, bowel obstruction, vasculitis / vasospasm, inflammation and, less commonly, drugs or radiation.[1,3-5] A number of computed tomography (CT) findings are associated with acute bowel ischaemia in the current literature, mainly mural thickness, bowel dilatation, mural enhancement, mesenteric stranding, ascites, vascular occlusion, pneumatosis intestinalis, and portal venous gas.[3-8] It is not easy for radiologists, especially those who are inexperienced, to confidently diagnose ischaemic bowel. Radiological suspicion, however, would certainly help clinicians decide whether a potentially life-saving surgery should be performed. Therefore, this study evaluated specific CT findings and their association with acute bowel ischaemia to help both the radiologist and clinician to better manage these patients.

This study aimed to determine which MDCT findings among mural thickness, bowel dilatation, mural enhancement, pneumatosis intestinalis, portomesenteric venous gas, and superior mesenteric artery or venous (SMA/SMV) occlusion, correlate most with acute bowel ischaemia.

METHODS

Subject Selection

This cross-sectional study included patients attending the Tuen Mun Hospital, Hong Kong between July 2005 and July 2011 who fulfilled one of the following criteria: (1) had undergone CT abdomen for clinical suspicion of bowel ischaemia, (2) CT showed evidence of bowel ischaemia with or without clinical suspicion, or (3) had operative findings of bowel ischaemia and had undergone CT previously. CT reports were searched using the hospital's Radiology Information System and Clinical Management System. Patients who died without a confirmed operative diagnosis were excluded (Figure 1).

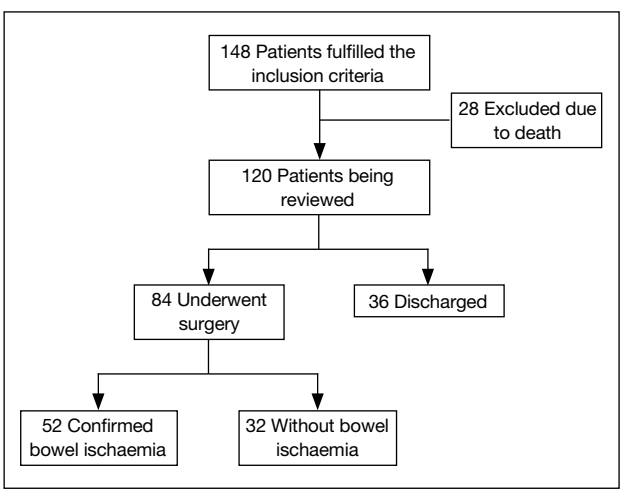

Figure 1. Flowchart showing patient selection for the study.

Computed Tomography Examination Technique

All patients were scanned at the hospital's 16-slice MDCT unit (Brilliance CT; Philips Healthcare, Cleveland, USA). Unenhanced and intravenous contrast-enhanced studies with 70-second delays were acquired in all the patients. No oral or rectal contrast was used. Contiguous 2-mm thick sections were obtained from the lung base to the abdomen or pelvis using standard protocol of 120 kV and 250 mA.

Analysis of the Computed Tomography Findings

All CT images were reviewed independently by three radiologists with 1 to 2 years of experience in radiology. All three radiologists were blinded to the clinical outcome. The Picture Archiving and Communication System was used to retrieve and review all CT studies. Six specific CT findings including mural thickness, bowel dilatation, mural enhancement, pneumatosis intestinalis, portal or mesenteric venous gas, and SMA/SMV occlusion were documented. Mural thickening was defined by ≥3-mm thickening in the wall of a non-collapsed segment. Small bowel dilatation was defined by ≥3 cm dilatation and large bowel dilatation by ≥5 cm dilatation. Enhancement of bowel was based on the qualitative visual comparison of the attenuation of the bowel wall at and around the site of suspected pathology in both non-contrast and contrast-enhanced scans. The appearance of gas pockets or a rim of gas within the wall was defined as pneumatosis intestinalis. Any suspicious filling defect within the SMA or SMV was considered vascular occlusion (Figure 2).

Diagnosis of Acute Bowel Ischaemia

The definitive diagnosis of acute bowel ischaemia was established by operative findings. Acute bowel ischaemia was excluded when there was negative operative finding or when patients who were not operated on remained free from abdominal symptoms for at least 3 months after discharge.

