

## ORIGINAL ARTICLE

# Clinical impact of laparoscopic surgery and adhesion prevention material for prevention of small bowel obstruction

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## Abstract

**Aim:** Adhesive small bowel obstructions (SBO) are one of the most common complications following abdominal surgery, and they decrease patient quality of life. Since 2000, laparoscopic surgery has been employed with increasing frequency, as has adhesion prevention material (APM). In this study we tried to evaluate whether laparoscopic surgery and APM reduce the incidence of SBO.

**Methods:** In Cohort 1, we included patients who developed SBO and received inpatient treatment between 2015 and 2018. We evaluated the elapsed time between precedent surgery and the onset of SBO, and what kind of surgery most often causes SBO. In Cohort 2, we included patients who underwent digestive surgery between 2012 and 2014 and evaluated SBO incidence within 5 y after the precedent surgery.

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**Results:** In all, 2058 patients were included in Cohort 1. Of these, 164 had experienced no precedent surgery. Among patients with a history of abdominal surgery, 29.7% experienced SBO within 1 y after the precedent surgery and 48.1% within 3 y. Altogether, 18798 patients were analyzed in Cohort 2. The incidence of SBO after laparoscopic colorectal surgery was lower than that of open colorectal surgery ( $P < .001$ ), and laparoscopic gastroduodenal surgery was also lower ( $P = .02$ ). However, there were no differences between laparoscopic and open surgery for other types of surgery. The use of APM had no effect on SBO incidence in any type of abdominal surgery.

**Conclusions:** Laparoscopic surgery helps to reduce SBO incidence only in colorectal surgery, and possibly in gastroduodenal surgery. APM does not reduce SBO after abdominal surgery.

#### KEYWORDS

acute abdomen, digestive surgery, morbidity, small bowel obstruction

## 1 | INTRODUCTION

Adhesive small bowel obstructions (SBO) are one of a most common complications following abdominal surgery, and they decrease patient quality of life.<sup>1</sup> Patients cannot avoid the risk of SBO, even 10 y after laparotomy, because ~10% of SBO develops 10 to 20 y post-surgery and over 10% of patients develop SBO more than 20 y later.<sup>2</sup>

Since 2000, laparoscopic surgery has become increasingly common, and adhesion prevention material (APM) is also being used more frequently. It is commonly assumed that both laparoscopic surgery and APM reduce SBO incidence. Three APMs (Seprafilm,<sup>3,4</sup> which comes in rolls and Interceed,<sup>5,6</sup> provided in sheets, and AdSpray,<sup>7,8</sup> which is a spray) are now available in Japan. However, there is no evidence that these APMs decrease SBO incidence. One non-randomized controlled trial (RCT) reported that APMs decreased the incidence of early postoperative (within 30 d postsurgery) SBO<sup>3</sup>; however, an RCT reported the opposite.<sup>4</sup> According to still other studies, APMs did not decrease adhesion incidence, but did decrease their severity.<sup>9,10</sup> APMs were concluded to have decreased the incidence of SBOs requiring reoperation after intestinal resection.<sup>11</sup> Nonetheless, APMs did not significantly reduce the SBO incidence in patients who underwent gastrectomy for gastric cancer.<sup>12</sup>

Compared with open colorectal surgery, laparoscopic colorectal surgery has been credited with reduced rates of SBO.<sup>13</sup> Also, an RCT found that, compared with open surgery, laparoscopic distal gastrectomy suffered fewer early or late complications, particularly SBOs (2.0% vs 4.4%, respectively;  $P = .0447$ ).<sup>14</sup> However, a large non-RCT reported that the incidence of SBO after laparoscopic gastrectomy was equal to that after open surgery.<sup>15</sup> Moreover, no studies have shown whether a laparoscopic approach can reduce the prevalence of SBOs in patients who underwent esophageal, liver, or pancreatic surgery.

