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► **To cite this version:**

Claire Humbert, Franck Grillet, Alexandre Malakhia, Fanny Meuriot, Zaher Lakkis, et al.. Stratification of sigmoid volvulus early recurrence risk using a combination of CT features. *Diagnostic and Interventional Imaging*, 2022, 103 (2), pp.79-85. 10.1016/j.diii.2022.01.005 . hal-03617638

HAL Id: hal-03617638

<https://hal.science/hal-03617638v1>

Submitted on 22 Jul 2024

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Stratification of sigmoid volvulus early recurrence risk using a combination of CT features

Running head: Stratification of sigmoid volvulus early recurrence risk with CT

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Original research

Stratification of sigmoid volvulus early recurrence risk using a combination of CT features.

ABSTRACT

Purpose. The purpose of this study was to identify computed tomography (CT) features associated with early recurrence of sigmoid volvulus (SV) after a first uncomplicated episode and to develop a score for early SV recurrence risk stratification.

Materials and methods. A total of 95 patients (59 men, 36 women; mean age, 72 ± 15 [SD] years; age range: 57–87 years) who underwent abdominal CT examination for a first uncomplicated SV episode from January 1st 2006 to July 31st 2020 in two French University Hospitals were retrospectively included. An SV recurrence occurring within six months was defined as early SV recurrence. CT findings associated with SV were searched for using univariable analysis. CT features associated with early recurrence were computed into a multivariable logistic regression model, used to build a score to stratify SV recurrence risk. Kaplan-Meier curves were built to evaluate recurrence-free survival.

Results. Early SV recurrence occurred in 53 patients (56%). At multivariable analysis, left lateral section volume $< 150 \text{ cm}^3$ and maximal colon distension $> 10 \text{ cm}$ were associated with early SV recurrence (Odds ratio [OR] = 4.62; 95% CI: 1.77–13.33; $P = 0.002$ and OR = 4.43 95% CI: 1.63–13.63; $P = 0.005$) respectively), and an early SV recurrence score with 1 point attributed to each of these two variables was built. Early SV recurrence was observed in 26%, 54% and 89% of patients with score of 0, 1 and 2, respectively ($P < 0.001$).

Conclusion. A simple CT score allows stratification of early SV recurrence after a first episode and helps to select patient who would not benefit from prophylactic colonic surgery because of a low SV recurrence risk.

List of abbreviation

AUC: Area under the curve

AUROC: Area under the receiver operating characteristics curve

CI: Confidence interval

CRP: C-reactive protein

CT: Computed tomography

OR: Odds ratio

PACS: Picture archiving and communication system

qSOFA: quick Sepsis-related Organ Failure

SD: Standard deviation

SV: Sigmoid volvulus

Keywords

Colon

Intestinal volvulus;

Recurrence;

Computed tomography;

Risk assessment

1. Introduction

Sigmoid volvulus (SV) is a cause of mechanical large bowel obstruction, defined by a twisting of sigmoid colon [1]. When SV is uncomplicated and treated by endoscopic detorsion, recurrence rate after a first SV episode ranges between 30 and 90% worldwide [2,3]. Risk factors for SV recurrence remain unclear. Early surgery after endoscopic detorsion is recommended for patients with a low surgical risk, but the management of high-risk patients is not clearly established. Some patients will benefit from prophylactic surgery whereas some will not [2,4–7].

SV is the third cause of large bowel obstruction after cancer and diverticular disease [2,8]. SV incidence varies according to geographic location. In countries of the "Volvulus Belt" such as West Africa, India and Russia, it accounts for 50 to 85% of intestinal obstruction [8,9]. In Western countries, SV represents 5-7% of large bowel obstruction [10]. SV main constitutional risk factor is dolichosigmoid [11]. Other risk factors include causes of slowed transit, advanced age, history of abdominal surgery and Hirschprung's disease [2,3,12].

Patients with SV usually present with obstipation, abdominal distension and abdominal pain, which are non-specific clinical signs. Thus, abdominal CT remains a standard for SV diagnosis showing a whirl sign of the sigmoid, defined as a whirlpool formed by winding of anatomical structures [13,14]. Two types of SV have been described depending on the single or the double limb of sigmoid (*i.e.*, organo-axial and mesenterico-axial respectively) [15,16].

To date, one major role of abdominal CT is to identify patients with complicated SV who require immediate surgery following SV diagnosis or those who will undergo a first endoscopic detorsion. Absence of sigmoid wall enhancement, pneumoperitoneum, sigmoid mesenteric haziness and the newly described dark torsion knot sign have been associated with complicated SV [17].

A previous study tried to evaluate extension findings (ventral liver overlap or extension to the subphrenic space) and distended sigmoid colon as risk factors of SV recurrence [18]. Left lateral section volume has also already been evaluated as a CT feature associated with SV recurrence [19].

The aim of our study was to identify CT features associated with early recurrence of SV and to develop a simple score for early SV recurrence risk stratification, to better select

patients who would not benefit from prophylactic colonic surgery because of a low SV recurrence risk.

2 Materials and methods

2. 1. Patients

This study was approved by institutional review board (approval number CRM-2109-195) and complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [20].

The databases of two institutions were queried to retrieve all patients who experienced SV from January 1st 2006 to July 31st 2020. Patients were further included when they met the following inclusion criteria: (*i*), they were older than 18 years; (*ii*), they had a first episode of SV; and (*iii*), they underwent abdominal CT examination during the SV episode.

The initial search retrieved 289 patients assessed for eligibility. Seventy-eight patients with no available CT examination and 87 patients for which the actual SV episode was a recurrence were excluded. Among the 124 first SV episode observed during the study period, 27 patients were excluded because they required colonic surgery during the acute phase of the disease, defined by urgent surgery without endoscopic examination (13 patients) or urgent surgery following endoscopic examination (14 patients). Two patients died without any specific care (comfort care only). Ninety-five patients met the inclusion criteria and were included in the study (**Figure 1**).

