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GASTROINTESTINAL

Sigmoid volvulus: identifying patients requiring emergency surgery with the dark torsion knot sign

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Abstract

Objectives To determine which clinical or CT imaging factors can help accurately identify complicated sigmoid volvulus (SV), defined as irreversible bowel ischaemia or necrosis requiring emergent surgery in patients with SV.

Methods We performed a retrospective study of 51 patients admitted consecutively to the emergency department for SV. All patients attempted endoscopic detorsion as the first treatment. Clinical and contrast-enhanced CT factors were analysed. A newly described dark torsion knot sign (sudden loss of mucosal enhancement in the volvulus torsion knot) was included as a CT factor. Patients were diagnosed with complicated versus simple SV based on either surgery or follow-up endoscopic findings. Univariate and multivariate analyses were used to identify predictors of complicated SV.

Results Of 51 study patients, 9 patients (17.6%) had complicated SV. Univariate analysis revealed that three clinical factors (sepsis, elevated C-reactive protein, and elevated lactic acid levels) and four CT factors (reduced bowel wall enhancement, increased bowel wall thickness, dark torsion knot sign, and diffuse omental infiltration) were significantly associated with complicated SV. Multivariate analysis identified only dark torsion knot sign (odds ratio = 104.40; $p = 0.002$) and sepsis (odds ratio = 16.85; $p = 0.043$) as independent predictive factors of complicated SV.

Conclusion A newly defined CT imaging factor of dark torsion knot sign and a clinical factor of sepsis can predict complicated SV necessitating emergent surgery instead of colonoscopic detorsion as a primary treatment of choice.

Key Points

- *A newly defined CT imaging factor of dark torsion knot sign and a clinical factor of sepsis can be helpful for predicting complicated SV necessitating emergent surgery instead of endoscopic detorsion.*

Keywords Sigmoid colon · Intestinal volvulus · Multidetector-row computed tomography · Sepsis · Emergency treatment

Abbreviations

CRP	C-reactive protein
NPV	Negative predictive value
OR	Odds ratio
PPV	Positive predictive value
SV	sigmoid volvulus

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Introduction

Sigmoid volvulus (SV) is an emergent disease that typically causes closed-loop obstruction by abnormal twisting of the sigmoid colon along its mesenteric axis. This accounts for 60–75% of all cases of colonic volvulus and 2–5% of all cases of colonic obstruction [1, 2]. There is rarely an alternative form of organo-axial type [3]. Prompt diagnosis can be made with computed tomography (CT), which delivers a diagnostic accuracy approaching 100% by demonstrating an abrupt transition between a normal and dilated colon as well as convergence of both ends of the dilated loop toward the fulcrum point [4–6]. Urgent endoscopic detorsion of the SV is the primary treatment of choice, and thereafter, elective surgery becomes the second treatment of choice to prevent recurrent volvulus in patients with simple SV [7, 8]. However, if left untreated or a certain period passes after the onset of SV,

venous return to arterial blood supply can be compromised as colonic obstruction with distension is aggravated. Ultimately, simple SV progresses to complicated SV, resulting in irreversible colonic ischaemia, gangrene, and perforation as a life-threatening condition [9]. This explains the persistently high mortality rates up to 60% in patients with complicated SV [7, 10], and these patients should undergo emergent laparotomy for complete therapeutic cure instead of endoscopic detorsion [8, 11–13]. Distinguishing between simple and complicated SV is therefore essential before performing urgent endoscopic detorsion.

Several authors have identified various CT findings, such as decreased, absent, or increased bowel wall enhancement, increased bowel wall thickness, ascites, mesenteric haziness, pneumatosis intestinalis, or intraperitoneal free air, as predictive factors indicating irreversible bowel ischaemia to infarction [14–23]. However, such studies have focused primarily on small bowel strangulation rather than the colon. Furthermore, to the best of our knowledge, there has been no previous study demonstrating the comprehensive clinical and radiological factors that may influence prediction of complicated SV.

We therefore aimed to identify the clinical and CT factors that can be helpful for predicting patients with complicated SV necessitating emergent surgery.

Materials and methods

This was a retrospective, observational two-centre study. The institutional review boards from each hospital approved this study, and the requirements for informed written consent were waived.

