Published in final edited form as:

Pharmacoepidemiol Drug Saf. 2016 April ; 25(4): 405–412. doi:10.1002/pds.3974.

Validation of a coding algorithm for intra-abdominal surgeries and adhesion-related complications in an electronic medical records database

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Abstract

PURPOSE—Epidemiological data on adhesion-related complications following intra-abdominal surgery are limited. We tested the accuracy of recording of these surgeries and complications within The Health Improvement Network (THIN), a primary care database within the United Kingdom.

METHODS—Individuals within THIN from 1995–2011 with an incident intra-abdominal surgery and subsequent bowel obstruction (SBO) or adhesiolysis were identified using diagnostic codes. To compute positive predictive values (PPVs), requests were sent to treating physicians of patients with these diagnostic codes to confirm the surgery, SBO, or adhesiolysis code. Completeness of recording was estimated by comparing observed surgical rates within THIN to expected rates derived from the Hospital Episode Statistics (HES) dataset within England. Cumulative incidence rates of adhesion-related complications at 5 years were compared to a previously published cohort within Scotland.

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Declaration of originality: This research was presented as a Quick Shot oral presentation at Digestive Diseases Week in 2015 and as an oral presentation at ICPE 2015. It has not been submitted elsewhere for publication and will not be copyrighted, submitted, or published elsewhere while acceptance by the Journal is under consideration.

Author Contributions: Dr. Frank I. Scott had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Scott, Lewis, Mamtani, Haynes. Acquisition, analysis, and interpretation of data: Scott, Lewis, Haynes, Mamtani, Goldberg, Mahmoud. Drafting of the manuscript: Scott, Lewis. Critical revision of the manuscript for important intellectual content: Scott, Mamtani, Haynes, Goldberg, Mahmoud, Lewis. Statistical analysis: Scott. Obtained funding: Scott, Lewis. Study supervision: Lewis.

RESULTS—217 of 245 (89%) questionnaires were returned (180 SBO and 37 adhesiolysis). The PPV of codes for surgery was 94.5% (95%CI: 91–97%). 88.8% of procedure types were correctly coded. The PPV for SBO and adhesiolysis was 86.1% (95% CI: 80–91%) and 89.2% (95% CI: 75–97%), respectively. Colectomy, appendectomy, and cholecystectomy rates within THIN were 99%, 95%, and 84% of rates observed in national HES data, respectively. Cumulative incidence rates of adhesion related complications following colectomy, appendectomy, and small bowel surgery were similar to those published previously.

CONCLUSIONS—Surgical procedures, SBO, and adhesiolysis can be accurately identified within THIN using diagnostic codes. THIN represents a new tool for assessing patient-specific risk factors for adhesion-related complications and long term outcomes.

Introduction

Adhesions are fibrous connections that develop in response to peritoneal trauma. Up to 93% of individuals with prior abdominal surgery have adhesions compared to 10.4% undergoing an incident intra-abdominal surgery^{1,2}. Adhesions are responsible for significant morbidity, including 75% of small bowel obstructions (SBO) and 40% of cases of infertility^{3,4}. In a large cohort within Scotland (the Surgical and Clinical Adhesions Research (SCAR) study), 5.7% of individuals undergoing an incident intra-abdominal surgery required a readmission for adhesion-related complications within 5 years of their procedure⁵.

It remains uncertain which patients are at highest risk for adhesion-related complications or may eventually require surgical interventions such as lysis of adhesions (LOA). Research to date has focused on procedure-related factors. There is strong evidence that SBO and LOA rates are dependent on the type of surgery, with increased risk after surgery involving the bowel compared to cholecystectomy or appendectomy^{5,6}. The impact of laparoscopic approaches and new anti-adhesion barriers are less clear^{7–9}. Recently published data utilizing the National Hospital Discharge Summary demonstrate no significant change in rates of admissions for SBO or inpatient adhesiolysis from 1988 to 2007 in the United States, despite increasing utilization of laparoscopic techniques and barrier products during this period¹⁰. Patient-related factors may also influence the risk for adhesion-related complications, but these remain largely unexplored. Specifically, almost no research has focused on the potential for concomitant medications to modulate the risk of this complication.

