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WJGS mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal surgery and covering a wide range of topics including biliary tract surgical procedures, biliopancreatic diversion, colectomy, esophagectomy, esophagostomy, pancreas transplantation, and pancreatectomy, etc.

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Retrospective Cohort Study

## Predicting the outcome of closed-loop small bowel obstruction by preoperative characteristics

Masja K Toneman, Bente M de Kok, Frank M Zijta, Stanley Oei, Gijs J D van Acker, Marinke Westerterp, Anne E M van der Pool

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### Abstract

#### BACKGROUND

Closed-loop small bowel obstruction (CL-SBO) can threaten the viability of the intestine by obstructing a bowel segment at two adjacent points. Prompt recognition and surgery are crucial.

#### AIM

To analyze the outcomes of patients who underwent surgery for CL-SBO and to evaluate clinical predictors.

#### METHODS

Patients who underwent surgery for suspected CL-SBO on computed tomography (CT) at a single center between 2013 and 2019 were evaluated retrospectively. Patients were divided into three groups by perioperative outcome, including viable bowel, reversible ischemia, and irreversible ischemia. Clinical and laboratorial variables at presentation were compared and postoperative outcomes were analyzed.

#### RESULTS

Of 148 patients with CL-SBO, 28 (19%) had a perioperative viable small bowel, 86 (58%) had reversible ischemia, and 34 (23%) had irreversible ischemia. Patients with a higher age had higher risk for perioperative irreversible ischemia [odds ratio (OR): 1.03, 95% confidence interval (CI): 0.99-1.06]. Patients with American Society of Anaesthesiologists (ASA) classification  $\geq 3$  had higher risk of perioperative irreversible ischemia compared to lower ASA classifications (OR: 3.76, 95%CI: 1.31-10.81). Eighty-six patients (58%) did not have elevated C-reactive protein ( $> 10$  mg/L), and between-group differences were insignificant. Postoperative in-hospital stay was significantly longer for patients with irre-



versible ischemia (median 8 d,  $P = 0.001$ ) than for those with reversible ischemia (median 6 d) or a viable bowel (median 5 d). Postoperative morbidity was significantly higher in patients with perioperative irreversible ischemia (45%,  $P = 0.043$ ) compared with reversible ischemia (20%) and viable bowel (4%).

## CONCLUSION

Older patients or those with higher ASA classification had an increased risk of irreversible ischemia in case of CL-SBO. After irreversible ischemia, postoperative morbidity was increased.

**Key Words:** General surgery; Laparoscopy; Laparotomy; Critical care; Intestinal obstruction; Morbidity

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**Core Tip:** We studied the preoperative characteristics and postoperative outcomes of 148 patients with closed-loop small bowel obstruction, based on the perioperative small bowel viability (viable, reversible ischemia, or irreversible ischemia). Retrospective evaluation found that older age or an American Society of Anesthesiologists classification of 3 or higher increased the risk of perioperative irreversible ischemia. C-reactive protein (CRP) that is not increased above normal levels does not assure the presence of a viable bowel, and 55.83% of patients with ischemia had normal CRP levels. Perioperative irreversible ischemia significantly increased postoperative morbidity. These risks should be mentioned in preoperative consultations.

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## INTRODUCTION

Small bowel obstructions (SBOs) are a common cause of (sub)acute abdominal pain in patients presenting to the emergency department, and account for approximately 300000 hospitalizations in the United States annually[1]. Simple SBOs that occur at one site because of a single adhesion may allow conservative treatment without surgery[2-4]. However, in about 10% of SBOs, the intestine is occluded at two separate sites at one anatomic location because of adhesions, internal herniation, or torsion of the small bowel[5-7]. Such closed-loop SBOs (CL-SBOs) present with (sub)acute abdominal pain, vomiting, abdominal distension, and sometimes obstipation[6,8,9].