Statistical Analysis

The degree of association between the six specific CT findings was analysed using binary logistic regression to control for any possible confounding factors. The sample size required for the logistic regression analysis was determined based on the work of Peduzzi et al.[9] Adjusted odds ratio (OR) was calculated for each specific CT sign and the level of statistical significance was set at 5%. Multicollinearity that resulted from high degree of correlation between any two of the six specific CT findings was checked for by constructing a correlation matrix. Interaction term was constructed to replace the highly correlated CT findings in the regression model. Intraclass correlation coefficient (ICC) was calculated to determine the interobserver agreement among the three radiologists in assessing the six CT findings.

RESULTS

A total of 148 patients met the inclusion criteria, of which 28 were excluded due to death without confirmed operative findings within the same admission. The remaining 120 patients and their CT studies were included for review. The mean age was 68 years; patients included three children aged 7 months to 13 years, and 117 adults aged 13 to 91 years. There were 63 males and 57 females. All patients presented with acute abdominal pain. The interval between the onset of symptoms and the CT examination was 1 to 96 hours (mean, 22 hours). Operation was performed in 84 patients of whom 52 were confirmed to have bowel ischaemia and 32 patients had no features of bowel ischaemia. In the 52 patients with proven bowel ischaemia, the aetiology was small bowel obstruction (adhesions, hernia, gastrointestinal stromal tumour) in 18, large bowel obstruction (colorectal carcinoma, volvulus, intussusception, malrotation) in 15, inflammation (pancreatitis, diverticulitis, inflammatory bowel) in 6, SMA occlusion in 4, and shock bowel in 2; the cause was unclear in 7 patients. The remaining 36 patients were discharged with no evidence of bowel ischaemia after follow-up for at least 3 months (Figure 1).

During analysis of the variables using the correlation matrix, we observed that bowel dilatation had a strong negative correlation with bowel wall thickening. Therefore, these two factors were combined into an interaction term (combined bowel dilatation and mural thinning) for more accurate regression analysis.

A combined feature of bowel dilatation with mural thinning was found to be the most powerful CT indicator of acute ischaemic bowel with an OR of 30.3 ($p < 0.001$), sensitivity of 73%, specificity of 94%, and a positive predictive value of 88%. The second strongest CT indicator was mural hypoenhancement with an OR of 6.3 ($p = 0.001$), sensitivity of 63%, specificity of 80%, and positive predictive value of 68%. The rest of the CT findings were not statistically significant. Portal