The date of the first SV recurrence and the date of the colonic surgery were retrospectively collected. Early SV recurrence was defined as a SV recurrence within six months after the first SV episode. Patients demographic and biological data were retrieved:

neuropsychiatric disorder, abdominal pain, abdominal tenderness, rectal bleeding, clinical signs of sepsis, elevated CRP (>5 mg/L), elevated serum lactic acid (> 2.0 mmol/L) [21]. The quick Sepsis-related Organ Failure (qSOFA) score (respiratory rate \geq 22/min; altered mental status, Glasgow score scale < 15; systolic blood pressure \leq 100 mmHg; 1 point per each variable) was assessed for each patient

2.2. CT protocol

In the first center (Besançon), CT examinations were performed on three different CT units (Brilliance[®] 64, Philips HealthCare; Somatom[®] Definition AS, Siemens Healthineers; and Somatom[®] Definition AS+,) with 64 rows of detectors. In the second center (Dijon), CT examinations were performed either on a Aquilion ONE[®] scanner (Canon Medical Systems) or on a Discovery[®] CT 750 HD (General Electric Healthcare,). Standard CT protocol included an unenhanced phase followed by an abdominal and pelvic portal phase after intravenous administration of iodinated contrast material (iomeprol, 350 mg I/mL, Iomeron[®], Bracco Imaging), at a dose of 1.5 mL/kg and an injection rate of 3–4 mL/s using an automatic injector, without enteric contrast use. Ten CT examinations were performed without contrast material injection because of renal insufficiency or allergy).

2.3 CT image analysis

All abdominal CT examinations were reviewed by two radiologists (C.H. and F.G., with three and six years of experience emergency imaging, respectively), blinded to each other on a Picture archiving and communication system (PACS) system workstation

(Carestream Health Inc.). Disagreements between the two radiologists were resolved during a joint analysis to obtain consensus opinion.

Readers were asked to assess the following features: (i), type of SV based on the whirl sign analysis of the transitional area and number of visible beaks (1 in organo-axial SV, 2 in mesenterico-axial SV) [15,16]; (ii), extension findings (liver overlap and/or extension to subphrenic space). Liver overlap was defined as the location, ventral to the liver, of the distended sigmoid colon. Extension to subphrenic space was evaluated in coronal sections and was defined as a contact between distended sigmoid colon and diaphragm ; (iii), diameter of the most distended sigmoid colon segment on axial CT images, labeled as larger colonic distension; (iiii), total liver volume, calculated after semi-automated contouring on a Carestream PACS workstation (Carestream Health Inc.) using an algorithm to perform interpolation between the marked slices; (v), left lateral section volume, using the same semi-automated technique, with left lateral section defined as the association of liver segments II and III [22,23]; (vi), signs of complicated SV that included absence of sigmoid wall enhancement (by comparison with a normal adjacent bowel), pneumoperitoneum, sigmoid mesenteric haziness and dark torsion knot sign (defined as the sudden loss of mucosal enhancement in the center of the whirl sign) [17]. Due to the assistance of semi-automatic contouring, hepatic volumes were assessed by only one radiologist (C.H.).

2.4 Statistical analysis

Continuous variables were expressed as means, standard deviations (SD) and ranges or, interquartile range (IQR) and ranges. Categorical variables were expressed as raw numbers, proportions and percentages. Comparisons between quantitative variables were performed using Student *t*-test or Mann-Whitney U test. Comparisons between qualitative

variables were performed using chi square (χ^2) or Fisher exact tests. Continuous variables were dichotomized according to their best area under the receiver operating characteristics curve (AUROC). Inter-reader agreement was analyzed using Cohen kappa test for qualitative variables and using Pearson correlation test for quantitative variables. Kappa values between 0.00–0.20; 0.21–0.40; 0.41–0.60; 0.61–0.80; and 0.81–1.00, indicated slight, fair, moderate, substantial, and almost perfect agreement, respectively [24]. Kappa values were reported with their 95% confidence (CI) intervals.

Qualitative CT features associated with SV recurrence at univariable analysis with a *P* value < 0.10 were entered into a multivariable logistic regression model. A simple score of SV probability recurrence was computed and presented as Kaplan Meier curves to illustrate free SV recurrence survival within six months following a first SV episode. A score with 1 point for each variable was used instead of a weighted score for the simplest possible use and considering that odds ratios (OR) of the two significant variables was similar. Performance of the early SV recurrence score was evaluated by means of the AUROC. All tests were two-sided. A *P* value < 0.05 was considered to indicate significant differences. All analyses were performed with R version 3.4.4 (R Core Team 2017).

3. Results

3.1. Patients

The study population included 59 men (62%) and 36 women (38%), with a mean age of 72 ± 15 (SD) (range: 57–87 years). There were 82 (86%) organo-axial SV and 13 (14%) mesenterico-axial SV. Clinical and biological findings of the 95 patients are summarized in **Table 1**. No patient had a positive qSOFA score.

3.2 .Recurrence of SV

SV recurrence occurred in 67/95 patients (71%) with a median delay of 19 days (IQR: 4–134 days) and among them, early SV recurrence was observed in 53 (79%) patients. There were no differences in clinical or biological features between patients with SV recurrence and those without (**Table 1**). CT features associated with early SV recurrence are displayed in **Table 2**. Patients with early SV recurrence had a larger colonic distension (10 ± 2.2 [SD]; range: 7.8–12.2 cm) than those without early recurrence (8.8 ± 1.6 cm; range: 7.2–10.4 cm) ($P = 0.004$). There were significantly more colonic distension > 10 cm in patients who experienced early SV recurrence (23/53; 43%) than in those who did not (8/42; 19%) ($P = 0.021$). Patients with early SV recurrence had a smaller left lateral section (119 ± 83 [SD] cm^3 ; range: 36–202 cm^3) than those without early SV recurrence (178 ± 117 [SD] cm^3 ; range: 61–295 cm^3) ($P = 0.008$). There were more patients with a left lateral section volume < 150 cm^3 in the group with early SV recurrence (42/53; 79%) than in the group without early SV recurrence (22/42; 52%) ($P = 0.008$). Inter-reader agreement towards maximal colon distension was almost perfect (kappa = 0.85; 95% CI: 0.69–1). Examples of main CT measures are presented in **Figure 2** and **Figure 3**.