One reason for the limited research in this field is the availability of large population-representative data with accurate recording of surgical procedures, adhesion-related complications, and patient characteristics of interest. The Health Improvement Network (THIN), a database derived from data collected during routine care, has the potential to meet this need. THIN has been validated for many chronic medical conditions and medications^{11–16}, but has not been validated for surgical procedures or adhesion-related complications such as SBO or LOA. In this study, we assessed the positive predictive value of diagnostic codes for intra-abdominal surgeries, SBO, and LOA within THIN.

Methods

Data Source

THIN includes more than 12 million patients, with 3.6 million active patients from over 550 general practices in the United Kingdom¹⁷. The database is derived directly from the electronic medical record (EMR), and contains information on medication use, medical diagnoses, laboratory data, discharge summaries, and demographic information such as age, sex, and practice data. Average follow-up time exceeds 5 years per patient. The accuracy and completeness of THIN has been previously validated for several diseases and prescription drug use^{11–16}. For validation purposes, researchers can directly survey practices and general practitioners of individuals within THIN. It is possible to request additional documentation via THIN's Additional Information Services (AIS) from over 200 practices, including discharge summaries and operative notes when available for specific individuals, allowing for direct comparisons of diagnostic codes within the database to medical records to confirm diagnoses or procedures.

Study Design

We conducted a cross-sectional study of individuals 18 years of age who had an incident intra-abdominal surgery recorded within THIN practices participating in AIS from 1995 to 2011, using a pre-determined list of 1435 READ codes (See Supplemental Material)¹⁸. The READ coding system includes codes for medical diagnoses and procedures. We employed a previously described multistep method for diagnostic code selection to identify surgical codes for laparotomy and laparoscopy within the peritoneum, and surgeries involving the colon, small bowel, appendix, stomach, esophagus, diaphragm, kidneys, hepatobiliary system, pancreas, female reproductive tract, and intra-abdominal vasculature.¹⁹ To maximize the probability that these were incident surgical events, we required individuals to have been registered within a THIN practice for at least 1 year prior to their first surgical code²⁰. We identified individuals with a subsequent READ code for SBO or LOA after their incident abdominal surgery. Those individuals with an SBO or LOA prior to or on the same day as the diagnostic code for surgery were excluded. We excluded individuals with a history of inflammatory bowel disease (IBD) as they often have SBOs due to other etiologies.

Using stratified random sampling, we sent questionnaires to the practices of GPs of patients who met our inclusion and exclusion criteria (See Supplemental Figure 1). This two stage random selection involved an initial phase with 20 questionnaires sent to practices to confirm that the questionnaire was being completed in entirety, followed by random selection from the remaining individuals within two strata: 1) patients with codes for SBO and 2) patients with codes for LOA. Questionnaires requested that practices confirm the occurrence, type, and date of the surgical procedure and whether or not a subsequent SBO or LOA had occurred. GPs were asked to provide confirmatory documentation (discharge summaries, operative notes) if available. Surgery types were grouped by category [upper GI tract, small bowel, colon, appendectomy, hepatobiliary, other bowel surgeries, female reproductive tract-based, and other intra-abdominal procedures (diagnostic laparoscopy, renal, vascular surgery, etc)].

Statistical Analysis

Descriptive statistics were calculated to compare randomly selected individuals to those eligible for selection. The positive predictive value (PPV) of codes for surgical events was calculated as the ratio of those with confirmed procedures to everyone with a surgical code. Confirmatory documents were considered the gold standard for identifying true cases when available. We assessed the accuracy of codes for identifying specific surgical procedures using confirmatory documents and questionnaires. We performed similar analyses for SBO and LOA. We calculated the PPV using only those with confirmatory documents, and the PPV of both the correct surgical code and SBO or LOA code. 95% confidence intervals (CIs) were computed using exact binomial distributions for all PPV estimates.

We conducted additional analyses to determine if there was a specific time window within which events could no longer be considered accurate in THIN. The recorded surgical or adhesion-related complication's date within the THIN database was compared to the date of the procedure as recorded by the GP or provided in supplemental documents. Confirmatory documentation served as the gold standard when available. For each outcome and surgery, we required the date in THIN to have occurred within a progressively more restrictive date window compared to the questionnaire or documentation, calculating a new PPV for each window from 30, 21, 14, and 7 days.