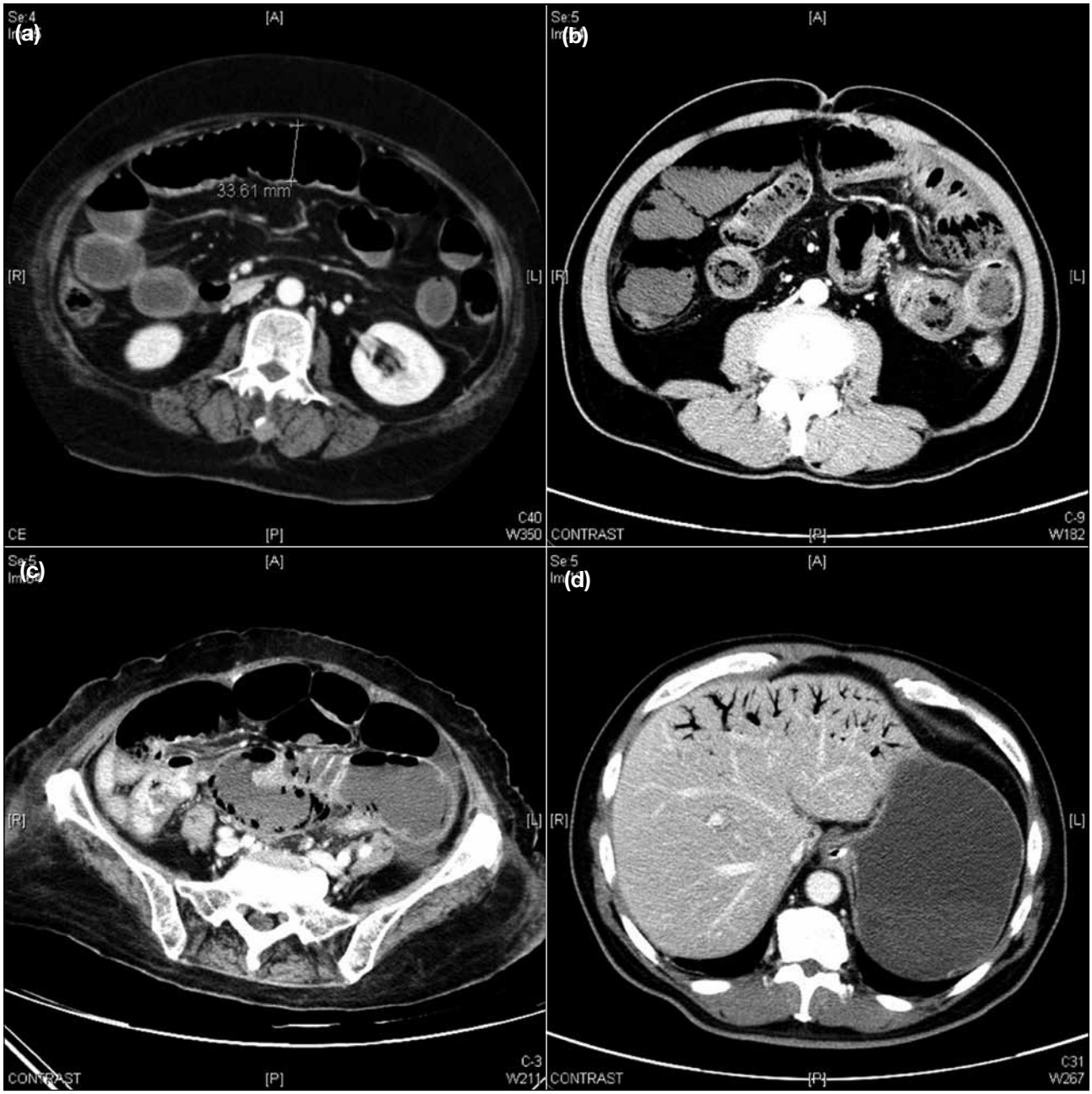

Figure 2. Axial contrast computed tomography scans show (a) small bowel dilatation and thin wall in the dilated segment, (b) mural hypoenhancement and pneumatosis intestinalis, (c) pneumatosis intestinalis, and (d) portal venous gas.

or mesenteric venous gas and pneumatosis intestinalis had ORs of 3.3 (p = 0.322) and 1.7 (p = 0.446), respectively (Table).

ICC was calculated to determine the interobserver agreement among the three radiologists in assessing the six CT findings. The ICC was found to be 0.85 (p < 0.001), indicating a high degree of interobserver agreement in assessing the CT signs of acute bowel ischaemia.

Table. Odds ratios and P values of individual CT findings using binary logistic regression.

CT finding	Odds ratio	P value
Bowel dilatation and mural thinning	30.3	<0.001
Hypoenhancement	6.3	0.001
Hyperenhancement	0.05	0.066
Pneumatosis intestinalis	1.7	0.446
Portal or mesenteric venous gas	3.3	0.322
SMA/SMV occlusion	0.7	0.865

Abbreviations: CT = computed tomography; SMA/SMV = superior mesenteric artery or venous.

DISCUSSION

Bowel dilatation, mural thickening or thinning, mural hypoenhancement or hyperenhancement, pneumatosis intestinalis, presence of portal or mesenteric venous gas, and SMA/SMV occlusion are the classic CT features of acute bowel ischaemia. In many previous studies, mural thickening and bowel dilatation were considered statistically independent CT variables in the assessment of acute bowel ischaemia.[3-8] However, it is suggested that mural thickening is affected by the degree of distention (Figure 2a) and peristalsis.[1,5] Wiesner et al[5] postulated that intramural nerves and intestinal musculature could be destroyed in arterio-occlusive transmural infarction, leading to a 'paper thin' bowel wall.[5] Our study clearly demonstrated that bowel dilatation and mural thickness are not independent parameters, and they were statistically correlated. After combining these two variables into an interaction term in the regression analysis, the odds of having acute bowel ischaemia were found to be 30 times higher in patients showing bowel dilatation with mural thinning than in those without the sign, indicating that the combined CT sign is highly predictive of the diagnosis.