In cases of CL-SBO, viability of the small bowel is threatened by the possibility of strangulation. Three factors increase the risk of strangulation and indicate emergency surgery, external compression of the vascular pedicle of the closed loop at the obstruction site, distension of the closed loop, and/or volvulus of the closed loop with twisting of its mesentery[5]. If a strangulated small bowel is not surgically released, bowel wall ischemia and necrosis can occur, which increase the risk of septic shock and other complications[10]. Prompt recognition and surgery are crucial to achieve a good patient outcome and to preserve the involved bowel.

To date, most studies have evaluated patients with SBOs by comparing surgical *vs* conservative treatments[2]. Studies for CL-SBOs have mostly focused on aspects of computed tomography (CT) imaging[5,11-13]. The perioperative findings of previous studies vary and there is often a lack information on the postoperative outcomes. The aim of this single-center study was to analyze the perioperative and postoperative outcomes of patients with CT imaging consistent with CL-SBOs, and to evaluate clinical predictors.

## MATERIALS AND METHODS

### Patients and study design

A series of Dutch patients who underwent surgery for suspected CL-SBOs between September 2013 and September 2019 were included. Potential patients were retrieved from a medical records database that included all abdominal surgeries involving the small bowel. Patients with a preoperative CT scan that diagnosed CL-SBO, defined as an SBO with two contiguous caliber changes at a single anatomic

location, were eligible for inclusion. Patients with bowel obstructions caused by external abdominal herniation (*e.g.*, inguinal or umbilical hernia) or malignancy, or with a history of bariatric surgery or surgery with Roux-and-Y reconstruction were excluded. Patients with Roux-and-Y surgery were excluded because of the difference in clinical presentation with intermittent and subacute pain, and difference in perioperative aetiology, *i.e.* small bowel herniation through an iatrogenic defect created in the mesentery[14,15].

The regional Medical Ethical Testing Committee evaluated the study protocol and declared that the law on medical scientific research concerning humans was not applicable because of the non-invasive and retrospective nature of the study. The scientific board of our hospital approved the study, and the need for written informed consent was waived. However, every patient file was checked for notes of refusal to participate in scientific research. No patients were excluded on that basis.

### **Patient characteristics**

Age, sex, American Society of Anesthesiologists (ASA) classification[16], body mass index and history of abdominal surgery were obtained from medical records. The presence of abdominal pain, vomiting, obstipation (no stool for > 24 h), and abdominal guarding, as well as vital signs, including tachycardia (> 100 beats/min), tachypnoea (> 20 breaths/min), and fever (body temperature > 38.5 °C) had been recorded at the initial evaluation. Blood and laboratory tests at presentation included measures of hematocrit, thrombocyte and white blood cell (WBC) count, C-reactive protein (CRP), creatinine, urea, lactate dehydrogenase, creatine kinase, albumin, and glucose.

Patients were divided into three groups based on the perioperative findings, including viable bowel, reversible bowel wall ischemia, and irreversible bowel wall ischemia. The small bowel was considered viable when the affected region between the two sites of obstruction did not show signs of discoloration before the obstruction was released. Reversible ischemia required that a discolored portion of the small bowel regained normal color within 5 min after surgical release and repositioning of the bowel. If there was no evident return to viable bowel in 5 min, but a clear increase in color did occur, we waited a maximum of 20 min, as previously described[17]. If recoloration did not occur after release of the obstruction, the ischemia was considered irreversible and the affected bowel was resected. The type of surgery (laparoscopy/laparotomy), whether a resection was performed, and type of anastomosis (hand sutured/stapled) was recorded. The intervals between the onset of symptoms and CT imaging and between CT imaging and the start of surgery were recorded in hours of time. Postoperative data collected were length of hospital stay (days) and postoperative complications, which were recorded following the Clavien–Dindo classification[18].

### **Imaging**

For all included patients, CT imaging was performed with or without contrast and including the arterial and/or portal venous phase. The original radiology reports were scored for suspicion of small bowel ischemia because of CL-SBO and graded as no suspicion of ischemia, inconclusive, or strong suspicion of ischemia. Grades were based on suspicion of ischemia in the original radiology report. Imaging features reported in the original radiology report, such as decreased enhancement of mesenteric vessels and the bowel wall and the presence of peritoneal fluid or pneumatosis intestinalis, were taken into account.