Miller et al<sup>2</sup> reported that colorectal and gynecological surgery are the most common causes of SBO. The interval between surgery

and SBOs varies from as little as 6 mo to over 20 y. However, two decades ago, laparoscopic surgery was an uncommon procedure and APMs were not available. In the present study, we first sought to clarify how long patients who underwent abdominal surgery need to be followed so as to clarify the true incidence of SBO, and we wanted to determine what kinds of abdominal surgery cause SBO in the age of laparoscopic surgery. Finally, we tried to evaluate whether laparoscopic surgery and APMs reduce the SBO incidence.

## 2 | METHODS

This was a retrospective study conducted for the Japanese Society for Abdominal Emergency Medicine, using a standardized data collection sheet. It was conducted in accordance with the Declaration of Helsinki and approved by the local Institutional Review Board (Approval No. 20-01-887). This study included 32 participating hospitals and information about the right to opt-out was posted on the website of each hospital. We defined SBO as (a) inpatient treatment received with fasting, (b) diagnosed by computed tomography (CT) or abdominal X-ray, and (c) without cancer recurrence. We collected patient data from two cohorts, as described below. SBO was classified into simple SBO and bowel strangulation. Bowel strangulation was defined as SBO with a blood flow disorder that was diagnosed at the time of surgery, and simple SBO was defined as SBO without a blood flow disorder. Ileus was defined as a temporary arrest of intestinal peristalsis without a structural problem.

### 2.1 | Cohort 1

This cohort included patients who developed SBO and who received inpatient treatment between April 2015 and March 2018. The main purpose for analyzing this cohort was to clarify two issues: how long

it took from precedent surgery to SBO and what kind of surgery is the major cause of SBO. In this study precedent surgery was defined as the surgery that was judged to be the main cause of SBO in patients who received multiple surgeries. We classified them into 15 groups according to the type of precedent surgery: esophageal, gastroduodenal, liver, gall bladder (GB) and bile duct, pancreas, small intestine, appendix, colorectal, stoma (without other types of surgery), urological, gynecological, SBO, peritonitis, others, and none. We collected data regarding surgical history, insertion of a decompression tube for SBO, fasting duration, surgery for SBO, bowel resection for SBO, and the presence or absence of bowel strangulation.

## 2.2 | Cohort 2

This cohort included all patients who underwent digestive tract surgery between April 2012 and 2014 in the participating hospitals. We collected data regarding the disease name, surgical procedures, laparoscopic or open surgery, use of APMs, the amount of bleeding during surgery, surgical operative time, the use of a prophylactic drain, development of ileus, anastomotic leakage, and abdominal abscess. We recorded the presence or absence of SBOs within 5 y after surgery. Today, three kinds of APM (Seprafilm, Interceed, and AdSpray) are available in Japan. However, Interceed (approved in Jun 2017) and AdSpray (approved in Jun 2016) were not available for digestive surgery during the study period of Cohort 2.

## 2.3 | Statistical analysis

The efficacy of laparoscopic surgery and APM use were analyzed with the  $\chi^2$  test. Variables for multivariable analysis included open surgery, APM use, intraoperative bleeding (cutoff was the median value), surgical time (cutoff was the median value), drain tube, reoperation, anastomotic leakage, abscess formation, and ileus. All statistical analyses were performed using SPSS v. 22 Base System (SPSS, Japan), and the significance level was defined as 5%.

# 3 | RESULTS

## 3.1 | Cohort 1

Cohort 1 comprised 2058 patients. Of those, 788 (38.3%) required surgery and 313 (15.2%) underwent bowel resection. In all, 1698 patients were diagnosed as having simple SBO, 432 (25.4%) required surgery, and 135 (8.0%) required bowel resection. 360 patients (17.5%) were diagnosed with bowel strangulation. All of the latter patients required surgery and 178 (49.4%) required bowel resection.