Recurrent SV was not more severe than a SV. Among the 67 SV recurrences, 5/67 (7%) were complicated; four patients underwent immediate surgery following SV diagnosis and one patient died without surgery. Rates of complicated SV were not different between first SV (17/112; 15%) and recurrent SV (5/67; 7%) ($P = 0.16$).

3.3. Early SV recurrence score

Left lateral section < 150 cm³ and maximal colon distension > 10 cm were the two qualitative variables with a *P* value < 0.10 and were entered into a multivariable logistic regression model. At multivariable analysis, left lateral section < 150 cm³ and maximal colon distension > 10 cm were associated with early recurrence with corresponding OR of 4.62 (95% CI: 1.77–13.33; *P* = 0.002) and 4.43 (95% CI: 1.63–13.63, *P*= 0.005), respectively. A simple score combining these two features was developed with possible results being 0, 1, 2 and 3. Nineteen, 57 and 19 patients had an early SV recurrence score of 0, 1 and 2 respectively, associated with a rate of SV recurrence within six months of 5/19 (26%), 31/57 (54%) and 17/19 (89%) respectively.

Sensitivity and specificity for early SV recurrence diagnosis in patients with early-SV score ≥ 1 was 92% (49/53; 95% CI: 82–98) and 36% (15/42; 95% CI: 22–52), respectively. Accuracy of early-SV score ≥ 1 was 67% (64/95; 95% CI: 58–77). Sensitivity and specificity for early SV recurrence diagnosis in the patients with Early-SV score equal to 2 was 32% (17/53; 95% CI: 20–46) and 93% (39/42; 95% CI: 81–99,) respectively. Accuracy of early-SV score ≥ 1 was 59% (56/95; 95% CI: 49–69).

Kaplan-Meier curves of early SV recurrence according to the score are presented in **Figure 4**. AUROC for the score for early SV recurrence prediction was 0.70 (95% CI: 0.62–0.79). An algorithm for management after a first uncomplicated SV episode treated by endoscopic detorsion according to the score of SV probability recurrence is suggested in **Figure 5**.

4. Discussion

In our study, we observed that the prevalence of SV recurrence after a first uncomplicated episode was 71% and 79% of recurrences occurred within the following six months. Maximal colon distension > 10 cm and left lateral section < than 150 cm³ were the

two features associated with early recurrence at multivariable analysis. We established a simple predictive score for early SV recurrence after a first episode treated by endoscopic detorsion associating maximal colon distension (>10 cm) and left lateral section volume (<150 cm³) that allow stratification of early SV recurrence risk from 26 to 90%. AUROC for this score was 0.70 (95% CI: 0.62–0.79).

The prevalence of SV recurrence was high in our study and consistent the results of prior studies [3,18,25]. Yassaie et al. demonstrated the importance of early surgery after the first episode of SV in patients at low surgical risk because of the high risk of recurrence, but their study did not draw conclusions on the best management for patients with high surgical risk [7]. Indeed, patients with SV are most often elderly, with comorbidities and a surgical and anesthetic risk. SV surgery consists of sigmoidectomy, which is a major surgery for these frail patients and with a risk of anastomotic leakage in case of restorative surgery. Our new CT score may help in the management of patients presenting with a first SV episode, by selecting patients that will benefit from close prophylactic surgery following a first acute SV episode. The measurement of colon distension and the calculation of liver volumes are very easy and fast (only a few minutes), which allows our predictive score to be easily used in routine practice.

In patients with a score of 0 and at high risk of surgical complication, prophylactic colonic surgery might be avoided whereas in patients with a score of 1 and all the more in case of a score of 2, surgery must be strongly considered given the high risk of recurrence in the six months after a first SV episode (*i.e.*, 54 and 90% respectively).

The relationship between small left lateral section and SV has already been mentioned in some studies [26,27]. A small left lateral section may be constitutional, secondary to parenchymal atrophy or compressed by the distended, congestive sigmoid loop. We hypothesized that a small left lateral section would leave the epigastric region empty of any

solid organ, thus promoting the ascent of a sigmoid loop in the upper and central part of the abdomen, and thus facilitating the torsion of sigmoid loop.

In agreement with Kusunoki et al., maximal sigmoid colon distension was significantly associated with SV recurrence [18]. Colon distension may reflect the peritoneal space. Hence, the more distended the colon, the more space there is in the peritoneal cavity, and the greater the risk of recurrence. In our study, we established a cut off value of 10 cm for colon distension versus 8.9 cm for Kusunoki et al. [18]. Kusunoki et al. also reported what they labeled “extension findings” (extension to subphrenic space and liver overlap) like risk factors of SV recurrence [18]. In our study, unlike them, extension findings were not significantly associated with SV recurrence risk. This could be explained by the few patients with positive extension findings.

An unenhanced acquisition was obtained in a quasi-systematic way in our study in the two centers. The unenhanced phase helps analyze the spontaneous attenuation of the bowel wall and further assess degree of enhancement [28]. In several centers, only one acquisition during the portal venous phase is performed to reduce radiation dose. However, considering the aging population of our study (i.e., mean age of 72 years), the risk related to radiation exposure is mild. Moreover, the increased use of low dose, ultra-low dose CT and iterative reconstructions algorithms tend to reduce radiation exposure for patients requiring CT for abdominal emergencies [29–31].

Our study has several limitations. Some patients may have had a recurrence of SV at another institution than our two centers. However, most patients are institutionalized with little independence. Thus, their medical follow-up is probably performed in the same center, reducing the risk of being lost to follow-up. The two university hospitals in our study are in the same geographic area, which also reduces the risk of patients being lost during follow-up. Finally, maximal colon distension was measured in transversal CT sections and does not

correspond exactly to the maximal value that could be measured after multiplanar reconstruction. However, this method of measurement is easier to perform, is more reproducible with excellent inter-reader agreement, thus making the predictive score quick to use in clinical practice.