### **Statistical analysis**

The statistical analysis was performed with SPSS version 22 (IBM Corp., Armonk, NY, United States). Categorical data were reported as numbers and percentages. Differences between proportions were compared with chi-square or Fisher's exact tests, as appropriate. Continuous data with a significantly skewed distribution were reported as medians and were compared using Kruskal–Wallis test. Univariate analysis was performed to identify whether any clinical characteristics were associated with specific perioperative outcomes. For characteristics with significant between-group differences, odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated through logistic regression. The significance level was set at  $P < 0.05$ .

## **RESULTS**

### **Patients**

A series of 148 patients included in a database of 763 patients (19.40%) with abdominal surgery of the small bowel between September 2013 and September 2019 met the inclusion criteria. In total, 28 patients (18.92%) had perioperative viable small bowel, 86 patients (58.11%) had reversible ischemia, and 34 patients (22.97%) had irreversible ischemia and resection. The baseline characteristics are shown in Table 1. Fifty-eight percent of patients (86/148) had previous abdominal surgery. Between-group differences were not significant. The median ages of the groups were significantly different, and the patients with irreversible ischemia were the oldest. Patients with irreversible ischemia were significantly

**Table 1** Baseline characteristics of patients in the three study groups

Baseline characteristics	Total, <i>n</i> = 148	Viable bowel, <i>n</i> = 28	Reversible ischemia, <i>n</i> = 86	Irreversible ischemia, <i>n</i> = 34	<i>P</i> value
Male, <i>n</i> (%)	64 (43.24)	13 (46.43)	41 (47.67)	10 (29.41)	0.18
Age in yr, median (range)	68 (15–98)	57 (35–98)	68 (15–93)	76 (23–92)	0.04
ASA classification (%)					0.01
1–2	82 (55.41)	18 (64.29)	53 (61.63)	11 (32.35)	
≥ 3	66 (44.59)	10 (35.71)	33 (38.37)	23 (67.65)	
BMI in kg/m <sup>2</sup> , median (range)	24 (16–35)	23 (17–31)	24 (16–35)	23 (18–30)	0.89
Previous abdominal surgery, median (%)	86 (58.11)	19 (67.86)	45 (52.33)	22 (64.71)	0.24

ASA: American Society of Anaesthesiologists; BMI: Body mass index.

more frequently classified as ASA ≥ 3. The ORs of these two characteristics are shown in [Table 2](#).

All 148 patients presenting to the emergency department with CL-SBO had abdominal pain that was accompanied by vomiting in 112 (75.68%) and obstipation in 43 (29.05%). Fifteen patients (10.14%) presented with abdominal guarding and four (2.82%) presented with fever (body temperature > 38.5 °C); between-group differences were not significant ([Table 3](#)). Tachycardia was reported in 26 patients (17.67%) and tachypnoea in 30 of the 75 patients with that information (40.00%). The occurrence of tachycardia and tachypnoea on admission did not differ significantly in the three study groups ([Table 3](#)).

### Blood and laboratory results

One hundred patients (67.57%) had elevated WBC counts and sixty-six patients (44.90%) had an elevated CRP, but between-group differences were not significant ([Table 4](#)). The median values of the other laboratory results ([Table 5](#)) were within the normal ranges and no significant between-group differences were observed. Arterial blood gases were analyzed in only 9 patients; hence, no conclusions could be drawn.

### CT imaging

The baseline evaluation of the CT scans included no suspicion of ischemia in 18 of the 28 patients (64.29%) with a perioperative viable bowel. The reports for the other 10 patients were inconclusive ([Table 6](#)). When ischemia was found during surgery, more than half of the radiology reports had been inconclusive for the suspicion of ischemia (78/148, 52.70%). Strong suspicion of ischemia was reported in only 13.96% of the patients with reversible ischemia (12/86) and 38.24% of patients with irreversible ischemia (13/34).

### Timing

Although the interval between the onset of symptoms and surgery was very variable (2–264 h), the differences in the median hours for the three groups were not significant ([Table 7](#)).