Study population

The study coordinators searched the electronic medical records of two medical centres for patients diagnosed with SV among those admitted to an emergency department between January 2006 and October 2017. A total of 86 consecutive patients were initially eligible for diagnosis of SV in the two centres. Thirty-five patients were excluded because of (1) no available CT scan ($n = 16$), (2) neither endoscopic detorsion trial nor surgical treatment ($n = 13$), (3) no available laboratory results or vital signs at the time of admission ($n = 3$), or (4) SV due to other reasons such as colon cancer ($n = 3$). The remaining 51 patients were included in our study. The study population with exclusion criteria is presented in Fig. 1.

Reference standard

Diagnosis of SV was confirmed by a combination of pathological, surgical, or endoscopic findings. Endoscopic findings for the diagnosis of SV are spiral twisting of the colonic lumen and inability to insert the endoscope into the sigmoid colon proximal to the twisted area [7]. Complicated SV was defined as irreversible bowel wall ischaemia or necrosis noted by surgical and histopathological reports in patients who underwent endoscopic trial for detorsion followed by emergent or elective surgery (Fig. 2). Patients who underwent only endoscopic detorsion were diagnosed with complicated SV if definite bowel wall necrosis was noted by an endoscopic report and it did not return to normal by follow-up endoscopy. Patients with stable vital signs, normal laboratory findings, and normal endoscopic findings obtained during the follow-up period were diagnosed with simple SV (Fig. 3) even though an initial endoscopic report noted an ischaemic bowel.

Clinical data analysis

Study coordinators reviewed the electronic medical records of all patients for demographic details (age and sex), previous or current medical history (diabetes mellitus, hypertension, neuropsychiatric disorder, constipation, history of previous operations, and previous SV event), clinical symptoms (abdominal pain and distension) with duration, physical examinations (direct and indirect abdominal tenderness), vital signs, and laboratory findings obtained at the time of admission to the emergency department. Patients' vital signs, laboratory findings (serum platelet, bilirubin, creatinine, and lactate levels), and mental status required for sepsis criteria were also extracted from the patients' reports. Sepsis was defined as life-threatening organ dysfunction caused by a dysregulated host response to infection as described by the "Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3)" [24]. The success rate of endoscopic detorsion, type of surgery (emergent or elective), hospitalisation days, follow-up period, and presence or absence of patients' death were analysed. Surgeries performed within one year of an endoscopic detorsion without recurrent SV were considered elective operations.

CT technique

All 51 patients underwent abdominopelvic CT examinations using variable (16–128) multichannel multidetector scanners (Sensation 16, Somatom Definition Edge, or Somatom Definition AS, Siemens Medical Solutions). After obtaining unenhanced CT images, contrast-enhanced portal or delayed phased CT scanning began 70 to 90 s after intravenous injection of 100 to 150 mL of a non-ionic contrast medium (Iopamiro 300, Bracco Imaging; Omnipaque 300, GE Healthcare) at a rate of 2.5 to 3 mL/s. The scan parameters for the 16-, 64-, and 128-channel scanners were as follows: beam collimation, 0.6 to 0.75 mm; slice thickness, 3 to 5 mm; reconstruction interval, 3 to 5 mm; rotation time, 0.3 to 0.5 s;

