Risk of adhesive bowel obstruction after abdominal surgery. A national cohort study of 665,423 Danish women

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ARTICLE INFO

ABSTRACT

Background: Adhesive bowel obstruction is associated with considerable morbidity and mortality, but the magnitude of the risk is debated.
Method: In a national cohort of all Danish women with an abdominal operation (N = 665,423) between 1977 and 2013, the risk of adhesive bowel obstruction was assessed by Cox multiple regression. Covariates were the number of abdominal operations, the surgical methods, the anatomical site involved, and the calendar year.
Results: In the cohort, 1.4% experienced an episode of adhesive bowel obstruction. The risk increased 33−43% during the study period, was lower after gynecological and obstetrical procedures compared to gastrointestinal (HR 0.36 [0.34−0.38]), lower after laparoscopic compared to laparotomic surgery (HR 0.51 [0.48−0.54]) and increased proportionally after each additional operation.
Conclusions: The risk of adhesive bowel obstruction after abdominal operations depends on the site of earlier operations, the method of access and the number of earlier operations.

Abdominal surgery is the most common cause of adhesions, and adhesive bands can be found in the majority of patients with previous abdominal surgery.[1] Depending on the location and severity, adhesions may be asymptomatic, or cause chronical abdominal pain, infertility, and adhesive bowel obstruction.[1,2] Bowel obstruction accounts for approximately 1% of admissions to the acute surgical units, implies considerable morbidity, decreased quality of life, and has a mortality ranging from 3 to 30%.[3−6]

Improvements in both surgical methods and perioperative care

may have widened the indications for abdominal surgery in the general population including the elderly and patients with concomitant medical diseases.[7,8] Laparoscopy gives less tissue damage, is associated with a lower risk of wound complications, a shorter convalescence period, and is expected to give fewer adherences compared to laparotomy.[8−12] An increasing number of abdominal operations are performed by laparoscopy, however, some studies have suggested, that the risk of adhesive bowel obstruction remains unchanged.[13,14]

The risk of adhesive bowel obstruction is highest within the first year after surgery, but remains elevated for more than ten years.[15] The risk depends on the anatomical site of previous surgery. Lower abdominal and gynecological surgeries seem to cause bowel obstruction more often than upper abdominal surgery.[16] A systematic review from 2014 estimated the mean adhesion formation rate to 54% after abdominal surgery, ranging from 66% after

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gastrointestinal, 51% after gynecological, and 22% after urological surgery.[17] However, the review only contains smaller studies with low overall study quality and large heterogeneity between them. No generic study has examined the overall impact of the anatomical site and the surgical method in a population of women surgically treated on benign indication.

In this study we aimed to assess the risk of adhesive bowel obstruction over time according to anatomical site of surgery (foregut, midgut, hindgut, appendix, vessels and other uterine, adnexal and Cesarean section) after abdominal and pelvic benign operations in women in a nation-wide cohort. Furthermore, we aimed to assess the risk of adhesive bowel obstruction according to the surgical method (laparoscopy, laparotomy or vaginal surgery) and the number of abdominal operations.

Methods

Study design and population

We addressed all Danish women with an abdominal surgery and no malignant diagnosis. (Appendix S0).

Data were collected from the Danish National Patient Registry, which holds information on admissions, diagnoses, and surgical procedures in all hospitals in Denmark. This register is continuously maintained by the Danish Health Data Agency and has a nearly complete registration of hospital diagnoses and most procedures.[18–21]

We retrieved all gastrointestinal, gynecological and obstetric abdominal surgical procedures in women from 1 January 1977 to 31 December 2013 from the Danish National Patient Registry. To reduce bias due to left truncation, we excluded women with an abdominal surgery or a diagnosis of adhesive bowel obstruction from 1977 to 1984.

In the present study we used the unique Danish ten-digit person identification number to link to the Danish Civil Registration System for information on date of birth, death, immigration and emigration.

The study cohort consisted of all Danish women with an abdominal operation from 1 January 1984 through 31 December 2013, who were less than 100 years old and had no prior diagnosis of neither malignancy nor adhesive bowel obstruction.

Data

For each operation the date, the surgical method, and the anatomical site of surgery was extracted. Two authors independently defined all relevant codes for exposure, outcome and exclusion and consulted senior consultant surgeons in the field of gynecology, abdominal surgery, urology or vascular surgery.