To assess completeness of recording of adhesion-related complications and surgeries, we compared incidence rates for these outcomes in nationally available data from the UK. We calculated the cumulative rate of adhesion-related complications within 5 years of a surgical event within THIN using Kaplan-Meier methods. Follow-up time was censored at the earliest of the following: an adhesion-related complication, death, transfer out of practice, or 5 years after the incident surgery. Cumulative rates were then compared to adhesion-related complication rates from a cohort of those undergoing surgery from April 1996-March 1997, stratified by surgery type⁶. To assess for completeness of recording in those practices not participating in THIN AIS, we examined the cumulative 5-year incidence of SBOs after surgeries, stratified by whether that individual's practice contributed to THIN AIS. For surgical procedures, we calculated annual rates of colectomy, appendectomy, and cholecystectomy within THIN for the year 2011 among all eligible individuals and compared these to national rates derived from publically available data. These surgeries were selected as they require same day or multi-day hospital admission. To calculate national rates for comparison, we determined incidence rates for these surgeries within England from 2010–2011 within the Hospital Episode Statistics (HES) database, an annually collated comprehensive summation of all inpatient admissions, outpatient visits, and surgical procedures occurring during inpatient and same day stays within England²¹. This year was selected given the availability of published UK census data from 2011 allowing for the calculation of incidence rates²². Standardized incidence ratios (SIRs) were calculated comparing the procedural rates within THIN to estimates generated from HES.

We estimated that a sample size of 230 questionnaires would allow us to determine a PPV with a 95% confidence interval of $\pm 6\%$ for surgical procedures. Among these, we chose a stratified sample of those having a subsequent SBO or LOA, based on exploratory analyses

of the ratio of SBO outcomes and LOA outcomes within the THIN database. Assuming a non-response rate of 5–10%, 200 patients with SBOs and 45 with LOA were selected.

All statistical analyses were conducted utilizing Stata version 13 (StataCorp LP, College Station, TX, USA) and Microsoft Excel 2011 (Microsoft, Redmond, WA, USA). This study was approved by the University of Pennsylvania institutional review board and THIN scientific review committee.

Results

A total of 134,121 individuals meeting our inclusion and exclusion criteria with an incident intra-abdominal surgery were identified within THIN. Among this group, 2,297 individuals had a subsequent diagnostic code for SBO or LOA (1549 with SBO and 578 with LOA; FIGURE 1). 200 individuals with SBO and 45 with LOA were randomly selected and questionnaires were mailed to their GPs. 180 of 200 (90%) questionnaires were returned for those with an SBO outcome, and 37 of 45 (82%) were returned for those with an LOA outcome, for an overall questionnaire response rate of 89% within the cohort. Baseline characteristics including sex, age of first surgery, and age of SBO or LOA were similar between those in the entire cohort and those who were randomly selected for evaluation (TABLE 1). The median age of those with SBO (63.2, IQR 49.6–74.2) was greater than those with LOA (38.3, IQR 33.4–43.1). The proportion of men and women was similar in those with subsequent SBO; a much larger proportion of those with a LOA were female. Subsequent SBO was most often seen after initial colectomy, where as in our sample LOAs were more commonly preceded by an initial gynecologic procedure.

Positive Predictive Values of surgical, SBO, and LOA diagnostic codes

Of 217 returned questionnaires for intra-abdominal surgeries, 205 surgical events were confirmed (PPV 94.5% (95%CI: 90.5–97.1%). 159 (73.3%) were returned with confirmatory documents. The PPV (97.5% (95% CI: 93.7–99.3%)) was similar within this group compared to the entire cohort (TABLE 2). The PPV decreased when requiring the date of the actual surgery to be closer to the date recorded within THIN. When requiring the date returned via questionnaire or additional documentation to be within 7 days of the date recorded within THIN, the PPV decreased to 76.5% (95%CI: 70.3–81.9%). When stratified by surgery type, the PPV remained high (85%) for all surgeries, except for gastric and esophageal surgeries (PPV 75.0%, 95% CI: 42.8–94.5%), though sample size for this subgroup was small (TABLE 3).