### Surgery

In all 34 patients with irreversible ischemia, the affected bowel was resected. The median length of the resected bowel was 45 (range: 30–100) cm. In 30 patients (88.24%), bowel continuity was restored with either a hand-sutured (53.33%) or stapled (46.67%) anastomosis. In 3 patients (9.00%), a temporary ileostomy was constructed. A laparotomy was performed in 128 of the 148 patients (86.49%). In 5 of the patients with viable bowel (17.86%), the obstruction was relieved laparoscopically. Laparoscopic procedures were performed in 13 patients (15.11%) with reversible ischemia and in 2 (5.88%) with irreversible ischemia.

### Postoperative course

The median postoperative hospital stay was 5 (range: 2–13) d for patients with a viable bowel, 6 (range: 2–45) d for those with reversible ischemia, and 8 (range: 3–45) d for those with irreversible ischemia (*P* = 0.001). Only 32 of 148 patients (21.62%) had postoperative complications ([Table 8](#)). Only 1 of those patients was in the viable bowel group. Postoperative morbidity was reported in 44.11% (15/34) of patients with irreversible ischemia and resection, which was significantly higher (*P* = 0.043) than the frequency in those with reversible ischemia (19.77%, 17/86) and viable bowel (3.57%, 1/28). With reference to the patients with preoperative viable bowel, the ORs for postoperative complications was



**Table 2 Logistic regression of predictors of perioperative ischemia**

Patient characteristics	Viable bowel, OR (95%CI)	Reversible ischemia, OR (95%CI)	Irreversible ischemia, OR (95%CI)
Age	Ref.	1.01 (0.98-1.03)	1.03 (0.99-1.06)
ASA classification			
1-2	Ref.	Ref.	Ref.
≥ 3	Ref.	1.12 (0.46-2.72)	3.76 (1.31-10.81)

ASA: American Society of Anaesthesiologists; CI: Confidence interval; OR: Odds ratio.

**Table 3 Clinical symptoms and vital signs at presentation**

Signs at presentation	Overall, <i>n</i> = 148	Viable bowel, <i>n</i> = 28	Reversible ischemia, <i>n</i> = 82	Irreversible ischemia, <i>n</i> = 34	<i>P</i> value
Vomiting, <i>n</i> (%)					0.07
No	36 (24.32)	9 (32.14)	15 (17.44)	12 (35.29)	
Yes	112 (75.68)	19 (67.86)	71 (82.56)	22 (64.71)	
Obstipation <sup>1</sup> , <i>n</i> (%)					0.60
No	105 (70.95)	22 (78.57)	60 (69.77)	23 (67.65)	
Yes	43 (29.05)	6 (21.43)	26 (30.23)	11 (32.35)	
Abdominal guarding, <i>n</i> (%)					0.35
No	133 (89.86)	27 (96.43)	77 (89.53)	29 (85.29)	
Yes	15 (10.14)	1 (3.57)	9 (10.47)	5 (14.71)	
Heart rate <sup>2</sup> , <i>n</i> (%)					0.42
Bradycardia	2 (1.35)	0 (0.00)	1 (1.16)	1 (2.94)	
Normocardia	120 (81.08)	26 (92.86)	67 (77.91)	27 (79.41)	
Tachycardia	26 (17.67)	2 (7.14)	18 (20.93)	6 (17.65)	
Respiratory rate <sup>3,4</sup> , <i>n</i> (%)					0.50
Normopnoea	45 (60.00)	9 (69.23)	27 (64.29)	9 (45.00)	
Tachypnea	30 (40.00)	4 (30.77)	15 (35.71)	11 (55.00)	
Fever <sup>5</sup> , <i>n</i> (%)					0.52
No	138 (97.18)	25 (96.15)	79 (96.34)	34 (100.00)	
Yes	4 (2.82)	1 (3.85)	3 (3.66)	0 (0.00)	

<sup>1</sup>Obstipation: No defecation > 24 h.

<sup>2</sup>Bradycardia: ≤ 50 beats/min; Normocardia: 50-100 beats/min; Tachycardia: > 100 beats/min.