Exposure (anatomical site of surgery and surgical method)

Gastrointestinal surgery was categorized in accordance with a previous study[16] into the following regions: Foregut (gastric, gallbladder, pancreas, kidney, ureter, bladder, and hernias), midgut (small intestines, adhesiolysis, and abdominal wall), hindgut (colon and rectum), appendix (appendix operations), and 'vessels and other abdominal operations' (exploratory laparotomy/laparoscopy and operations on vessels). The pelvic operations were categorized by the anatomical sites into: Uterine operations (hysterectomy and myomectomy), adnexal surgery (ovaries, fallopian tubes, parametries, peritoneal pouch of Douglas operations), vaginal operations (vaginal hysterectomy and other vaginal abdominal operations), and Cesarean section. If more than one anatomical site was involved in an operation, the operations were ranked

according to the risk of adhesive bowel obstruction as follows: 'mid- and hindgut', 'foregut', 'gynecological' and 'obstetric' categories and the highest category applied). The method of surgical access was divided into laparoscopic, laparotomic or vaginal (Appendix S0), and the numbers of surgeries were counted consecutively from 1 January 1977.

For the surgical procedures the Danish version of the Nordic NCSP, NOMESCO Classification of Surgical Procedures was used.

Outcome

The primary outcome was the incident episode of adhesive bowel obstruction after abdominal surgery. In 1977–1995 the outcome was defined by a discharge diagnosis of adhesive bowel obstruction only, but after 1996 either the discharge diagnosis or a surgical code of adhesiolysis of the obstruction were used. (Appendix S0).

During the study period, the women were censored at date of emigration, immigration, a diagnosis of malignancy, death, at age 100 years, and a diagnosis of adhesive bowel obstruction.

Covariates

Age and calendar time were covariates in the analyses. Age was divided into 10- year age-bands, and year of surgery into three ten-year periods: 1984–93, 1994–2003, and 2004–2013.

Statistical methods and analyses

The risk of incident adhesive bowel obstruction was calculated for gastrointestinal, gynecological and obstetric surgery, for the surgical method, and the anatomical site of initial surgery by Cox multiple regression providing hazard ratios with 95% confidence intervals. Date of entry was 1 January 1984 and end of follow-up 31 December 2013. The risk was calculated in 10 years age groups as underlying time scale. The time-period was divided into three ten-year periods: 1984–93, 1994–2003 and 2004–2013. The proportional hazard assumption was checked graphically by log (-log survival) versus log (time) curves to ensure no crossing of curves.

The risk of adhesive bowel obstruction was estimated after the first operation and after repeated operations.

The number of operations was considered a time varying exposure, implying that women undergoing a new operation changed exposure status. The risk of adhesive bowel obstruction after repeated operations was calculated only if a 2nd, 3rd or 4th operation was performed in the years 1984–2013 and the primary operation was performed in the interval between 1977 and 2013. The models of the cohorts with repeated operations were independently managed.

To analyze the influence of the fact that the laparoscopic procedures were used less often in the first time-period, a sensitivity analysis was performed excluding 1984–1993, and to analyze the influence of changes in coding procedures a sensitivity analysis was performed comparing the outcome with and without inclusion of the surgical codes for adhesive bowel obstruction. We additionally performed a sensitivity analysis comparing the risk with and without exclusion of obstruction during the first postoperative month, to exclude the cases categorized as adhesive bowel obstruction but caused by paralytic ileus.

In order to estimate the risk of adhesive bowel obstruction at the different anatomical sites in the abdomen after the initial operation, and to compare the risk according to the surgical method we performed a sub-analysis by censoring women at their 2nd operation. Seven analyses were conducted with the laparotomic procedure at each anatomical site as reference.

The risk of bowel obstruction after repeated surgery was additionally analyzed in women with at least two, three or more abdominal or pelvic surgeries.

To estimate the impact of prior surgery, we stratified all abdominal procedures based on the risk of bowel obstruction after the initial operation with censoring at 2nd operation into four groups: High risk with a hazard ratio (HR) > 3, medium risk HR 2–3, low risk, HR 1, and very low risk with HR < 1. If the woman simultaneously had more than one category of surgery, we used the one with the highest risk. This stratification of prior surgery was then used as covariate in the analyses of repeated operations.