Intervals between precedent surgery and onset of SBO are shown in Table 1. Altogether, 164 patients (8.0%) experienced no surgery. Among patients with a history of abdominal surgery, 29.7%

**TABLE 1** Interval between precedent surgery and small bowel obstruction

	N (2058)	Frequency (%)	Cumulative frequency (%)
<1 mo	124	8.3	8.3
1–3 mo	123	8.3	16.6
3–6 mo	72	4.8	21.4
6 mo–1 y	124	8.3	29.7
1–2 y	156	10.5	40.2
2–3 y	118	7.9	48.1
3–5 y	173	11.6	59.7
5–10 y	266	17.8	77.5
>10 y	336	22.5	100.0
None	164		
NA	402		

Abbreviations: mo, month; NA, not available; y, years.

experienced an SBO within 1 y after antecedent surgery, 40.2% did so within 2 y, and 48.1% developed an SBO within 3 y; however, an additional 22.5% of the patients developed an SBO more than 10 y after antecedent surgery.

Types of antecedent surgery varied (Table 2). The most frequent causative type was colorectal surgery, followed by gastroduodenal and gynecological surgery. SBO frequency after an appendectomy is comparatively uncommon; however, because so many of these operations are performed, appendectomy ranked 4th.

## 3.2 | Cohort 2

Of 18830 patients who were registered, those with insufficient data were excluded. Nonetheless, 18798 patients were retained and analyzed. The kind of surgery that most frequently resulted in SBOs was surgery for a prior SBO, followed by stoma surgery (creation or closure), esophageal surgery, and colorectal surgery (Table 3).

The incidence of SBO after laparoscopic colorectal surgery was significantly lower than that of open colorectal surgery ( $P < .001$ ; colon surgery: 3.07% vs 5.71%,  $P < .001$ , rectal surgery: 6.01% vs 8.68%,  $P = .02$ ). Similarly, the incidence of SBOs after laparoscopic gastroduodenal surgery was significantly lower than that of open gastroduodenal surgery ( $P = .02$ ). However, there were no differences between laparoscopic and open surgery for other types of surgery (Table 3).

The use of APMs had no beneficial effect on SBO incidence in any type of surgery (Table 4). APMs did not reduce SBO incidence in either laparoscopic or open gastroduodenal, nor in laparoscopic or open colorectal surgery (Table 5). Multivariable analysis showed that reoperation was an independent risk factor for SBOs after gastroduodenal surgery, and that open surgery, reoperation, and ileus were independent risk factors for an SBO after colorectal surgery (Table 6).

## 4 | DISCUSSION

In this retrospective study, we included 2058 SBO patients hospitalized between 2015 and 2018 and 18798 patients who underwent abdominal surgery between 2012 and 2014. We present four important findings. First, ~60% of SBOs occur within 5 y after surgery; however, one-quarter of SBOs occur more than 10 y later. Second, as a cause of SBOs, colorectal surgery is the most frequent, followed by gastroduodenal and gynecological surgery. Third, laparoscopic surgery has limited value in preventing SBOs. Finally, APMs had no efficacy in preventing SBOs.

We confirmed that SBOs can develop decades after abdominal surgery, even in the era of laparoscopic surgery. Many earlier studies

also reported that in the era of open surgery, the interval between surgery and the onset of SBOs was highly variable<sup>16</sup> and some patients developed SBOs 10 y or more after surgery. We expected that laparoscopic surgery would reduce the incidence of SBOs, because the smaller wounds of laparoscopic surgery can prevent strong adhesions; however, the tendency of SBOs to occur long after surgery did not change. As expected, we found that the cumulative incidence of SBOs is ~8% within 1 mo, 30% within 1 y, 60% within 5 y, and 78% within 10 y. In a study that included 675 SBO patients who were treated between 1986 and 1996, cumulative SBO incidence was ~5% within 1 mo, 28% within 1 y, 58% within 5 y, and 69% within 10 y.<sup>2</sup> Ellis et al<sup>17</sup> reported that only 20% of SBOs occurred within 1 y after surgery. Thus, studies in which follow-up periods are short underrepresent the true incidence of SBOs.