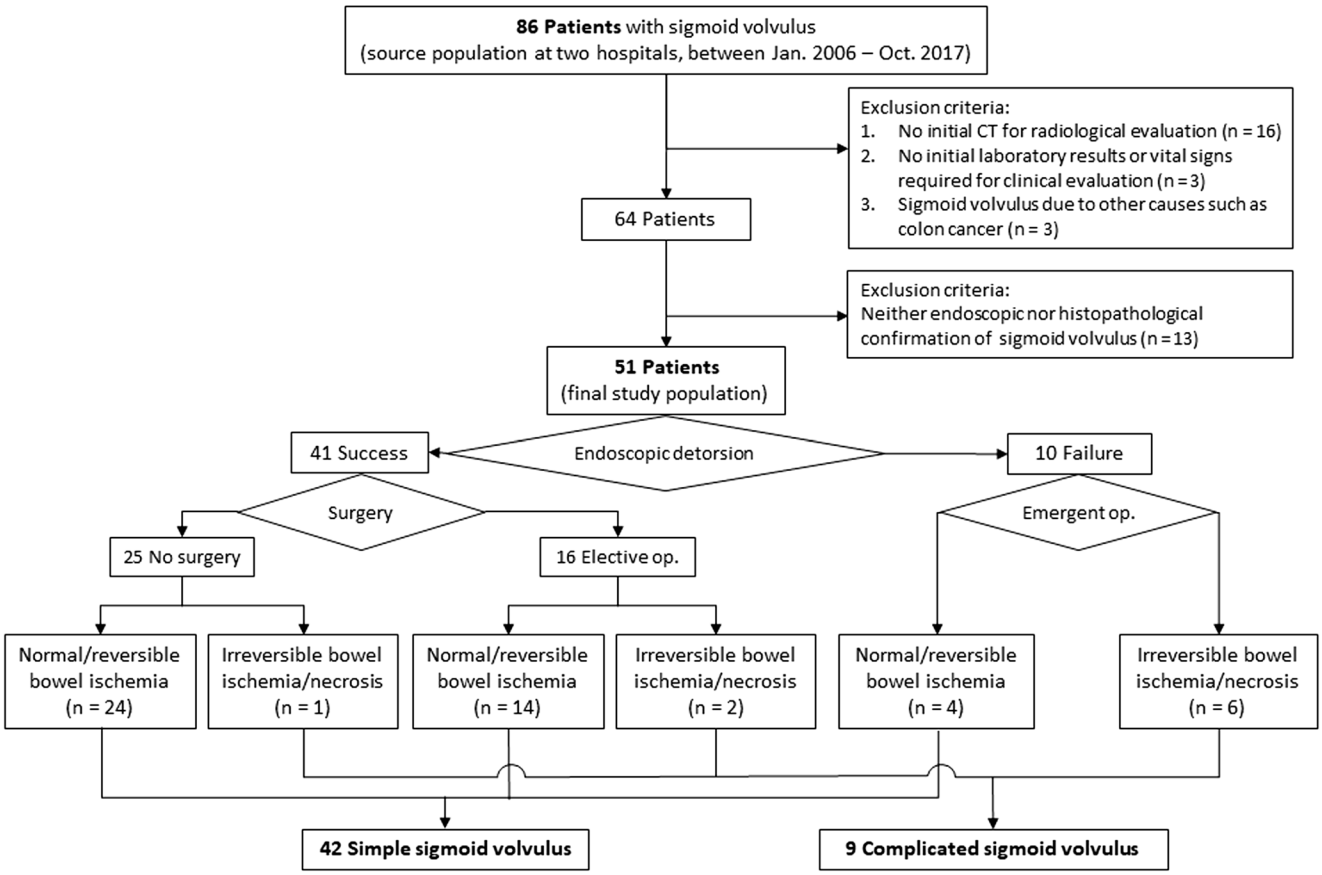

Fig. 1 Patient flow diagram; *op* operation

effective tube current-time charge, 200 to 260 mAs; and voltage, 100 to 120 kVp. Contrast-enhanced images were obtained using axial and coronal reconstruction and unenhanced CT images with axial reconstruction.

CT imaging analysis

All CT images were randomly collected in an anonymized state in a research folder located on the picture and archiving