Age at first operation, time between repeated operations, and time from first operation to adhesive bowel obstruction were described by medians and percentiles. Descriptive data were presented as percentages.

All data were analyzed using SAS software version 9.4.

Fig. 1. Flow diagram of the cohort.
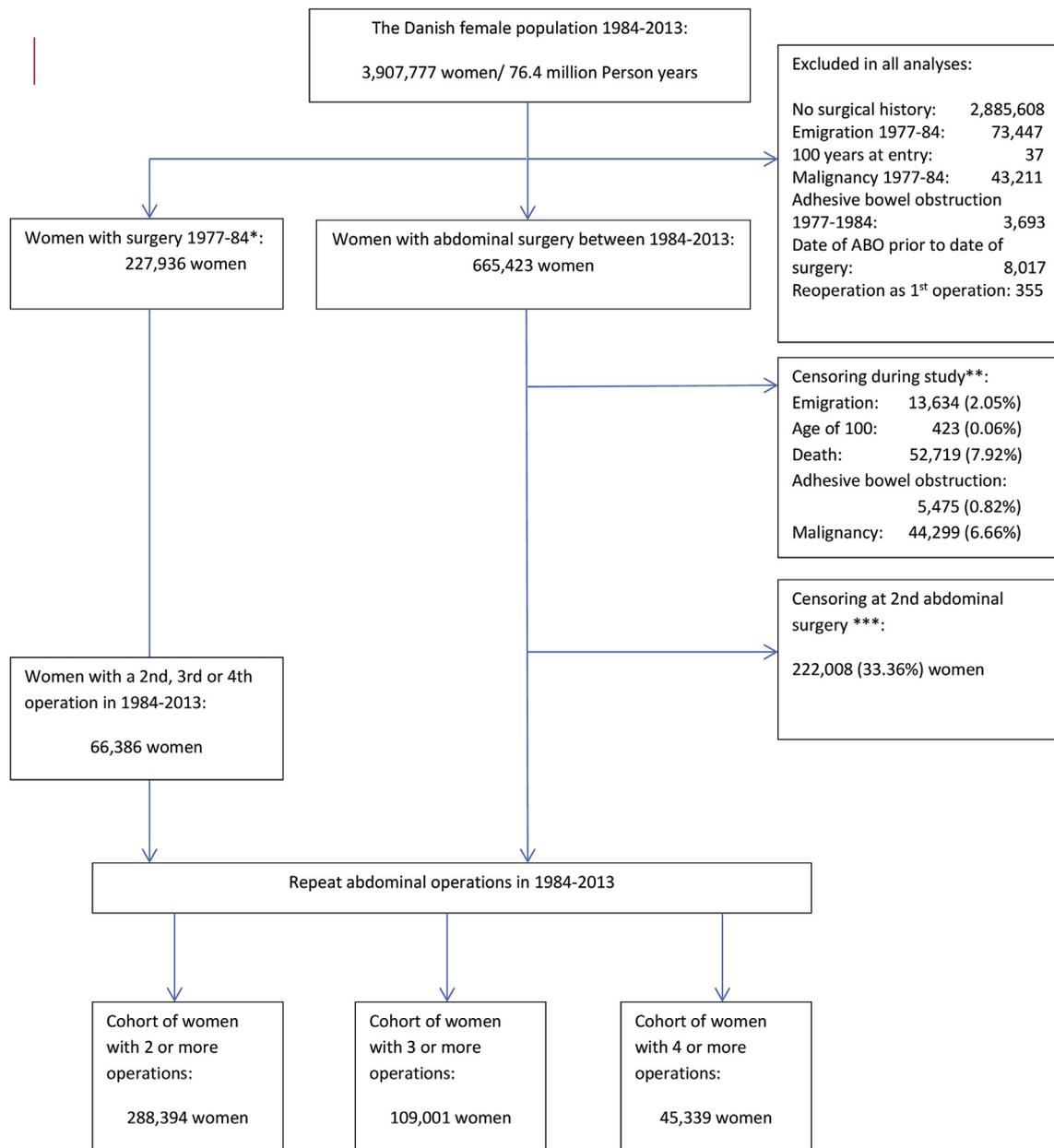
*   Excluded in analyses of risk of adhesive bowel obstruction in first abdominal operation

**   Censored for analyses of risk adhesive bowel obstruction in all analyses

*** Censored in subanalysis of risk of adhesive bowel obstruction from first surgery when censored at 2nd operation

The Danish Data Protection Agency approved the study (j.no. HIH-2013-030) and ethical approval was not required for register studies.