In conclusion, our study shows that abdominal CT provides useful features to stratify the risk of early recurrence in patients with SV, namely maximal colon distension > 10 cm and left lateral section volume < 150 cm³. A simple score using these two CT features was developed to stratify the risk of early SV recurrence, and thus to better select patients who would not benefit from prophylactic colonic surgery because of a low risk for SV recurrence.

Human rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors have no conflicts of interest to declare. The authors did not receive support from any organization for the submitted work.

Authors contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

CRedit authorship contribution statement

Claire Humbert: Conceptualization – Investigation- Writing - Original Draft - Writing - Review & Editing

Franck Grillet: Conceptualization – Methodology - Investigation - Writing - Original Draft- Writing - Review & Editing

Alexandre Malakhia: Investigation - Writing - Original Draft

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Romarc Loffroy: Writing - Original Draft

Paul Calame: Conceptualization- Methodology -Formal analysis -Writing - Original Draft- Writing - Original Draft- Visualization

Eric Delabrousse: Conceptualization- Validation - Writing - Original Draft -Writing - Review & Editing- Supervision

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Figures legend

Figure 1: Flowchart shows patient selection process based on inclusion and exclusion criteria
CT: Computed tomography

Figure 2. A 48-year-old woman presenting a first uncomplicated episode of sigmoid volvulus.

a: Abdominal computed tomography (CT) image in the axial plane obtained during the portal venous phase shows a maximal colon distension of 8 cm (double arrow).

b: Measurement of liver volume shows a left lateral section (in purple) volume of 210 cm³.
Early recurrence score was calculated at 0. Patient had no sigmoid volvulus recurrence.

Figure 3. A 66-year-old man presenting with a first uncomplicated episode of sigmoid volvulus.

a: Abdominal computed tomography (CT) in the axial plane obtained during the portal venous phase shows a maximal colon distension of 10.5 cm (double arrow)

b: Measurement of liver volume shows a left lateral section (in purple) volume of 110 cm³.
Early recurrence score was calculated at 2. Patient had sigmoid volvulus recurrence 23 days after the first episode.

Figure 4: Graph shows Kaplan-Meier curves of time to recurrence according to the early sigmoid volvulus recurrence score.

CT= Computed tomography; SV= Sigmoid volvulus

Figure 5: Algorithm for management after a first uncomplicated SV episode, treated endoscopically.

CT = Computed tomography; SV = Sigmoid volvulus

289 consecutive patients with sigmoid volvulus from January 1st 2006 to July 31st 2021