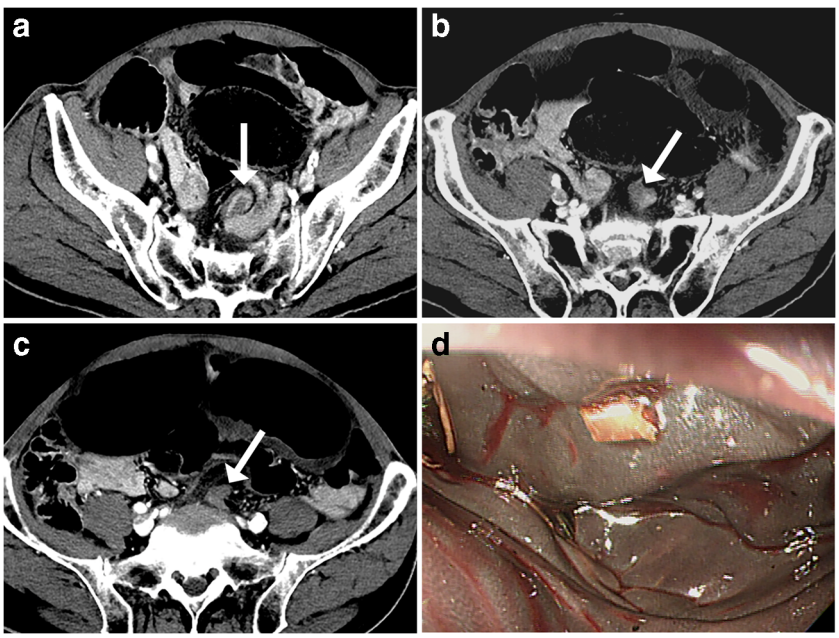

Fig. 2 Dark torsion knot sign in a 69-year-old man with complicated sigmoid volvulus. (**a**–**c**) Serial contrast-enhanced axial CT images show a sudden loss of the inner mucosal layer enhancement of the normal sigmoid colon at the torsion knot level when traced from the distal rectum to the sigmoid colon (arrows). **d** Sigmoidoscopy shows the black-coloured mucosal changes indicating ischaemia in the sigmoid colon proximal to the torsion knot after endoscopic detorsion. This patient died of sepsis during the pre-operative preparation

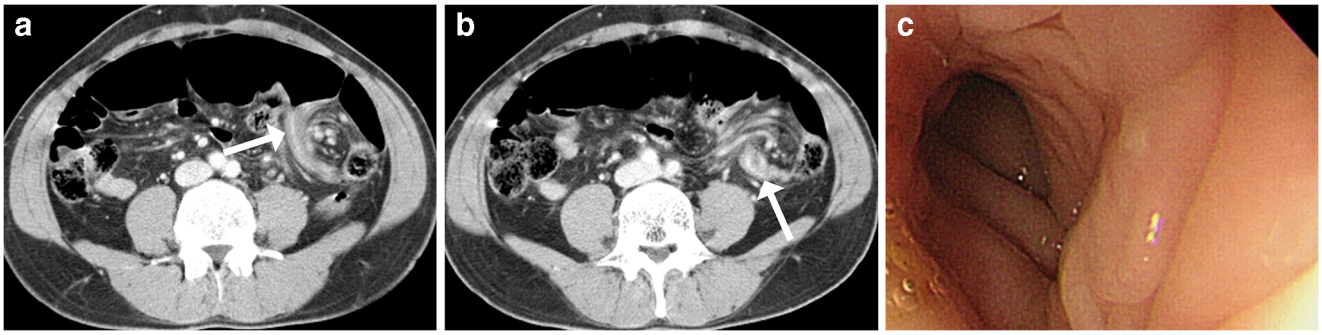

Fig. 3 A 43-year-old man with a simple sigmoid volvulus without a dark torsion knot sign. **a**, **b** Serial contrast-enhanced axial CT images show the normally enhanced inner mucosal layer at the torsion knot (arrows). (**c**) On sigmoid colonoscopy performed 3 h after CT, the colonic mucosa proximal and distal to the torsion knot appeared normal after endoscopic detorsion and decompression

and communication system of each centre and were retrospectively reviewed by two radiologists with 13 and 5 years of experience in emergency imaging interpretation by consensus. Readers were aware that all patients had SV, but were blinded to all other clinical and laboratory findings, original reports of CT imaging, specific diagnosis between simple and complicated SV, and treatment methods with patient outcomes.

First, variable CT signs and findings associated with SV were evaluated: (1) type of SV (mesenterico-axial vs. organo-axial) [12], (2) whirl sign, (3) X-marks-the-spot sign (two crossing sigmoid transition points), (4) split-wall sign (separation of the sigmoid colonic walls by interposed mesenteric fat due to incomplete torsion) [25], (5) northern exposure sign (upward position of the sigmoid colon relative to the transverse colon) [26], (6) length of the sigmoid mesentery (longitudinal axis of the mesentery between the twisted sigmoid colon at coronal CT imaging), (7) axial luminal diameter of the most dilated sigmoid colonic volvulus, (8) torsion degree, (9) presence of air-fluid level in the sigmoid colon, and (10) presence of rectal gas [25]. Second, potential CT findings suggesting complicated SV were evaluated as follows: (1) reduced bowel wall enhancement (compared with a normal adjacent bowel), (2) hyper-enhanced bowel wall (compared with a normal adjacent bowel), (3) bowel wall thickness near the torsion knot, (4) ascites, (5) mesenteric haziness (increased mesenteric fat attenuation), (6) mesenteric vessel engorgement, (7) diffuse omental infiltration (increased omental fat attenuation), (8) intramural gas, (9) intraperitoneal free air, and (10) dark torsion knot sign (sudden loss of normal sigmoid mucosal enhancement at the level of the torsion knot of the SV) as a new potential imaging finding suggesting complicated SV (Fig. 2).