Results

Abdominal surgery from 1984 through 2013

We identified 665,423 women with an abdominal operation between 1984 and 2013, and after censoring 548,873 (82,5%) were included (Fig. 1). Of these, 326,865 (60%) were only operated once and 222,008 (40%) had repeated abdominal surgery during the study period. (Fig. 1). The age distribution was similar in the three decades of the study (Table 1), but those operated laparoscopically were younger than women operated by laparotomy. Appendectomy during childhood was predominantly performed by laparotomy (appendix S1).

Throughout the study period, the frequency of the laparoscopic approach increased at all anatomical sites, most evident for operations on the foregut, adnexae and appendix (Fig. 2).

In women with more than one operation during the study, the time between surgeries declined with the number of repeat procedures from 4.8 years between the first two, 2.4 years between the next two, and 1,5 years between the third and fourth operation (Appendix S2).

Risk of adhesive bowel obstruction after the first abdominal operation

During a median follow-up of 12.9 years (range 1 day–29.9 years) including 9,066,919 person years (py), 9502 (1.4%) of 665,423 women had an episode of adhesive bowel obstruction, corresponding to an incidence of 10.5 [10.3–10.7] per 10,000 py. The proportion was 2.1% (Table 2) (6933 cases, incidence 16.7 [16.3–17.1] per 10,000 py) after gastrointestinal surgery, 1.0% (1993 cases, incidence 6.5 [6.2–6.8] per 10,000 py) after gynecological operation, and 0.4% (576 cases, incidence 3.1 [2.9–3.4] per 10,000 py) after Cesarean Section. If only gastrointestinal laparotomies were addressed, the proportion was 2.8% corresponding to an incidence of 20.7 [20.2–21.3] per 10,000 py.

The time interval between the primary operation and adhesive bowel obstruction was generally shorter after a laparoscopic operation than after an open operation except for adnexal surgery and surgery on the vessels (Appendix S4, S5). For instance, the median time interval between open colorectal surgery and bowel obstruction is estimated to 2.5 years but 0.8 years after laparoscopic access. Adhesive bowel obstruction developed faster after surgery on the intestines than on lateral parts of the abdomen (Appendix S4, S5).

Overall, the risk of adhesive bowel obstruction was lower after gynecological and obstetric compared to gastrointestinal surgery, HR 0.36 (0.34–0.38), and lower after laparoscopy compared to laparotomy, HR 0.51 (0.48–0.54) (Appendix S6).

The risk of adhesive bowel obstruction was also lower after laparoscopic than after open surgeries at the different anatomical sites of the initial surgery. (Table 2). The highest risk was seen after colorectal surgery (hindgut) with a HR of 6.11 [5.66–6.60] for laparotomy and 4.13 [3.24–5.26] for laparoscopy compared to laparotomic operations on the foregut (Table 2).

Sensitivity analyses showed that neither the increased use of the laparoscopic approach during the study period nor the changes in coding praxis had significant impact on the hazard ratios (Appendix S7 and S8).

Graphic examination of the proportional hazard assumption showed a slight violation of the assumption for open appendectomy. Splitting the model on follow-up time indicated that the risk

Table 1
The age distribution and number of women operated abdominally during three decades in a cohort of 665,423 Danish women with a surgical history.