Of the 180 individuals with a diagnostic code for an intra-abdominal surgery and subsequent SBO, the PPV for SBO was 86.1% (95%CI 80.2–90.8%). 130 (72.2%) of these individuals had confirmatory documentation. The PPV was similar between the subset with confirmatory documentation and the entire cohort with SBO (TABLE 2). When looking at both the surgical code and SBO code within this cohort, the PPV of both codes was 81.1% (95% CI: 74.6–86.5%). The PPV for SBO codes decreased when requiring the confirmed SBO to be within 7 days of the date recorded within THIN (68.9% , 95%CI: 61.6–75.6%).

Of 37 returned questionnaires for individuals with diagnostic codes for both intra-abdominal surgery and subsequent LOA, 33 confirmed the LOA by questionnaire (PPV 89.2%, 95%CI 74.8–97.0%). The PPV was 93.1% (95%CI 77.2–99.2%) in those with confirmatory documents (n=29). When requiring both the surgical code and LOA code to be correct, the PPV was 89.2% (95%CI 74.8– 97.0%). Restricting the procedure based on dates reduced the PPV, though not as markedly as with SBO or surgery (TABLE 2).

Comparison of THIN to external cohorts

The incidence of obstruction-related outcomes in our full cohort of 134,121 eligible individuals mirrored those within a cohort of individuals undergoing surgery in 1996–1997⁶. For individuals undergoing an initial colectomy, the adhesion-related complication cumulative incidence rate was 5.8% (95% CI 5.2%–6.4%), compared to 5.0% in SCAR-3 (FIGURE 2). Nearly all of these (95.8%) were coded as SBO. For small bowel surgeries, the cumulative adhesion-related rate was 5.3% (95% CI 4.2%–6.8%), consistent with the previously published rate of 5.1%. For appendectomy, the adhesion-related complication rate was much lower than those with other bowel related surgeries, at 0.8% (95% CI 0.7%–1.0%). This rate was consistent with rates within SCAR-3 (0.9%). Recorded SBO rates after colectomy, appendectomy, and small bowel surgery were similar when comparing those enrolled in practices participating in the AIS program to those that had not (TABLE 4).

Incidence rates of selected intra-abdominal surgical diagnostic codes within THIN were similar to those rates within England in 2011. Incidence rates of colectomy, appendectomy, and cholecystectomy codes in THIN closely approximated those seen in HES data in England for that calendar year (SIR for colectomy: 1.00 (95%CI 0.95–1.04), SIR for appendectomy 0.95 (95%CI 0.91– 0.99), SIR for cholecystectomy 0.84 (95%CI 0.82–0.87)).

Discussion

In this study, we assessed the accuracy of diagnostic codes for intra- abdominal surgeries and adhesion-related complications of SBO and LOA in a large, population-based dataset derived from the electronic medical record in the UK. We demonstrated that diagnostic codes for surgical procedures accurately identify surgical events, with a similar PPV in the subset with supplemental operative notes or discharge summaries. Diagnostic codes for SBO were also accurate for identifying individuals who had an obstruction. The incidence of intra-abdominal surgeries in THIN closely paralleled that recorded throughout the UK; similarly, the incidence of subsequent obstruction related outcomes were comparable to that reported in a large prospective cohort study. Therefore, these data, coupled with previous validation studies of comorbidities and medications with THIN, demonstrate that this dataset is a useful new tool for the future study of patient-related factors that may influence the risk for adhesion-related complications after a surgical event.

By focusing on the PPV of diagnostic codes in this validation study, we demonstrate that individuals having surgical diagnostic codes within THIN are very likely to have had the surgery of interest. PPV is an ideal measure when determining how well a diagnostic code or algorithm functions as a surrogate for the disease or exposure of interest²³. Furthermore, we demonstrate a high degree of accuracy within THIN for identifying the correct type of

surgical procedure. Given that different surgical procedures carry with them different risks of adhesion-related complications, this is an important finding for future research using this dataset in this field. Similarly, we were able to discern between two important and separate adhesion-related complications (SBO and LOA) in those that have had intra-abdominal surgery.

We were also able to assess the time-stamped dates associated with these diagnostic codes within THIN. We demonstrated that the PPV for the assessed codes is impacted by the time-window employed. We suspect this is in part due to variability in how and when procedure codes are entered into the electronic medical record by general practitioners, who may become aware of the surgical procedure or complication at the time of admission to hospital, time of discharge, or upon receipt of a discharge summary. Furthermore, some general practitioners may back date the record to match the date of the surgery or complication while others may record this on the date that they receive the discharge summary. Therefore, caution should be used when designing studies that require high levels of precision in identifying the date of the surgical event within THIN.