Statistical analysis

The frequency of each clinical, laboratory, and CT imaging factor was compared between patients with simple SV and those with complicated SV. Categorical variables were tested using the Pearson χ^2 or Fisher's exact test, while continuous variables were tested with the *t* test or Wilcoxon rank-sum test. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each clinical, laboratory, and CT finding, with a binomial 95% confidence interval (CI). Areas under the receiver operating characteristic curves were used to determine the best cutoff value to differentiate between patients with simple SV and those with complicated SV for continuous variables. All variables with a p value < 0.05 in the univariate logistic regression analysis were included in the multivariate logistic regression analysis to assess the independent association with the presence of complicated SV. The level of significance was set at a two-tailed p value < 0.05 for all tests. R software (version 3.5.0.; R Foundation for Statistical Computing) and SPSS software version 23.0 (SPSS Inc.) were used to perform all statistical analyses.

Results

Reference standard and patients

Distribution of the 51 patients between the simple and complicated SV according to the treatment procedure is shown in Fig. 1. Endoscopic detorsion was initially tried in all patients after radiological diagnosis of SV with CT. It was successful in 41 patients (80.4%) and unsuccessful in 10 (19.6%). Failed endoscopic detorsion was found significantly more in patients with complicated SV (6 of 9; 66.7%) than those with simple SV (4 of 42; 9.5%; $p = 0.001$). Sixteen of 41 patients (39.0%) with successful endoscopic detorsion underwent subsequent elective surgical operation, whereas 10 of 10 patients (100%) with failed endoscopic detorsion underwent emergent operation.

The baseline characteristics of 51 patients are shown in Table 1. Median age was 71 years, ranging from 21 to 88 years. Constipation was the most common clinical factor associated with SV. There was no significant difference in symptom period between patients with simple and

Table 1 Demographic and clinical characteristics of patients diagnosed with sigmoid volvulus

Characteristics	Patients (%)
Patients	51 (100%)
Simple sigmoid volvulus	42 (82.4)
Complicated sigmoid volvulus	9 (17.6)
Age (years)	65.35 ± 17.20[a]
Male sex	43 (84.3)
Associated factors	
Diabetes mellitus	8 (15.7)
Hypertension	20 (39.2)
Neuropsychiatric disorder	20 (39.2)
Constipation	27 (52.9)
History of previous operation	9 (17.6)
History of previous sigmoid volvulus	8 (15.7)
Clinical presentation	
Abdominal distension	48 (94.1)
Abdominal pain	43 (84.3)
Symptom period (days)	3.64 ± 2.24[a]
Physical examination	
Abdominal direct tenderness	28 (54.9)
Abdominal indirect tenderness	1 (2.0)
Treatment	
Endoscopic detorsion only	24 (47.1)
Surgical resection after endoscopic detorsion	27 (52.9)
Follow-up	
Follow-up period (days)	604.24 ± 582.97[a]
Death	4 (7.8)

[a] Values indicate mean ± standard deviation

complicated SV ($p = 0.93$). The median number of hospitalisation days was 8 (interquartile range, 5–10 days) and was significantly longer in patients with complicated SV (18 days, interquartile range, 10–20 days) than in those with simple SV (7 days, interquartile range, 5–14 days) ($p = 0.02$). The median follow-up period was 7.1 months (interquartile range, 1.8–40.1 months), and there was no significant difference in follow-up period between patients with simple and complicated SV ($p = 0.604$). Among the deceased four patients, two with complicated SV died of perioperative sepsis and two with simple SV died—one due to pneumonia irrespective of SV and the other due to recurrent volvulus with colonic perforation and sepsis 4 months after a successful endoscopic detorsion.

Clinical and CT imaging factors to predict complicated SV

Univariate analysis of the patients' clinical and CT imaging features to predict complicated SV is shown in Tables 2 and 3. Among the clinical factors, sepsis and elevated lactic acid and C-reactive protein (CRP) levels were significantly associated with complicated SV. Both elevated serum lactic acid and CRP levels achieved 100% sensitivity (95% CI, 59–100% in lactic acid and 95% CI, 66–100% in CRP), whereas sepsis was the most specific (93% specificity; 95% CI, 81–99%). There was no difference in age ($p = 0.363$), sex ($p = 0.556$), or previous SV event ($p > 0.999$) between patients with simple and complicated SV.