<sup>3</sup>Normopnoea: < 20 breaths/min; Tachypnoea: > 20 breaths/min.

<sup>4</sup>11 patients missing, *n* = 137.

<sup>5</sup>Fever: > 38.5 °C body temperature.

6.65 (95%CI: 0.84-52.47) in patients with reversible ischemia and 19.89 (95%CI: 2.40-164.42) in those with irreversible ischemia.

Severe Clavien-Dindo classification ≥ IIIa complications occurred in 12 patients (14%) with reversible ischemia and in 10 (30%) with irreversible ischemia. Twelve re-exploration procedures were performed during postoperative recovery; one was for an intra-abdominal abscess with ileus in a patient in the viable bowel group. Three patients with reversible ischemia required re-exploration for a suspected perforation, which was not confirmed. Hence, no additional small bowel resection was performed. Two re-exploration procedures resulted in small bowel resection after initial surgery with irreversible ischemia; one was performed because of intra-abdominal bleeding and the other because of an ischemic colostomy that required reversion. In addition, 2 patients developed respiratory insufficiency and 1 patient was septic; no explanation was found during re-exploration.

**Table 4 Patient characteristics and findings of perioperative ischemia**

Infection parameters at presentation	Overall, <i>n</i> = 148	Viable bowel, <i>n</i> = 28	Reversible ischemia, <i>n</i> = 86	Irreversible ischemia, <i>n</i> = 34	<i>P</i> value
WBC, median (%)					
4.5–11 × 10 <sup>9</sup> /L	48 (32.43)	9 (32.14)	31 (36.05)	8 (23.53)	0.42
> 11 × 10 <sup>9</sup> /L	100 (67.57)	19 (67.86)	55 (63.95)	26 (76.47)	
CRP, median (%)					0.92
1–10 mg/L	82 (55.10)	15 (53.57)	49 (56.47)	18 (52.94)	
11–74 mg/L	38 (25.85)	7 (25.00)	23 (27.06)	8 (23.53)	
> 75 mg/L	28 (19.05)	6 (21.43)	14 (16.47)	8 (23.53)	

CRP: C-reactive protein; WBC: White blood cell.

**Table 5 Blood and laboratory results in the three study groups**

Laboratory results at presentation	Overall, median (range)	Viable bowel, median (range)	Reversible ischemia, median (range)	Irreversible ischemia, median (range)	<i>P</i> value
Haematocrit, L/L	0.43 (0.31–0.59)	0.43 (0.37–0.52)	0.44 (0.34–0.59)	0.42 (0.31–0.53)	0.34
Thrombocytes × 10 <sup>9</sup> /L	263.00 (145.00–687.00)	280.50 (161.00–687.00)	266.00 (145.00–650.00)	235.50 (148.00–511.00)	0.20
WBCs × 10 <sup>9</sup> /L	11.80 (4.0–27.2)	12.40 (4.80–21.30)	11.55 (4.00–25.00)	12.00 (5.50–27.20)	0.33
CRP, mg/L	6.00 (1.00–630.00)	6.00 (1.00–216.00)	5.50 (1.00–630.00)	5.00 (1.00–434.00)	0.84
Creatinine, μmol/L	80.00 (38.00–785.00)	81.00 (53.00–141.00)	80.00 (38.00–785.00)	81.00 (45.00–258.00)	0.97
Urea, mmol/L	6.60 (2.30–30.60)	5.95 (2.70–23.10)	6.40 (2.30–30.60)	7.60 (3.00–20.70)	0.33
LDH, U/L	208.00 (109.00–333.00)	184.00 (142.00–309.00)	210.00 (109.00–309.00)	208.00 (151.00–333.00)	0.15
CK, U/L	112.00 (24.00–472.00)	107.50 (30.00–207.00)	127.50 (51.00–472.00)	95.00 (24.00–192.00)	0.47
Albumin, g/L	44.00 (36.00–52.00)	43.00 (36.00–50.00)	44.00 (37.00–52.00)	40.50 (37.00–51.00)	0.10
Glucose, mmol/L	8.00 (5.00–15.60)	7.40 (5.40–12.20)	8.00 (5.00–15.60)	8.20 (5.10–15.00)	0.19

CK: Creatine kinase; CRP: C-reactive protein; LDH: Lactate dehydrogenase; WBC: White blood cell.