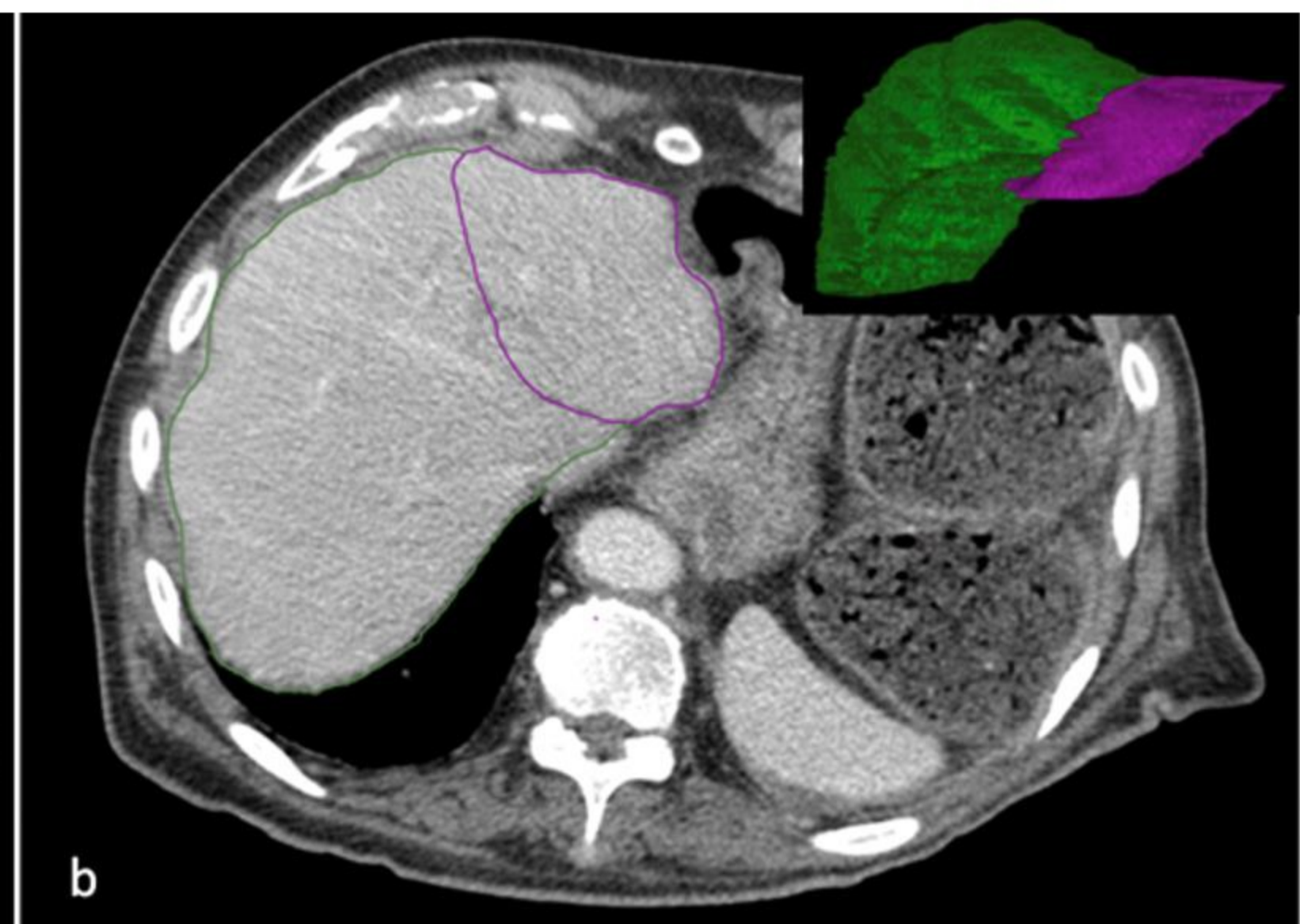
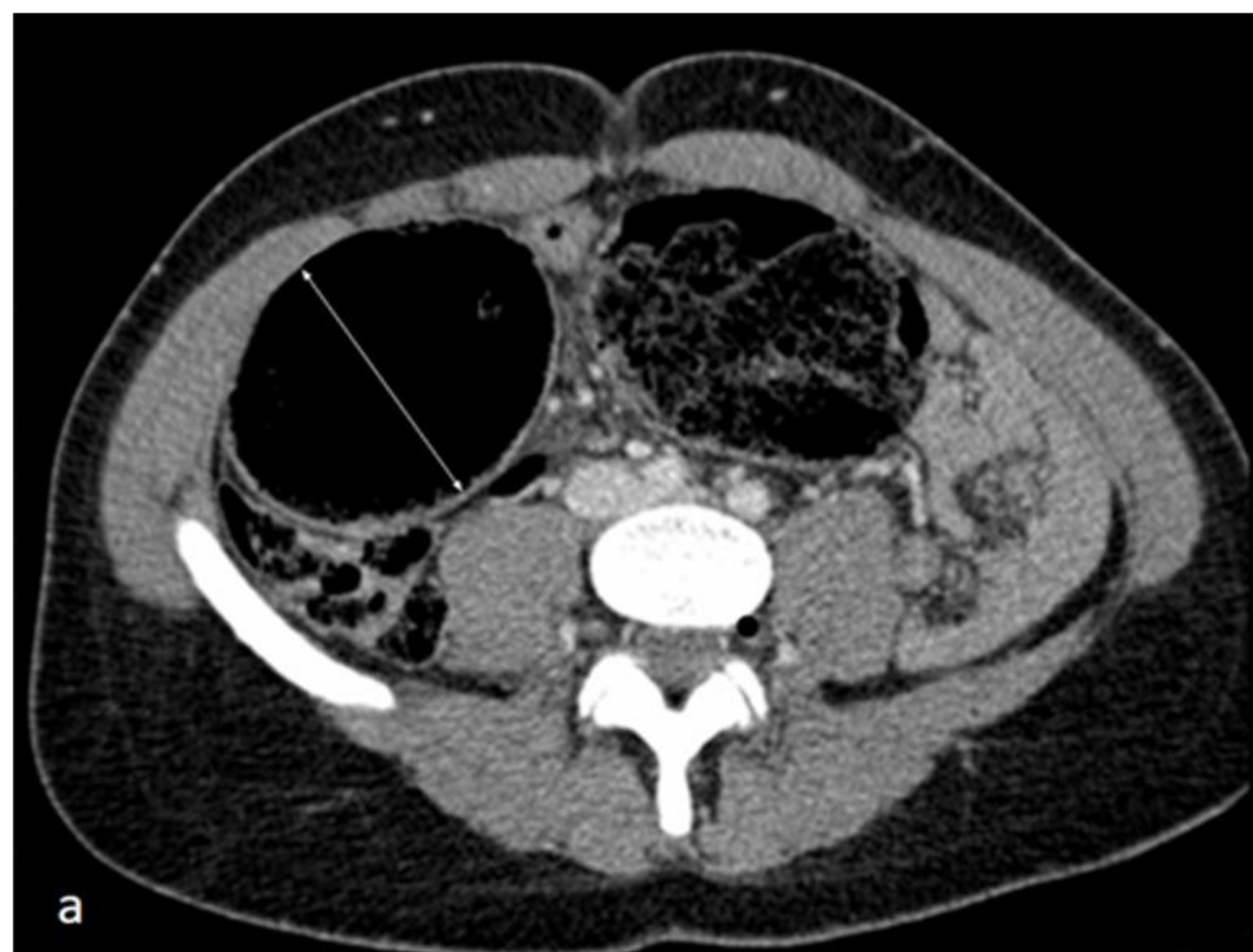
124 patients with a first episode of sigmoid volvulus with available CT examination