There are several limitations of this study. It is possible that by examining those with both a surgical event and subsequent complication, we may have introduced selection bias, selecting those with better coding accuracy due to having both a surgery and a complication. Similarly, we did not determine the sensitivity of a diagnostic code for a surgical procedure, SBO, or LOA as sample size requirements for estimating sensitivity are generally prohibitively large and therefore not feasible. However, we demonstrated that incidence rates of colectomy closely matched the estimated rates of these procedures in England for the same calendar year. Rates of appendectomy and cholecystectomy were only modestly lower than expected. This suggests that it is unlikely that we are failing to detect a large proportion of surgical events. It is also unlikely that THIN data capture outpatient procedures that would not be captured in HES, thereby inflating results, as surgical procedures involving entering the peritoneum typically occur in the inpatient setting. We were only able to obtain confirmatory records from those practices that are registered with AIS. It is possible that recording quality may differ between AIS and non-AIS practices. However, the observation that rates of SBO were similar regardless of whether the practice participated in AIS makes this less likely.

We employed several methods to assess for the completeness of SBO and LOA recording within THIN. We demonstrated that rates of these outcomes are similar to those that have been published from other surgical cohorts in Scotland⁶. If we were unsuccessful in identifying a significant proportion of individuals who had had the outcome without the diagnostic code, we would anticipate these rates to be lower than previously published estimates. Similarly, it is unlikely that THIN is capturing outpatient specific post-operative complications, as SBO is rarely managed in the outpatient setting. We excluded patients with IBD, who often have SBOs for other reasons. Other less common conditions, including malignancy, can also cause SBO unrelated to prior surgery. The uncommon nature of these conditions makes them unlikely to have influenced our results. Nonetheless, studies focusing on SBO as a complication of prior surgery may benefit from excluding patients with a diagnosis of intra-abdominal cancer near the time of the SBO diagnosis.

Another potential limitation is that we did not assess the accuracy of SBO and LOA codes in those without prior abdominal surgery. It is possible that the accuracy of these codes in individuals without a documented abdominal surgery may be different than that observed in this study.

Conclusion

In summary, this research demonstrates that diagnostic codes within THIN identify intra-abdominal surgical events with a high PPV. THIN is an appropriate dataset for studying the epidemiology of post-operative SBOs and LOAs. Collectively, this study demonstrates that THIN represents a novel dataset in which to study host-related factors that may modify the risk for adhesion-related complications after an intra-abdominal surgery.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Grant Support via NIH: K08-DK095951 (Scott FI), K24-DK078228 (Lewis JD), K08-DK098272 (Goldberg DS), K12-CA-076931, K23-CA187185 (Mamtani R)

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Figure 1. Selection algorithm to identify individuals for evaluation with surgery, SBO, and LOA within THIN

An eligible cohort of individuals with an incident intra-abdominal surgery was identified within THIN, and from this cohort, a randomly selected cohort of those with subsequent SBO or LOA was identified for evaluation via questionnaires sent to their GPs.

Figure 2. Rates of adhesion-related complications by surgery type in THIN compared to another cohort

Overall rates of adhesion-related complications (“All outcomes” above), stratified by surgery, within THIN were similar to the SCAR-3 cohort, a prospective cohort of surgical patients from Scotland. The majority of outcomes in THIN are SBO-specific codes. Results were stratified by surgical site, including colectomy, small bowel, and appendectomy.

Table 1

Comparison of baseline characteristics of randomly selected small bowel obstruction and lysis of adhesion cases to full cohort of eligible individuals.