**Table 6 Suspicion of ischemia on computed tomography imaging in the three study groups**

Grading of initial radiology reports	Viable bowel, <i>n</i> = 28	Reversible ischemia, <i>n</i> = 86	Irreversible ischemia, <i>n</i> = 34
No suspicion of ischemia, <i>n</i> (%)	18 (64.29)	23 (26.74)	4 (11.76)
Inconclusive, <i>n</i> (%)	10 (36.71)	51 (59.30)	17 (50.00)
Strong suspicion of ischemia, <i>n</i> (%)	0	12 (13.96)	13 (38.24)

Ten patients (6.76%) died during their hospital stay following surgery, including seven of eight-six with reversible ischemia (8.14%) and three of thirty-four with irreversible ischemia (8.82%). None of the patients with perioperative viable small bowel died after surgery. The causes of death were multiorgan failure because of postoperative systemic inflammatory response syndrome, aspiration, and pneumonia with congestive heart failure.

**Table 7 Intervals between onset of symptoms and computed tomography and surgery in the three study groups**

Intervals	Viable bowel, <i>n</i> = 28	Reversible ischemia, <i>n</i> = 86	Irreversible ischemia, <i>n</i> = 34	<i>P</i> value
Onset of symptoms to CT, median (range)	16.50 h (2.00–120.00 h)	20.50 h (1.00–260.00 h)	18.00 h (2.00–120.00 h)	0.79
CT to surgery, median (range)	4.00 h (1.00–65.00 h)	4.00 h (1.00–51.00 h)	4.00 h (1.00–71.00 h)	0.98
Onset of symptoms to surgery, median (range)	23.00 h (3.00–124.00 h)	26.00 h (2.00–264.00 h)	25.50 h (5.00–126.00 h)	0.91

CT: Computed tomography.

**Table 8 Clavien–Dindo classification of complications and perioperative findings**

Clavien–Dindo	Overall, <i>n</i> = 148	Viable bowel, <i>n</i> = 28	Reversible ischaemia, <i>n</i> = 86	Irreversible ischaemia, <i>n</i> = 34
No complications, <i>n</i> (%)	115 (77.70)	27 (96.43)	69 (80.23)	19 (55.88)
Grade I, <i>n</i> (%)	3 (2.03)	0 (0.00)	2 (2.33)	1 (2.94)
Grade II, <i>n</i> (%)	7 (4.73)	0 (0.00)	3 (3.49)	4 (11.76)
Grade III, <i>n</i> (%)				
a	1 (0.68)	0 (0.00)	1 (1.16)	0 (0.00)
b	10 (6.76)	1 (3.57)	3 (3.49)	6 (17.65)
Grade IV, <i>n</i> (%)				
a	1 (0.68)	0 (0.00)	1 (1.16)	0 (0.00)
b	1 (0.68)	0 (0.00)	0 (0.00)	1 (2.94)
Grade V, <i>n</i> (%)	10 (6.76)	0 (0.00)	7 (8.14)	3 (8.82)

Grade I: Complication without pharmacological, surgical, endoscopic, or radiologic treatment (anti-emetics, antipyretics, analgesics, diuretics, electrolytes and physiotherapy were acceptable); Grade II: Complication requiring pharmacological management including blood transfusion or total parenteral nutrition; Grade IIIa: Complication requiring intervention under local anaesthesia; Grade IIIb: Complication requiring general or epidural anaesthesia; Grade IVa: Single organ dysfunction (including dialysis); Grade IVb: Multiorgan dysfunction; Grade V: Patient death.