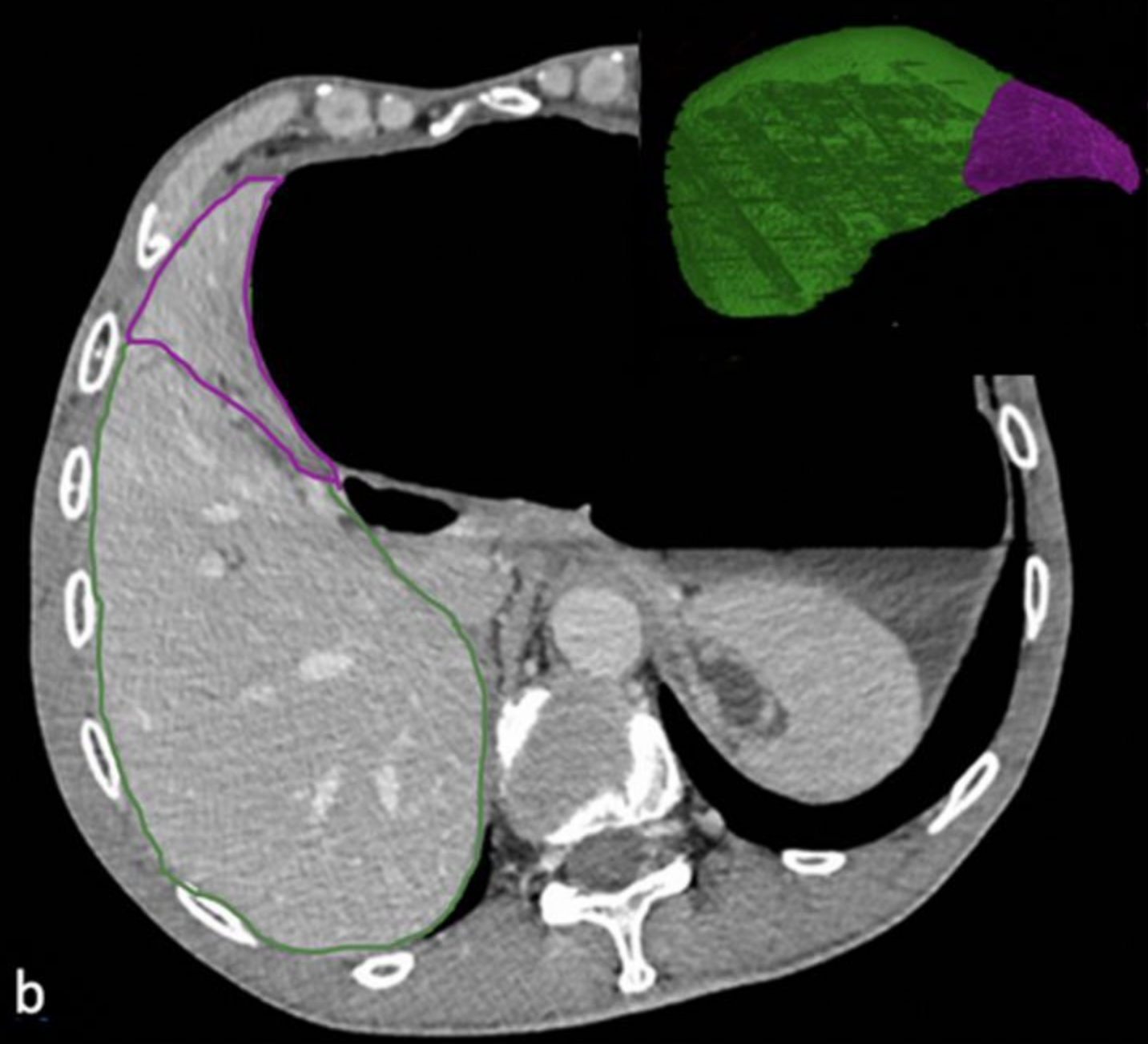
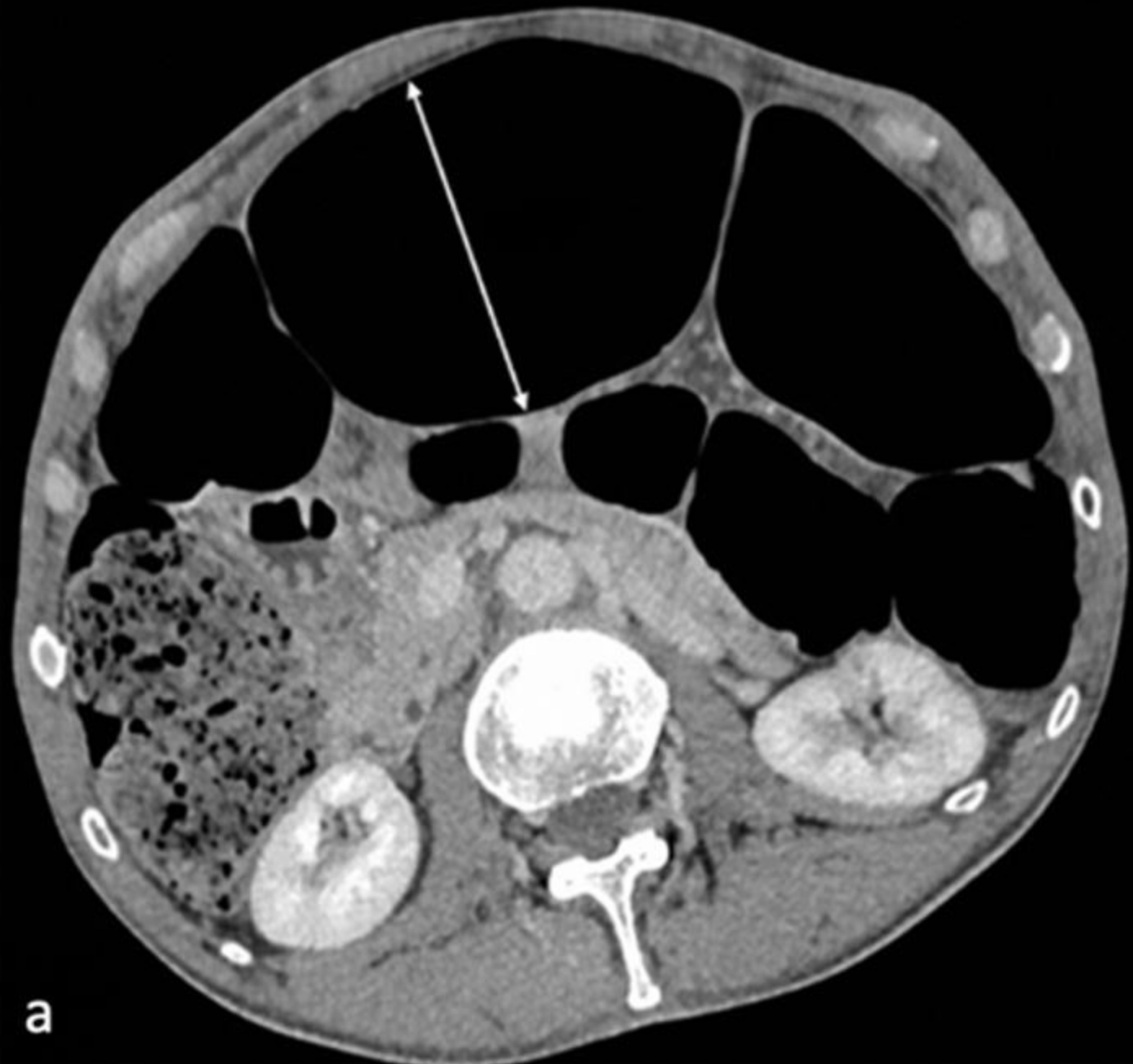
95 patients with uncomplicated sigmoid volvulus with available CT examination