As a cause of SBOs, colorectal surgery is the most frequent, followed by gastroduodenal and gynecological surgery. More than half of colorectal surgeries were performed laparoscopically. Miller et al<sup>2</sup> examined 675 SBO patients hospitalized between 1986 and 1996, during the era of open surgery, and reported that the most frequent cause of SBOs was colorectal surgery, followed by gynecological surgery, herniorrhaphy, and appendectomy. Ten Broek et al<sup>18</sup> and Ellis et al<sup>17</sup> also reported that colorectal surgery is the most frequent cause of SBOs, except for pediatric abdominal surgery. Thus, prevention of SBOs caused by colorectal surgery could significantly reduce the incidence of SBOs. In the present study, 8% of patients had virgin abdomens (no prior abdominal surgery). Previous studies reported that SBOs in virgin abdomens accounted for 5%–16% of all SBOs.<sup>19–21</sup>

Laparoscopic abdominal surgery generally does little to prevent SBOs; however, in the present study laparoscopic surgery did reduce SBOs following colorectal surgery. Some other studies have also reported the same advantage to laparoscopic colon surgery,<sup>22</sup> colorectal surgery,<sup>13</sup> or emergency colon surgery.<sup>23</sup> Conversely, Petersson et al<sup>24</sup> reported that there was no difference between laparoscopic and open surgery for the risk of SBO in patients with rectal cancer;

TABLE 2 Precedent surgery before small bowel obstruction

	N (2058)	%
Esophagus	52	2.5
Gastroduodenal	332	16.1
Liver	22	1.1
GB and bile duct	53	2.6
Pancreas	34	1.7
Small intestine	43	2.1
Appendix	175	8.5
Colorectal	661	32.1
Stoma	14	0.7
Urological	44	2.1
Gynecological	253	12.3
SBO	88	4.3
Peritonitis	44	2.1
Others	71	3.4
None	165	8.0
NA	7	0.3

Abbreviations: GB, gall bladder; SBO, small bowel obstruction.

TABLE 3 Effect of laparoscopic surgery for the incidence of small bowel obstruction

	Total incidence (N)	Laparoscopic (N)	Open (N)	P
Esophagus (N = 514)	5.8% (30)	6.2% (13/211)	5.6% (17/303)	.77
Gastroduodenal (N = 2610)	4.3% (113)	4.1% (49/1201)	4.5% (64/1409)	.02
Liver (N = 1042)	1.5% (16)	2.2% (5/229)	1.4% (11/813)	.38
GB and bile duct (N = 2599)	1.0% (26)	0.9% (19/2148)	1.6% (7/451)	.20
Pancreas (N = 706)	1.45 (10)	2.0% (2/101)	1.3% (8/605)	.95
Small intestine (N = 197)	5.1% (10)	6.5% (3/46)	4.6% (7/151)	.90
Appendix (N = 1688)	1.6% (27)	1.4% (8/572)	1.7% (19/1116)	.79
Colorectal (N = 5811)	5.5% (318)	4.3% (144/3325)	7.0% (174/2486)	<.001
Stoma (N = 741)	8.2% (61)	3.8% (2/53)	8.6% (59/688)	.33
SBO (N = 695)	10.2% (71)	3.8% (3/78)	11.0% (68/617)	.08
Peritonitis (N = 809)	4.0% (32)			
Others (N = 1385)	3.4% (47)			

Abbreviations: GB, gall bladder; SBO, small bowel obstruction.