Mural enhancement is a relatively subjective CT finding (Figure 2b). The same CT study could have both hypoenhancement and hyperenhancement in different segments of the bowel, depending on the different stages of insult. Mural hypoenhancement is a result of oedema or compromised blood flow and hyperenhancement could represent haemorrhage or hyperaemia.[1,5] In our study, hypoenhancement was the second strongest indicator of acute bowel ischaemia with an OR of 6.3. This result echoes with that from many previous studies showing hypoenhancement in patients with necrotic bowels.[6-8,10,11] As for hyperenhancement, there were only seven (6%) cases in our sample; this could be related to the difficulty in interpreting enhancement visually. Some reports have proposed that mural enhancement or hyperenhancement is a sign of reversible ischaemia and a good prognostic indicator.[5,6]

Pneumatosis intestinalis and portomesenteric venous gas were less common CT findings of acute bowel ischaemia in our study (21% and 8%, respectively; Figures 2c and 2c). Pneumatosis intestinalis is the dissection of luminal gas into the bowel wall and it can occur in a wide range of benign to life-threatening diseases.[12-15] Wiesner et al[5] suggested that presence of pneumatosis in ischaemia may represent more advanced disease. Kernagis et al[13] also proposed that pneumatosis intestinalis does not always indicate transmural infarction in cases of bowel ischaemia; however, when pneumatosis was associated with portomesenteric venous gas, these patients were more likely to have transmural infarction than those with pneumatosis alone.[13]

Portomesenteric venous gas refers to the presence of small gas pockets within the mesenteric veins or extending into the intrahepatic branches of the portal vein where it typically appears at the periphery of the liver.[5] The cause of gas formation in the portal or mesenteric system remains uncertain. It could be related to intestinal wall alterations, bowel distention, or even sepsis.[16] Sebastià et al[16] reported that the most serious and most frequent cause of portomesenteric vein gas in adults is mesenteric ischaemia. However, the association of portomesenteric vein gas with this disease process does not imply a worse prognosis.[16]

SMA/SMV occlusion is also a relatively infrequent CT finding of acute ischaemic bowel in our study with only four patients demonstrating SMA occlusion and no patients with SMV occlusion. Acute arterial occlusion is one of the most common causes of acute mesenteric ischaemia accounting for approximately 60% of cases.[4] Venous occlusion accounts for around 10% of cases.[4] The accuracy of CT in the diagnosis of occlusion, however, remains debatable with a sensitivity of 37% to 80%.[3] This could be related to the critically ill status of many of these patients making scanning suboptimal; their poor haemodynamic status may also affect enhancement of the vessels.

There are a few limitations in our study. First, visual comparison of the bowel wall enhancement may not be as accurate as attenuation measurements. However, from the high ICC indicating good interobserver agreement, we feel visual comparison remains a practical and realistic qualitative way of assessing enhancement in daily practice. Second, the distribution of sites of mural thickening and bowel dilatation was not assessed. In the current literature, small bowel and large bowel ischaemia are often separately investigated. If a larger sample size is recruited in the study, we should consider analysing small bowel and large bowel CT findings separately. Third, the imaging findings might have been influenced by the duration between onset of abdominal pain and the CT examination because the appearance of acute bowel ischaemia on an early CT may differ from that of a later study. Finally, we excluded 28 patients

who died without operation in the same admission; such exclusion may influence our results by excluding patients who died of fulminant acute bowel ischaemia. Two of these patients refused operation. The remaining 26 patients either deteriorated too quickly due to sepsis, shock or congestive heart failure, or were considered unfit for operation.

This retrospective cross-sectional study has a reasonable sample size. All three radiologists were blinded to the outcome and the results were unbiased as proven by the high interobserver agreement. The odds (risk) of suffering from acute bowel ischaemia were increased by 30 times in patients showing bowel dilatation with mural thinning on CT versus those without the sign, and by 6 times in those showing mural hypoenhancement than those without. We conclude that a combined feature of dilatation with mural thinning, and mural hypoenhancement are the strongest indicators for diagnosing acute bowel ischaemia.

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