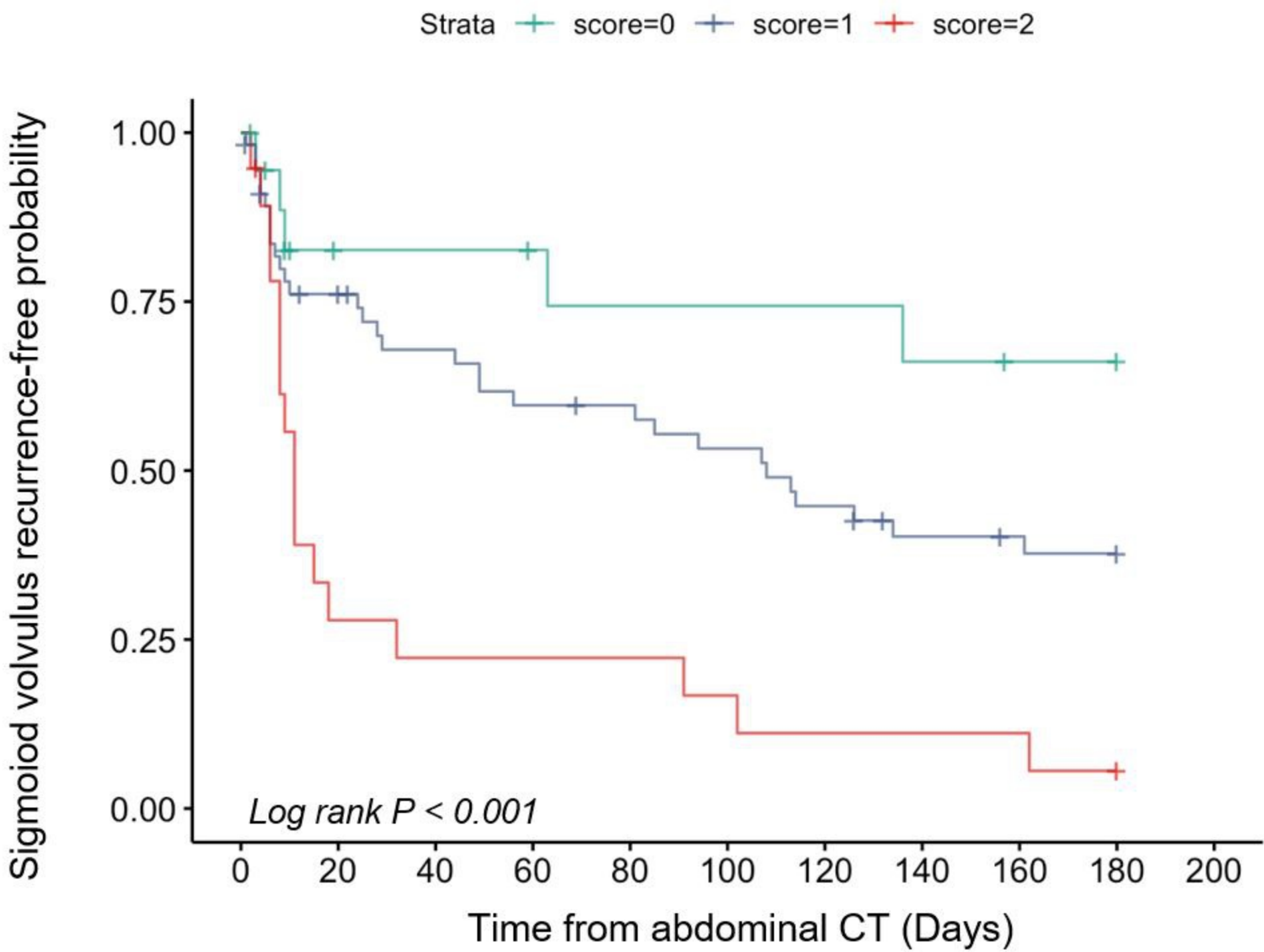
53 patients with early sigmoid volvulus recurrence
42 patients with no early sigmoid volvulus recurrence

Excluded patients (n = 165)
78 without available CT examination
87 with recurrence of sigmoid volvulus

Patients not included (n = 29)
13 with urgent surgery without endoscopy
14 with urgent surgery following endoscopy
2 who died without surgery or endoscopy







Number at risk

Strata	0	20	40	60	80	100	120	140	160	180	200
score=0	19	11	11	10	9	9	9	8	7	7	0
score=1	57	39	33	29	28	25	21	17	16	15	0
score=2	19	5	4	4	4	3	2	2	2	1	0