## DISCUSSION

CL-SBO is a serious clinical diagnosis that can be fatal if left untreated or undiagnosed. Despite the significance of the condition, diagnosis remains a challenge. In this study, a large cohort of patients with surgery for CL-BSO was retrospectively analyzed. Most patients in our cohort presented with abdominal pain that was accompanied with vomiting in 76% of cases, consistent with the 66% to 81% of cases in other studies[19,20]. We believe that obstipation does not often accompany CL-SBO because colon movements usually continue during an obstruction of the small bowel and because CL-SBO is considered a (sub)acute entity. In this cohort, 29% of the patients reported obstipation, as did 22% of the patients in another study[20]. Possibly the definition of obstipation, *i.e.* no stool for > 24 h, was not sufficiently specific, as not all patients have bowel movements every 24 h, and a change in their bowel movement pattern was not noted. With regard to patient characteristics, 42% had no history of abdominal surgery, which is noteworthy and more than reported in previous studies that included smaller cohorts[2,21]. Even in patients without a history of abdominal surgery presenting with abdominal pain and vomiting without fever, a CT should be performed to rule out CL-BSO.

Patients with CL-SBO and irreversible ischemia were significantly older and had higher ASA classifications than those in the other study groups. Older patients also had an increased risk of 3% *per* year for perioperative irreversible ischemia. Patients with an ASA classification of > 3 had an increased risk (OR of 3.76) of perioperative irreversible ischemia. Other studies have not reported a correlation between age or ASA classification and intraoperative outcome in CL-SBO patients[11,12]. To the best of our knowledge, this is the first study to report an association of comorbidities and ASA classification in patients with surgery for CL-BSO. The finding is very important for guiding the surgical approach and expectations of treatment for such high-risk patients.

Some studies reported that a WBC count of > 10 × 10<sup>9</sup> cells/L was predictive of perioperative bowel ischemia[2,19]. In our CL-BSO series, the WBC count was increased in most patients and was highest in patients with irreversible ischemia (77%), but the differences in WBC count were not significant. Another study reported a WBC count of > 10 × 10<sup>9</sup> and a CRP concentration of > 75 mg/L as two out of

six variables indicating the need for surgery with resection for ischemia. The reported sensitivity was 67.7% and the specificity was 90.8% [11]. CRP is an acute-phase reactant and considered a predictor of vascular compromise and bacterial translocation severity [22]. Contrary to a study by Schwenter *et al* [11], only 43% of the patients in our cohort with reversible ischemia and 48% with irreversible ischemia had an elevated CRP. That might have been a result of the short interval between the onset of symptoms and presentation. However, the results in our large patient cohort indicate that a CRP concentration within the normal range does not ensure the absence of ischemia in patients who present with signs of CL-SBO.

CT imaging is reported to have high interobserver agreement for the diagnosis of CL-SBO. However, small bowel ischemia can be much more difficult to predict, and has poor-to-moderate interobserver agreement [23,24]. Radiologists have a significant role in recognizing signs that require immediate surgical exploration. In studies of small cohorts, increased unenhanced bowel wall attenuation was reported to be predictive of (irreversible) ischemia [12,13,25,26].

When the need for surgery is determined, the choice between a laparotomy or laparoscopic procedure is made by the surgeon. In most of the literature on CL-SBOs, the type of surgical procedure is not discussed [2,19,21]. Most comparisons have found that recovery and in-hospital stays are longer after a laparotomy than after laparoscopic surgery and with less postoperative morbidity after laparoscopic surgeries [27]. Therefore, the type of surgical approach was taken into account in our dataset. Laparoscopic procedures comprised only 13% (20/148) of the procedures performed in this study. The percentage of laparoscopic procedures was the highest in patients with a perioperative viable bowel (17%, 5/28). This type of abdominal surgery will be performed more and more frequently by specialized gastrointestinal surgeons in the acute setting, which may lead to more laparoscopic procedures, with better postoperative morbidity and shorter in-hospital stay.

During surgery, 120 patients (81%) were found to have ischemia, which was reversible in 86 (58%). Although resection was not necessary in that group, 30-d morbidity was 20% and mortality was 8%. After surgery for irreversible ischemia, morbidity increased to 45% and mortality was 9%, consistent with the 39% and 9% rates reported in other study populations [5,21]. High morbidity and mortality in patients with CL-SBO and ischemia show that we have to pay close attention to patients who present with CL-SBO that requires emergent surgery. In this cohort, 2 of 86 patients (2.33%) with perioperative reversible ischemia required re-exploration and additional small bowel resection, suggestive of more advanced ischemia than initially expected. We have to pay close postoperative attention to patients with reversible ischemia.