With regard to the CT imaging factors, reduced bowel wall enhancement, dark torsion knot sign, diffuse omental infiltration, and increased bowel wall thickness were significantly associated with complicated SV ($p < 0.05$). The first three factors shared a sensitivity of 78% (95% CI, 40–97%), but increased bowel wall thickness had a relatively lower sensitivity (67%; 95% CI, 30–93%). All these factors showed a high specificity and NPV equal to or greater than 90%. Air-fluid level, ascites, and mesenteric haziness also showed 100% sensitivity in predicting complicated SV, but specificity was low, ranging from 12 to 31%.

Multivariate analysis showed that one CT imaging factor, dark torsion knot sign (odds ratio [OR] = 104.40; $p = 0.002$), and one clinical factor, sepsis (OR = 16.85; $p = 0.043$), were significant independent predictive factors indicating complicated SV (Table 4).

Discussion

Our study showed that clinical and CT imaging findings composed of dark torsion knot sign (OR = 104.40) and sepsis (OR = 16.85) were the significant independent predictive factors in identifying complicated SV among patients diagnosed with SV at emergency departments. The presence of one of these two factors suggested that emergency surgery should be considered preferentially rather than colonoscopic detorsion in patients with SV.

Sepsis is a life-threatening condition caused by physiological, pathological, and biochemical abnormalities in response to infection. The condition is associated with an overall mortality risk of approximately 10% in patients with infection [24]. In patients with SV, sepsis can occur sequentially with the following processes: increased intraluminal pressure by the colonic obstruction, decreased capillary perfusion, increased bacterial overgrowth due to translocation with gas formation, and toxic shock [5, 6, 13]. If sepsis is already present in a patient, it means a relatively long period of time has already passed since the disease onset, and there is a risk of transition from reversible to irreversible colonic ischaemia to necrosis. Several previous studies have supported that septic shock was significantly predictive for mortality in SV [27]. This is consistent with our study results, and we recommend that endoscopic detorsion should not be attempted in patients with sepsis [9].

Table 2 Univariate diagnostic performance of categorical clinical and CT imaging factors to predict complicated sigmoid volvulus

	Sensitivity	Specificity	PPV	NPV	*p* value
Clinical factors					
Abdominal distension	9/9 (100) [66, 100]	3/42 (7) [1, 19]	9/48 (19) [9, 33]	3/3 (100) [29, 100]	> 0.999
Abdominal pain	9/9 (100) [66, 100]	8/42 (19) [9, 34]	9/43 (21) [10, 36]	8/8 (100) [63, 100]	0.322
Abdominal direct tenderness	7/9 (78) [40, 97]	21/42 (50) [34, 66]	7/28 (25) [11, 45]	21/23 (91) [72, 99]	0.159
Abdominal indirect tenderness	0/9 (0) [0, 34]	41/42 (98) [87, 99]	0/1 (0) [0, 98]	41/50 (82) [69, 91]	> 0.999
Sepsis	6/9 (67) [30, 93]	39/42 (93) [81, 99]	6/9 (67) [30, 93]	39/42 (93) [81, 99]	< 0.001
CT imaging factors					
Mesenterico-axial type	8/9 (89) [52, 99]	12/42 (29) [16, 45]	8/38 (21) [10, 37]	12/13 (92) [64, 99]	0.417
Whirl sign	8/9 (89) [52, 99]	8/42(19) [9, 34]	8/42(19) [9, 34]	8/9 (89) [52, 99]	> 0.999
X-marks-the-spot sign	5/9 (56) [21, 86]	28/42 (67) [50, 80]	5/19 (26) [9, 51]	28/32 (88) [71, 96]	0.266
Split-wall sign	8/9 (89) [52, 99]	9/42 (21) [10, 37]	8/41 (20) [9, 35]	9/10 (90) [55, 99]	0.667
Northern exposure sign	6/9 (67) [30, 93]	20/42 (49) [32, 64]	6/28 (21) [8, 41]	20/23 (87) [66, 97]	0.487
Air-fluid level	9/9 (100) [66, 100]	5/42 (12) [4, 26]	9/46 (20) [9, 34]	5/5 (100) [48, 100]	0.571
Rectal gas	1/9 (11) [0, 48]	24/42 (57) [41, 72]	1/19 (5) [0, 26]	24/32 (75) [57, 89]	0.128
Reduced bowel wall enhancement	7/9 (78) [40, 97]	39/42 (93) [81, 99]	7/10 (70) [35, 93]	39/41 (95) [83, 99]	< 0.001
Dark torsion knot sign	7/9 (78) [52, 99]	41/42 (98) [87, 99]	7/8 (88) [47, 99]	41/43 (95) [84, 99]	< 0.001
Ascites	9/9 (100) [66, 100]	13/42 (31) [18, 47]	9/38 (24) [11, 40]	13/13 (100) [75, 100]	0.090
Mesenteric haziness	9/9 (100) [66, 100]	12/42 (29) [16, 45]	9/39 (23) [11, 39]	12/12 (100) [74, 100]	0.094
Mesenteric vein engorgement	4/9 (44) [14, 79]	20/42 (48) [32, 64]	4/26 (15) [4, 35]	20/25 (80) [59, 93]	0.726
Diffuse omental infiltration	7/9 (78) [40, 97]	38/42 (90) [77, 97]	7/11 (64) [31, 89]	38/40 (95) [83, 99]	< 0.001