**TABLE 4** Effect of adhesion prevention material for the incidence of small bowel obstruction: Analysis of each organ

	APM (+)	APM (-)	P
Esophagus (N = 454)	5.1% (4/79)	5.9% (22/375)	.99
Gastroduodenal (N = 2338)	4.5% (48/1067)	4.6% (59/1271)	.87
Liver (N = 968)	1.9% (8/419)	1.5% (8/549)	.77
GB and bile duct (N = 2343)	1.8% (3/166)	1.0% (22/2177)	.34
Pancreas (N = 706)	1.8% (5/278)	1.2% (4/344)	.75
Small intestine (N = 177)	4.2% (3/72)	5.7% (6/105)	.91
Colorectal (N = 5247)	5.5% (185/3385)	5.7% (107/1862)	.67
Stoma (N = 660)	10.2% (13/128)	8.1% (43/532)	.45
SBO (N = 649)	11.0% (35/317)	9.6% (32/332)	.56

Abbreviations: GB, gall bladder; SBO, small bowel obstruction.

**TABLE 5** Effect of adhesion prevention material for the incidence of small bowel obstruction: subset analysis

	APM (+)	APM (-)	P
Gastroduodenal			
Laparoscopic (988)	5.3% (15)	4.4% (31)	.53
Open (1350)	4.2% (33)	5.0% (28)	.51
Colorectal			
Laparoscopic (2996)	4.3% (74)	4.8% (60)	.49
Open (2252)	6.7% (111)	7.7% (47)	.41

Abbreviation: APM, adhesion prevention material.

however, the prevalence of SBO in laparoscopic surgery in that study was relatively high (10.1%). Stommel et al<sup>25</sup> reported interesting results. They included liver metastatic colorectal cancer patients who had undergone liver surgery after colorectal surgery and found that the rate of adhesion to the incision after open colorectal surgery was significantly higher than that after laparoscopic surgery. However, there was no difference in incidence of SBO between the two groups.

On the other hand, the advantage of laparoscopic surgery for any type of surgery other than colorectal surgery is controversial. Considering that the SBO incidence of open liver and pancreatic surgery was exceptionally low, the length of the incision may not be the greatest risk factor for SBOs. In the present study, laparoscopic gastroduodenal surgery reduced SBOs; however, the difference was exceedingly small. A large population study showed that the 5-y incidence rate of SBOs was higher with open surgery than with laparoscopic surgery for various procedures (Roux-en gastric bypass 2.1% vs 1.5%,  $P < .001$ ; cholecystectomy 2.2% vs 0.65%,  $P < .001$ ; partial colectomy 5.5% vs 2.8%,  $P < .001$ ; appendectomy 0.58% vs 0.35%,  $P < .001$ ; and hysterectomy 0.89% vs 0.54%,  $P < .001$ ).<sup>26</sup> However, Challine et al<sup>27</sup>, using a national cohort, reported that there was no difference between laparoscopic and open surgery for the risk of SBOs in patients with gastric cancer, and that there was no difference in a Japanese RCT (JCOG0912)<sup>28</sup> or a propensity-matched cohort study (LOC-A study).<sup>15</sup> Conversely, Hyung et al<sup>14</sup> reported that SBO incidence after laparoscopic distal gastrectomy was significantly lower than after open distal gastrectomy; however,

**TABLE 6** Multivariable analysis for risk factor of small bowel obstruction

	Odds ratio	95% CI	P
Gastroduodenal surgery			
Open surgery	1.174	0.718–1.920	.521
APM	0.982	0.643–1.500	.933
Intraoperative bleeding	0.896	0.560–1.436	.649
Surgical time	1.082	0.703–1.664	.721
Drain tube	1.073	0.583–1.976	.821
Reoperation	7.802	3.670–16.589	<.001
Anastomotic leakage	0.572	0.212–1.548	.272
Abscess formation	0.693	0.254–1.890	.473
ileus	2.355	0.939–5.908	.068
Colorectal surgery			
Open surgery	1.467	1.110–1.940	.007
APM	0.845	0.661–1.079	.177
Intraoperative bleeding	1.198	0.901–1.592	.213
Surgical time	1.045	0.803–1.360	.743
Drain tube	1.045	0.753–1.449	.793
Re-operation	6.751	4.756–9.582	<.001
Anastomotic leakage	1.218	0.980–1.514	.075
Abscess formation	0.631	0.376–1.058	.081
ileus	5.286	3.914–7.139	<.001