Variable	SBO		LOA	
	Total eligible cohort N=1549	Randomly selected cohort N=180	Total eligible cohort N=578	Randomly selected cohort N=37
Sex				
Male	810 (52.3%)	88 (48.9%)	75 (12.9%)	4(10.8%)
Female	739 (47.7%)	92 (51.1%)	503 (87.0%)	33(89.2%)
Age at Surgery (median, IQR)	66.4 (54.0– 74.9)	61.5 (46.9– 70.3)	37.5 (29.7– 48.7)	35.8(29.2– 41.6)
Age at SBO (median, IQR)	67.9 (55.3– 76.5)	63.2 (49.6– 74.2)	---	---
Age at LOA (median, IQR)	---	---	38.9 (31.3– 50.0)	38.3 (33.4– 43.1)
Surgical Category				
Upper GI (gastr+ eso)	59 (3.8%)	10 (5.6%)	9 (1.6%)	2 (5.4%)
Small Bowel	65 (4.2%)	8 (4.49%)	5 (0.9%)	0
Colon	408 (26.3%)	35 (19.4%)	24 (4.2%)	3 (8.1%)
Hepatobiliary (GB, Liver, biliary)	95 (6.1%)	24 (13.3%)	31 (5.4%)	3 (8.1%)
Appendix	130 (8.4%)	12 (6.7%)	47 (8.1%)	3 (8.1%)
Other Bowel-related surgery	191(12.3%)	31 (17.2%)	18 (3.1%)	0
Reproductive	179 (11.6%)	20 (11.1%)	138 (23.9%)	13 (35.1%)
Other	422 (27.2%)	40 (22.2%)	306 (52.9%)	13 (35.1%)

SBO: Small bowel obstruction, LOA: Lysis of adhesions, IQR: Inter-quartile range

Table 2

Positive Predictive Values for intra-abdominal surgery, small bowel obstruction, and lysis of adhesions

Variable	# confirmed events/total	PPV (95%CI)
---Surgical events	205/217	94.5% (90.5–97.1%)
---with confirmatory documents	155/159	97.5% (93.7–99.3%)
---within 30d of date	195/217	89.9% (85.1–93.5%)
---within 21d of date	187/217	86.2% (80.9–90.5%)
---within 14d of date	184/217	84.8% (79.3–89.3%)
---within 7d of date	166/217	76.5% (70.3–81.9%)
SBO events	155/180	86.1% (80.2–90.8%)
---with confirmatory documents	116/130	89.2% (82.6–94.0%)
---within 30d of date	149/180	82.8% (76.5–88.0%)
---within 21d of date	148/180	82.2% (75.8–87.5%)
---within 14d of date	131/180	72.8% (65.7–79.1%)
---within 7d of date	124/180	68.9% (61.6–75.6%)
LOA events	33/37	89.2% (74.8–97.0%)
---with confirmatory documents	27/29	93.1% (77.2–99.2%)
---within 30d of date	33/37	89.2% (74.6–97.0%)
---within 21d of date	33/37	89.2% (74.6–97.0%)
---within 14d of date	32/37	86.5% (71.2–95.5%)
---within 7d of date	31/37	83.4% (68.0–93.8%)

SBO: Small bowel obstruction, LOA: Lysis of adhesions, CI: Confidence Interval

Table 3

Positive predictive value of diagnostic codes for correct surgical procedure, by category

Surgery Category	Total verified procedure by category	Total number coded	PPV (95% CI)
Upper GI (gastric and esophageal)	9	12	75.0% (42.8–94.5%)
Small Bowel	7	8	87.5% (47.3–99.7%)
Colon	32	38	84.2% (68.7–94.0%)
Hepatobiliary (gallbladder,liver, biliary)	23	27	85.2% (66.3–95.8%)
Appendix	13	15	86.7% (59.5–98.3%)
Other Bowel-related surgery	29	31	93.5% (78.6–99.2%)
Reproductive	30	33	90.9% (75.7–98.1%)
Other abdominal surgeries	48	53	90.6% (79.3–96.9%)
TOTAL	191	217	88.1% (82.9–92.0%)

Table 4

Cumulative incidence of SBO by surgery type among AIS-participating practices and non-AIS practices

Surgery Type	Non-AIS participating practices		AIS participating practices	
	Cumulative incidence	95% Confidence Interval	Cumulative incidence	95% Confidence Interval
Colectomy 5y SBO rate	5.19%	(4.46–6.03%)	5.80%	(5.02–6.69%)
Appendectomy 5y SBO rate	0.71%	(0.56–0.91%)	0.55%	(0.42–0.73%)
Small bowel resection 5y SBO rate	4.34%	(2.94–6.39%)	5.85%	(4.19–8.14%)