Time

First episode of uncomplicated sigmoid volvulus

Early recurrence CT score calculation

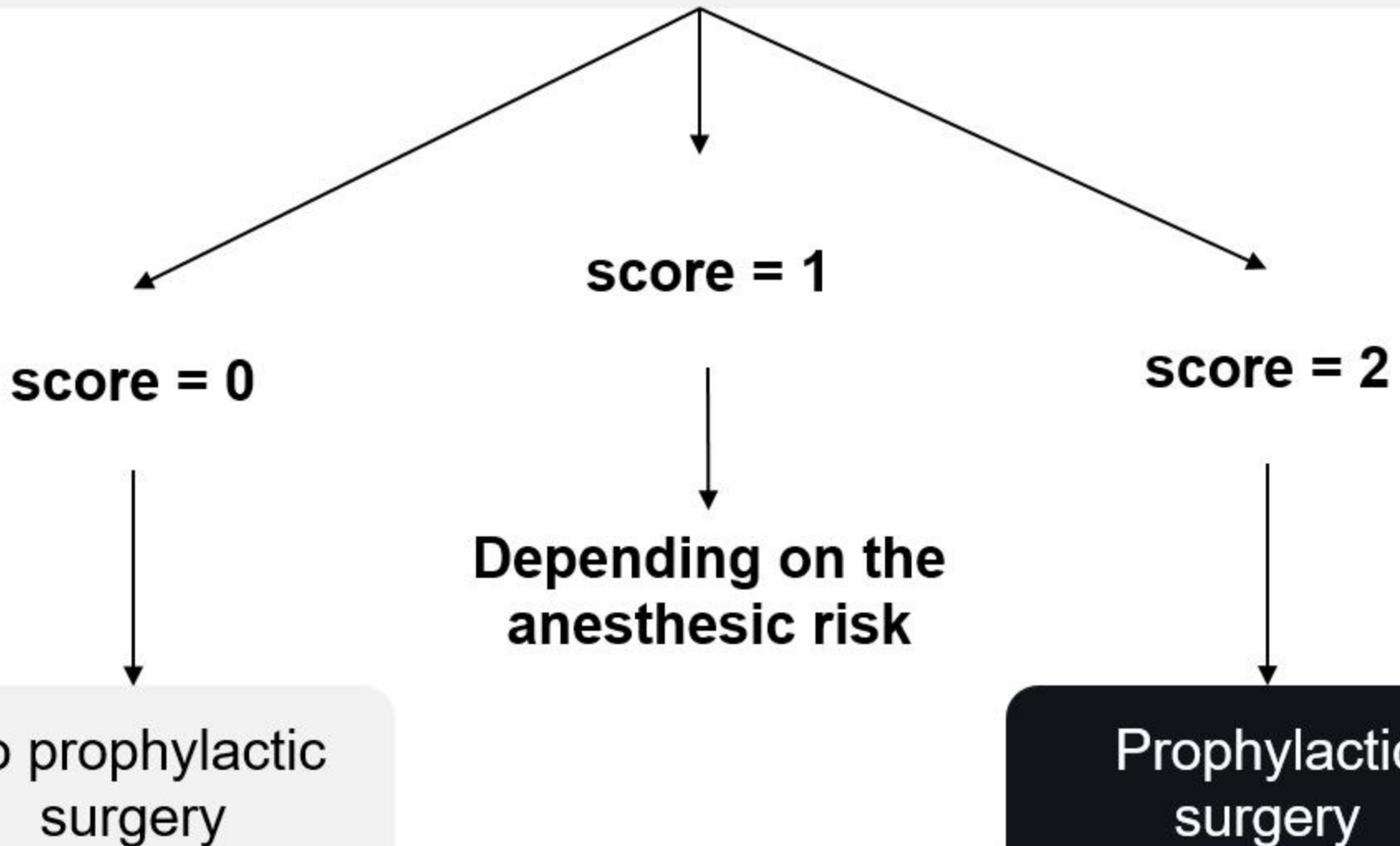


Table 1. Characteristics of the study population

	Total population (n = 95)	Early SV recurrence (n = 53)	No early SV recurrence (n = 42)	P value
Baseline characteristics				
Age (year)*	72 ± 15 [57-87]	73 ± 15 [58-88]	70 ± 15 [55-85]	0.362
Men	59 (62)	32 (60)	27 (64)	0.49
Neuropsychiatric disorder	59 (62)	34 (64)	25 (60)	0.643
Initial features				
Abdominal pain	60 (63)	39 (74)	21 (50)	0.070
Abdominal tenderness	75 (79)	41 (77)	34 (81)	>0.99
Rectal bleeding	3 (3)	3 (6)	0 (0)	0.551
Lactic acid > 2 mmol/L	5 (5)	3 (6)	2 (5)	0.639
Sepsis (qSOFA)	0 (0)	0 (0)	0 (0)	>0.99
CRP	28 (30)	19 (36)	9 (21)	0.466

CRP = C-reactive protein; SV= Sigmoid volvulus; qSOFA= quick Sepsis-related Organ Failure Assessment;

* Age is expressed as mean ± standard deviation; number in brackets are ranges.

Numbers in parentheses are percentages.

Table 2. CT features associated with early sigmoid volvulus recurrence at univariable analysis

CT features	Total population (n = 95)	Early SV recurrence (n = 53)	No early SV recurrence (n = 42)	P value	Kappa (95% CI)
Type of SV					
Mesenterico-axial	13 (14%)	8 (15%)	5 (12%)	0.881	0.81 [0.6–1]
Organo-axial	82 (86%)	45 (85%)	37 (88%)		
Severity features					
Dark torsion knot sign	8 (8%)	5 (9%)	3 (7%)	0.058	0.72 [0.47–0.98]
Absence of colonic wall enhancement	5 (5%)	5 (9%)	0 (0%)	0.060	0.73 [0.59–0.86]
Thinned wall	19 (20%)	14 (26%)	5 (11.9%)	0.120	0.64 [0.32–0.97]
Mesenteric fluid	47 (49%)	28 (53%)	19 (45%)	0.537	0.73 [0.59–0.86]
Abdominal features					
Extension findings	32 (34%)	13 (25%)	9 (21%)	0.912	0.96 [0.89–1]
Maximal colon distension (cm)	9.48 ± 2.06 [7.42–11.54]	10 ± 2.24 [7.76–12.24]	8.83 ± 1.6 [7.23–10.43]	0.004	0.93 [0.90–0.94] *
Colon distension > 10 cm	31 (33%)	23 (43%)	8 (19%)	0.021	0.85 [0.69–1]
Liver volume (cm ³)	1241 ± 349 [892–1590]	1214 ± 313 [901–1527]	1275 ± 391 [884–1666]	0.417	N.A.
Left lateral section volume (cm ³)	145 ± 103 [42–248]	119 ± 83 [36–202]	178 ± 117 [61–295]	0.008	N.A.
Relative left lateral section volume (%)	11 ± 6 [5–17]	10 ± 6 [4–16]	13 ± 7 [6–20]	0.015	N.A.
Left lateral section volume < 150 cm ³	64 (67%)	42 (79%)	22 (52%)	0.008	N.A.

CRP = C-reactive protein; CT= Computed tomography; N.A. = Not applicable; OR = Odds ratio; SV= sigmoid volvulus; Number in parentheses are %. Numbers in brackets are ranges or 95% confidence intervals.

* Results show Pearson coefficient correlation. Bold indicates significant *P* value