|	1984–93		1994–2003		2004–2013		Total	
	N	%	N	%	N	%	N	%
Age (years)								
0–9	5,996	2	7,403	3	6,419	3	19,818	3
10–19	20,931	8	12,540	6	12,235	7	45,706	7
20–29	64,996	25	50,770	23	45,589	25	161,355	24
30–39	61,469	24	61,322	27	52,841	28	175,632	26
40–49	41,259	16	32,011	14	23,085	12	96,355	14
50–59	19,375	8	22,089	10	13,779	7	55,243	8
60–69	17,928	7	15,682	7	13,632	7	47,242	7
70–79	15,799	6	13,652	6	10,787	6	40,238	6
80–89	7,423	3	7,201	3	6,241	3	20,865	3
90–99	733	0	1,082	0	1,154	1	2,969	0
Anatomical site of first surgery								
Foregut Laparotomy	33,888	13	17,111	8	10,063	5	61,062	9
Foregut Laparoscopy	2,335	1	20,356	9	27,790	15	50,481	8
Midgut Laparotomy	12,325	5	7,259	3	4,559	2	24,143	4
Midgut Laparoscopy	27	0	988	0	2,357	1	3,372	1
Hindgut Laparotomy	8,525	3	6,104	3	3,897	2	18,526	3
Hindgut Laparoscopy	0	0	460	0	1,238	1	1,698	0
Appendix Laparotomy	34,062	13	18,677	8	4,641	2	57,380	9
Appendix Laparoscopy	122	0	2,003	1	10,136	5	12,261	2
Vessels and other Laparotomy	13,576	5	17,828	8	8,424	5	39,828	6
Vessels and other Laparoscopy	27,089	11	17,211	8	12,136	7	56,436	8
Uterine Laparotomy	20,177	8	11,656	5	5,119	3	36,952	6
Uterine Laparoscopy	140	0	990	0	1,273	1	2,403	0
Adnexal Laparotomy	30,514	12	18,094	8	8,104	4	56,712	9
Adnexal Laparoscopy	28,959	11	37,408	17	32,992	18	99,359	15
Vaginal operations	2,071	1	3,784	2	5,777	3	11,632	2
Cesarean Section	42,099	16	43,823	20	47,256	25	133,178	20
Total	255,909		223,752		185,762		665,423	100
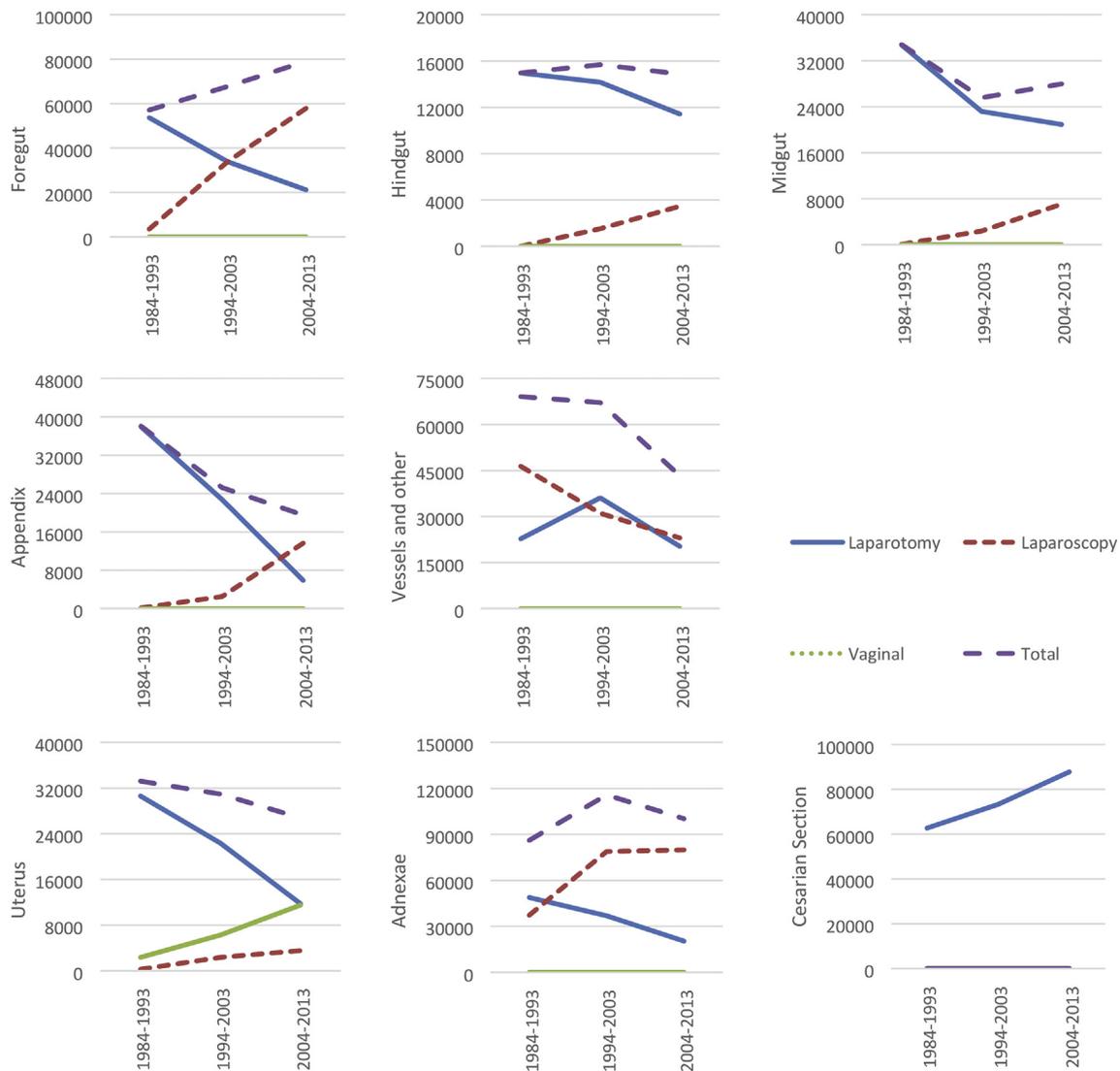
Fig. 2. Number, site and method of surgical access for abdominal operations in Danish Women 1984–2013.