Data in parentheses are percentages, and data in brackets are 95% confidence intervals

PPV positive predictive value, *NPV* negative predictive value, *CT* computed tomography

CT is the main diagnostic tool, together with colonoscopy, for evaluating the colonic wall in SV. Although colonoscopy can reveal colonic ischaemia or infarction by direct endoscopic viewing [13], failed colonoscopic detorsion or impacted colonic faeces may hamper the accurate evaluation of the proximal colonic mucosa located in the twisted sigmoid colon [27]. Colonoscopy has an inherently limited role in evaluating the whole colonic wall for differentiation between reversible colonic ischaemic mucosa and irreversible colonic muscle ischaemia. Furthermore, an endoscopic trial itself may increase the risk of colonic perforation in the presence of an irreversible ischaemic or infarcted colonic wall [27] or may cause a delay in emergent surgery. By contrast, CT can evaluate the whole colonic wall as well as the proximal colonic segment where colonoscopy could not pass through the twisted portion of the SV. In the early phase of SV (Fig. 3), bowel wall compromise starts with venous outflow obstruction and then causes bowel wall oedema. This is seen as a hypoattenuating outer submucosal/muscular layer and hyperattenuating inner mucosal layer at CT [19, 21]. In the late phase of SV (Fig. 2), reversible colonic ischaemia progresses to necrosis because arterial flow ceases due to vasoconstriction or elevated intraluminal pressure [16]. We have encountered the sudden loss of a hyperattenuating inner mucosal layer in the torsion knot level when backward tracing from the rectum normally showing the hyperattenuating inner mucosal layer toward the twisted colon at CT images of patients with complicated SV. This may reflect irreversible colonic ischaemia or necrosis at CT. We named this as "dark torsion knot sign". This sign might be easily recognisable at CT images by radiologists and proved to be the independent significant predictor of complicated SV in our study.

From our study, reduced bowel wall enhancement and increased bowel wall thickness on CT were included as potential imaging factors indicating complicated SV. This has been accepted as a classic indicator of bowel wall ischaemia or necrosis, especially in small bowel obstruction [14, 15, 17, 21]. Bowel wall enhancement can be easily assessed in dilated small bowel loops filled with fluid. However, it is difficult to assess the degree of bowel wall enhancement in a markedly distended sigmoid colon filled with air. In this circumstance, the paper-thin sigmoid colonic wall makes it difficult to measure the bowel wall thickness. All our study patients had marked air distension of the sigmoid colon measuring more than 5 cm in maximal axial diameter in SV. We inevitably evaluated both the degree of bowel wall enhancement and thickness from the measurable colonic wall near the torsion knot level that was not a centre of SV. These two factors were determined to be predictive factors at univariate analysis, but ultimately not in multivariate analysis.