Abbreviations: APM, adhesion prevention material; CI, confidence interval; SBO, small bowel obstruction.

the difference was exceedingly small, as in the present study (2.0% vs 4.4%, respectively;  $P = .0447$ ). The incidence of SBOs after laparoscopic surgery tended to be lower than that after open surgery in the present study; however, laparoscopic surgery for SBOs was associated with a higher risk of bowel injury.<sup>29</sup>

The present study found that APMs had no power to prevent SBOs in any kind of surgery (both univariable and multivariable analysis). APMs have been reported to reduce adhesion severity, but not



adhesion rate<sup>9,10</sup>; however, only one historical control study showed that APM reduced early postoperative (within 30 d after surgery) SBO incidence after gastrointestinal surgery (14.1% vs 6.5%).<sup>3</sup> However, the incidence of SBOs in that study was higher than in other studies. An RCT including 1791 patients showed that APMs did not reduce SBO incidence, but significantly reduced the incidence of SBOs requiring reoperation.<sup>11</sup> Likewise, SBO incidence after laparoscopic colorectal surgery with APMs was 1.0%.<sup>30</sup> However, the observational period was too short to evaluate the incidence of SBO (only 6 mo) because cumulative incidence of SBOs within 30 d was only 8%, as we found in the present study; thus, the conclusion that APMs decrease SBO incidence may be incorrect. Previous reviews also concluded that APMs are associated with a reduction in new adhesion formation; however, there was no evidence for efficacy of APMs other than reduced adhesion formation.<sup>31,32</sup> Considering the effect of APMs in terms of reduction of adhesions, proper application of APMs, eg, a patch applied not only just under the incision, but also over the surgical dissection layer including sites of lymph node dissection, can be extremely important. We have started a prospective study to test this hypothesis.<sup>33</sup>

This study has several limitations. First, because it was a retrospective study some patients had to be excluded for insufficient data. Second, evaluation of the efficacy of laparoscopic surgery and APMs is limited because the retrospective design had a large selection bias. Third, this study did not include data regarding blood examinations, pathological findings, or information about surgery for SBOs of patients; thus, the risk factors for SBO are not clear. We limited observation items because the main objective of this study was to evaluate the utility of laparoscopic surgery and APMs in decreasing the incidence of SBO, so we tried to collect as many patients as possible by simplifying data collection. Information about the number of past abdominal surgeries and about kinds of surgery SBO in Cohort 2 were also lacking. This information may deepen our understanding of SBO. Fourth, the observational period of Cohort 2 in the present study was 5 y, but as we showed here, only 60% of SBOs occur within 5 y after surgery; thus, longer observational periods may alter the results. Considering these limitations, further studies are needed. Fifth, analysis of Cohort 2 was based on surgery performed during the study period, not on patients. Some patients experienced both colorectal surgery and stoma closure during the study period. Some patients experienced colorectal surgery during the study period and stoma closure thereafter, and some patients experienced stoma closure during the study period and colorectal surgery before. In the first case, patients were registered twice (for colorectal surgery and stoma closure). The other two cases counted as surgeries performed during the study period. Accordingly, the present study also included patients who received stoma creation followed by colorectal surgery. Thus, stoma surgery included stoma surgery with or without other types of surgery (mainly colorectal surgery). We did not collect the information about "other surgeries."

In conclusion, laparoscopic surgery reduces the SBO incidence only in colorectal surgery, and perhaps also in gastroduodenal surgery. We found no advantage of APMs in preventing SBOs after

abdominal surgery. APMs can decrease the severity of adhesions<sup>9,10</sup>; thus, if possible, it is important to develop new ways to use APMs that decrease SBO incidence.

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## DISCLOSURES

Approval of the research protocol: This study was approved by the Ethics Committee for the local Institutional Review Board of Nippon Medical School (Approval No. 20-01-887).

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