of bowel obstruction was largest during the first 2 postoperative months, HR 2.98 [2.01–4.05], but the estimate was based on relatively few events.

The risk associated with the specific anatomical sites of surgery was analyzed for women censored at their 2nd operation (Table 3). In this population of 665,423 women, 5475 (0.8%) experienced adhesive bowel obstruction.

With open operations on the foregut as the reference, operations on the hindgut either performed by laparotomy or laparoscopy and open operations on the midgut were associated with the highest risk of bowel obstruction with HR's of 6.00 [5.43–6.62], 4.30 [3.18–5.83] and 2.85 [2.56–3.17] respectively, whereas adnexal laparoscopy, vaginal operations, and Cesarean section had the lowest risks (Table 3).

The laparoscopic approach was associated with a 4–78% lower risk of adhesive bowel obstruction compared to the corresponding laparotomy at most sites (Appendix S9).

Exclusion of cases of adhesive bowel obstruction within the first postoperative month after surgery (n = 4775, 50.3%) to account for potential miscoded paralytic obstructions did not alter the results substantially (appendix S10).

Risk of adhesive bowel obstruction after repeated abdominal operations

The rate of adhesive bowel obstruction increased with the number of operations from 19.4, to 25.4, and 32.2/1000 women in women with two, three or four earlier operations (Table 4), and the rates were lower in operations performed by laparoscopy compared to laparotomy. Hindgut laparotomy still had the highest rates and adnexal laparoscopy, vaginal surgery and Cesarean section the lowest (Table 4).

Women with adhesive bowel obstruction after the first operation were stratified according to the risk given after the first operation into four categories: prior very low risk, prior low risk, prior medium risk and prior high risk, which were used as covariates for prior surgery. The mean rate of adhesive bowel obstruction increased gradually between each category from 9.6 to 11.2, 22.9–26.5, 46.1–47.7 and to 114.3–139.5 per 1000 in the four categories (Table 4).

There was an interaction between the categories of the prior operations and the risk of adhesive bowel obstruction after subsequent operations. The prior operations determined to some

Table 2
The risk of adhesive bowel obstruction (ABO) according to the site of the first operation in the period 1984–2013 in 665,423 Danish women.

	Total (n)	Adhesive bowel obstruction cases (n)	HR	95% CI
Total	665,423	9502	–	–
Calendar period				
1984–93	255,909	5019	1	
1994–03	223,752	3013	1.11	1.06–1.17
2004–13	185,762	1470	1.43	1.33–1.53
Anatomical site of first surgery				
Foregut Laparotomy	61,062	1101	1	–
Foregut Laparoscopy	50,481	513	0.84	0.76–0.94
Midgut Laparotomy	24,143	956	2.51	2.30–2.74
Midgut Laparoscop	3372	31	1.00	0.70–1.43
Hindgut Laparotomy	18,526	1739	6.11	5.66–6.60
Hindgut Laparoscopy	1698	72	4.13	3.24–5.26
Appendix Laparotomy	57,380	994	0.97	0.88–1.07
Appendix Laparoscopy	12,261	80	0.73	0.58–0.92
Vessels and other Laparotomy	39,828	863	1.39	1.27–1.53
Vessels and other Laparoscopy	56,436	584	0.66	0.60–0.74
Uterine Laparotomy	36,952	472	0.75	0.67–0.84
Uterine Laparoscopy	2403	15	0.62	0.37–1.03
Adnexal Laparotomy	56,712	955	0.94	0.86–1.03
Adnexal Laparoscopy	99,359	451	0.36	0.32–0.40
Vaginal operations	11,632	100	0.52	0.42–0.63
Cesarean Section	133,178	576	0.33	0.30–0.37

Time since 1. Operation in 10 years age strata as underlying time scale and censured date of malignancy, death or end of follow-up.

extent the risk after the repeated operations, and therefore the results were reported in strata (Fig. 3).