The other potential CT imaging factors (type of sigmoid volvulus, torsion degree, maximal axial luminal diameter,

Table 3 Univariate diagnostic performance of continuous clinical and CT imaging factors to predict complicated sigmoid volvulus

	AUC [95% CI]	Cutoff value[a]	Sensitivity	Specificity	PPV	NPV	*p* value
Clinical factors							
Lactic acid (mmol/L)[a]	0.798 [0.586–0.933]	1.6	7/7 (100) [59, 100]	10/17 (59) [33, 82]	7/14 (50) [23, 77]	10/10 (100) [69, 100]	0.019
CRP level (mg/dL)	0.903 [0.663–0.904]	0.5	9/9 (100) [66, 100]	23/42 (59) [42, 74]	9/25 (36) [18, 57]	23/23 (100) [85, 100]	0.002
CT imaging factors							
Torsion degree (°)	0.651 [0.504–0.779]	315	4/9 (44) [14, 79]	32/42 (76) [61, 88]	4/14 (29) [8, 58]	32/37 (86) [71, 95]	0.236
Luminal diameter (cm)	0.620 [0.474–0.753]	8.6	8/9 (89) [52, 99]	15/42 (36) [22, 52]	8/35 (23) [10, 40]	15/16 (94) [70, 99]	0.242
Bowel wall thickness (mm)	0.709 [0.565–0.828]	2.9	6/9 (67) [30, 93]	42/42 (100) [92, 100]	6/6 (100) [54, 100]	42/45 (93) [82, 99]	< 0.001
Mesosigmoid length (cm)	0.550 [0.405–0.690]	26.2	4/9 (44) [14, 79]	28/42 (67) [50, 80]	4/18 (22) [6, 48]	28/33 (85) [68, 95]	0.703

Data in parentheses are percentages, and data in brackets are 95% confidence intervals

AUC area under the receiver operating characteristics curve, *CI* confidence interval, *PPV* positive predictive value, *NPV* negative predictive value, *CRP* C-reactive protein

[a] There are missing values in 27 patients who did not undergo lactic acid analysis at the emergency department

mesosigmoid length, mesenteric haziness, mesenteric vein engorgement, air-fluid level, rectal gas, ascites, and diffuse omental infiltration) had no significant association with complicated SV. Various CT imaging signs representing SV were helpful for diagnosing SV, but not for predicting complicated SV.

Our study corroborated previous studies that clinical presentations and physical examination are neither specific nor sensitive in predicting complicated SV [5]. Regarding other associated medical conditions such as repeated history of SV, there was no association with complicated SV. A previous study reported that patients with postoperative death had significantly longer periods of symptoms before admission than those with uneventful postoperative outcomes [28]. However, we found no significant relationship involving symptom period between patients with simple and complicated SV. Because of the small number of patients with complicated SV, further research with larger patient populations is needed to verify this risk factor.

Our study has several limitations. First, it was a retrospective study with a small number of patients, particularly in the subgroup of complicated SV. This can weaken the statistical analysis power. Nevertheless, this was the first study focused on both clinical and CT imaging factors to identify complicated SV at the emergency department. Second, we only enrolled patients who initially underwent endoscopic trial for detorsion. This study was for extracting patients necessitating emergent surgery instead of endoscopic treatment in patients with complicated SV as the initial treatment. Therefore, it was appropriate for patients undergoing emergent or elective surgery without endoscopic trial for detorsion to be excluded from our study. However, this may have introduced selection bias. Third, in patients who did not undergo surgery, endoscopic findings were the only standard reference for diagnosis of simple versus complicated SV. In patients who had a very short-term follow-up period or follow-up loss or in those considered to be in borderline state between reversible and irreversible bowel ischaemia after endoscopic detorsion, simple SV could be switched to complicated SV. This can cause errors in the subgroup classification of SV.

In conclusion, a CT imaging factor of dark torsion knot sign, defined as sudden loss of mucosal enhancement at torsion knot, and a clinical factor of sepsis could be helpful for predicting complicated SV necessitating emergent surgery instead of endoscopic detorsion.

Table 4 Significant clinical and CT imaging factors in multivariate logistic regression analysis to predict complicated sigmoid volvulus

Variables	Standard error	Wald test	*p* value	Odds ratio	95% confidence interval
Clinical factor					
Sepsis	1.39	4.11	0.043	16.85	1.10–258.79
CT imaging factor					
Dark torsion knot sign	1.47	10.01	0.002	104.40	5.86–1859.26

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Compliance with ethical standards

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Conflict of interest The authors declare that they have no competing interests.

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Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- retrospective
- observational
- performed at two institutions

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