Although surgery *vs* conservative treatment of complicated SBOs has been widely studied, to the best of our knowledge this is the first study to compare patients with absent, reversible, and irreversible ischemia, and the largest patient cohort to include only CL-SBO cases. We assessed patient characteristics, clinical presentation, blood values, and initial radiology reports as predictors of ischemia. Postoperative outcomes were taken into account. This relatively large cohort of 148 patients in a single center was analyzed retrospectively, with a focus on the clinical characteristics and blood results that were able to predict perioperative ischemia and postoperative outcomes.

## CONCLUSION

In conclusion, a diagnosis of CL-SBO should not be ignored in patients with no history of abdominal symptoms. In patients with CL-SBO, older age and an ASA classification  $\geq 3$  were predictive of irreversible ischemia, and urgent surgery is indicated. Patients should be informed of the relatively high chance of morbidity, longer in-hospital stay, and mortality after resection. Lastly, a CRP concentration within the normal range in patients with suspected CL-SBO does not ensure that ischemia is not present.

## ARTICLE HIGHLIGHTS

### Research background

Closed-loop small bowel obstruction (CL-SBO) can threaten the viability of the intestine by obstruction of a bowel segment at two adjacent points. Prompt recognition of CL-SBO, followed by surgery, is crucial. Clinical predictors of perioperative ischemia and postoperative outcome have not been previously analyzed in a cohort as large as this one.

### Research motivation

To date, most studies have evaluated patients with SBOs by comparing surgical *vs* conservative treatments. Studies for CL-SBOs have mostly focused on aspects of computed tomography imaging. The perioperative findings of previous studies vary and there is often a lack information on the postoperative outcomes.

**Research objectives**

The aim of this study was to analyze perioperative characteristics and postoperative outcomes of patients with surgery for CL-SBO and to evaluate clinical predictors.

**Research methods**

The medical records of a cohort of 148 patients who underwent surgery for CL-SBO were analyzed retrospectively. Univariate analysis was performed to identify clinical characteristics that were associated with specific perioperative outcomes. The odds ratios for those that were significantly associated with outcomes were analyzed by logistic regression.

**Research results**

Of 148 patients with CL-SBO, 28 (19%) had a perioperative viable small bowel, 86 (58%) had reversible ischemia and 34 (23%) had irreversible ischemia. Median age and American Society of Anesthesiologists (ASA) classification were significantly higher in patients with irreversible ischemia ( $P = 0.042$  and  $0.008$ , respectively). Postoperative morbidity was significantly higher in patients with perioperative irreversible ischemia (45%,  $P = 0.043$ ) than in those with reversible ischemia (20%) and a viable bowel (4%).

**Research conclusions**

Older patients and those with an ASA classification  $\geq 3$  had an increased risk of irreversible ischemia. C-reactive protein within the normal range did not ensure the absence of ischemia. After irreversible ischemia, postoperative morbidity was increased.

**Research perspectives**

The study results are relevant to preoperative informed consent procedures in patients with CL-SBO. Close attention should be paid to patients with perioperative ischemia for the prompt detection of postoperative complications.

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**FOOTNOTES**


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**Author contributions:** Toneman MK, de Kok BM, Zijta FM, Oei S, van Acker GJD, Westerterp M and van der Pool AEM designed the report; Toneman MK collected the patient's clinical data, analyzed the data and wrote the paper; de Kok BM, Zijta FM, Oei S, van Acker GJD, Westerterp M and van der Pool AEM revised the paper for important intellectual content; van der Pool AE supervised the report.

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**Informed consent statement:** The scientific board of our hospital approved the study. Because the law on medical scientific research concerning humans was not applicable due of the non-invasive and retrospective nature of the study, the need for written informed consent was waived. However, it was required that every patient file was checked for notes of refusal to participate in scientific research.

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