The women with repeated operations were analyzed in 3 independent cohorts: Those with at least two operations, those with at least three operations and those with at least 4 operations.

Both the prior and the repeated subsequent operation were categorized according to the risk of adhesive bowel obstruction into the four risk groups.

The risk of adhesive bowel obstruction after repeat operations increased with each step to a higher risk category of the previous operations. Simultaneously, the risk increased with increasing risk level of the subsequent operation (Fig. 3). In the prior very low risk category the HR increased from 1 in the repeated very low risk operation to HR 14.49 [12.47–16.83] after at least two operations and in the prior high-risk category the HR increased from 7.05 [5.20–9.56] to 21.97 [19.38–24.90] (Fig. 3). The colorectal operations were associated with the highest risk of bowel obstruction, and one surgery at this area in the abdomen carried a much higher risk than repeated operations at other sites of surgery (Fig. 3).

Table 3
The risk of adhesive bowel obstruction after the first abdominal operation in 10-year periods and according to the site of operation among 665,423 Danish women operated during 1984–2013.

	Total (n)	Adhesive bowel obstruction cases (n)	HR	95% CI
Total	665,423	5475	–	–
Calendar period				
1984–93	255,909	2745	1.00	
1994–03	223,752	1757	1.06	0.99–1.13
2004–13	185,762	973	1.33	1.22–1.44
Anatomical site of first surgery				
Foregut Laparotomy	61,062	679	1.00	–
Foregut Laparoscopy	50,481	339	0.87	0.76–1.00
Midgut Laparotomy	24,143	653	2.85	2.56–3.17
Midgut Laparoscopy	3372	10	0.61	0.33–1.14
Hindgut Laparotomy	18,526	992	6.00	5.43–6.62
Hindgut Laparoscopy	1698	46	4.30	3.18–5.83
Appendix Laparotomy	57,380	644	1.30	1.15–1.46
Appendix Laparoscopy	12,261	53	0.76	0.57–1.01
Vessels and other Laparotomy	39,828	554	1.69	1.50–1.89
Vessels and other Laparoscopy	56,436	225	0.64	0.54–0.74
Uterine Laparotomy	36,952	289	0.84	0.73–0.97
Uterine Laparoscopy	2403	8	0.58	0.29–1.17
Adnexal Laparotomy	56,712	594	1.09	0.98–1.22
Adnexal Laparoscopy	99,359	158	0.26	0.22–0.32
Vaginal op	11,632	72	0.54	0.42–0.68
Cesarean Section	133,178	159	0.22	0.19–0.27

Time since 1st operation in 10 years age strata was underlying time scale and Women were censured at 2nd operation, date of malignancy, death or end of follow-up.

Table 4
Incidence rates of adhesive bowel obstruction after 2nd 3rd and 4th operation categorized by anatomical site of surgery and operative method among 288,394, 109,001, and 45,339 Danish women respectively during 1984–2013.

	2nd operation			3rd operation			4th operation		
	Total	Cases	Rate/1000	Total	Cases	Rate/1000	Total	Cases	Rate/1000
Operations/adhesive bowel obstruction	288,394	5602	19.4	109,001	2767	25.4	45,339	1466	32.3
Calendar Period									
1984–93	82,059	2432	29.6	19,487	858	44.0	5694	365	64.1
1994–03	104,079	1994	19.2	41,768	1151	27.6	17,425	661	37.9
2004–13	102,256	1176	11.5	47,746	758	15.9	22,220	440	19.8
Anatomical site of surgery									
Foregut Laparotomy	23,822	696	29.2	8787	348	39.6	3792	203	53.5
Foregut Laparoscopy	23,893	354	14.8	9664	214	22.1	3974	130	32.7
Midgut Laparotomy	14,708	753	51.2	6691	495	74.0	3314	302	91.1
Midgut Laparoscopy	2300	38	16.5	1292	27	20.9	671	19	28.3
Hindgut Laparotomy	9239	1127	122.0	3575	557	155.8	1514	256	169.1
Hindgut Laparoscopy	1390	50	36.0	722	25	34.6	367	20	54.5
Appendix Laparotomy	6415	170	26.5	1389	48	34.6	383	10	26.1
Appendix Laparoscopy	2500	24	9.6	869	10	11.5	305	5	16.4
Vessels and other Laparotomy	21,027	507	24.1	7850	195	24.8	2974	97	32.6
Vessels and other Laparoscopy	24,583	412	16.8	8924	210	23.5	3578	85	23.8
Uterine Laparotomy	17,054	261	15.3	5106	107	21.0	1865	37	19.8
Uterine Laparoscopy	1879	9	4.8	895	14	15.6	461	12	26.0
Adnexal Laparotomy	26,575	509	19.2	10,745	202	18.8	4154	103	24.8
Adnexal Laparoscopy	46,900	297	6.3	23,043	170	7.4	11,813	110	9.3
Vaginal operations	5242	38	7.2	1828	18	9.8	672	8	11.9
Cesarean Section	60,867	357	5.9	17,621	127	7.2	5502	69	12.5
Prior surgery									
Very low-risk	162,608	1820	11.2	44,218	442	10.0	13,880	133	9.6
Low-risk	108,975	2495	22.9	51,384	1214	23.6	22,913	608	26.5
Medium-risk	9303	429	46.1	7628	364	47.7	4880	232	47.5
High-risk	7508	858	114.3	5771	747	129.4	3533	493	139.5

Prior surgery categories.
Very low-risk includes Uterine Laparotomy, Adnexal Laparoscopy, Vaginal operations, and Cesarean Section.
Low-risk includes Foregut Laparotomy, Foregut Laparoscopy, Midgut Laparoscopy, Appendix Laparotomy, Appendix Laparoscopy, Vessels and other Laparotomy, Uterine Laparoscopy, and Adnexal Laparotomy.
Medium-risk includes Midgut Laparotomy. High-risk includes Hindgut Laparotomy and Hindgut Laparoscopy.

Time trend

The risk of adhesive bowel obstruction increased with calendar time in all the analyses. The risk after a single operation increased by 11% in the first decade and by 43% in the second decade after 1984–1994 (Table 2). The numbers for the repeat operations showed the same trend. Adjusting for the difference in coding praxis by excluding the surgical codes from the outcome definition after 1996 reduced the differences over time, but the risk remained elevated during the last decade (Appendix S8).

Discussion

Key results

We found that the risk of adhesive bowel obstruction was lower after gynecological and obstetric operations than after gastrointestinal, lower after laparoscopic procedures than after laparotomy, and that surgery on the colon and rectum and repeated operations were associated with the highest risks.

We also found that the site of surgery had a larger impact on the risk of adhesive bowel obstruction than the number of operations. Consequently, if only the low-risk or very low-risk surgeries were performed, the hazards remained low even when the number of operations increased. However, ranking the prior surgical procedures into four categories (prior very low, low, medium, and high-risk operations) based on the risk of adhesive bowel obstruction after the first operation, showed that the rate of adhesive bowel obstruction after repeated surgeries doubled for each increase in risk category, i.e. was twice as large after low risk than very low risk category, and twice as large after high risk compared to medium risk operations.

Laparoscopy versus laparotomy

In contrast to our results, the SCAR group found comparable readmission rates of adhesive bowel obstruction after gynecological laparoscopy and laparotomy in their Scottish National Cohort Study.[22] However, the Scottish study included both adhesiolysis and adhesive bowel obstruction in the outcome and did not take the number of earlier operations into account.

Two recent meta-analyses of randomized and observational studies including 198,228 and 148,392 patients, respectively found a lower rate of adhesive bowel obstruction following colorectal surgery managed by laparoscopy compared to laparotomy,[23,24] which our data confirm. We also found that adhesive bowel obstruction occurred earlier after laparoscopy and the risk was higher for appendix laparotomy in the first two months of follow-up indicating that the mechanisms may differ, and the management of small and/ or enlarged trocar incision sites may be of importance.
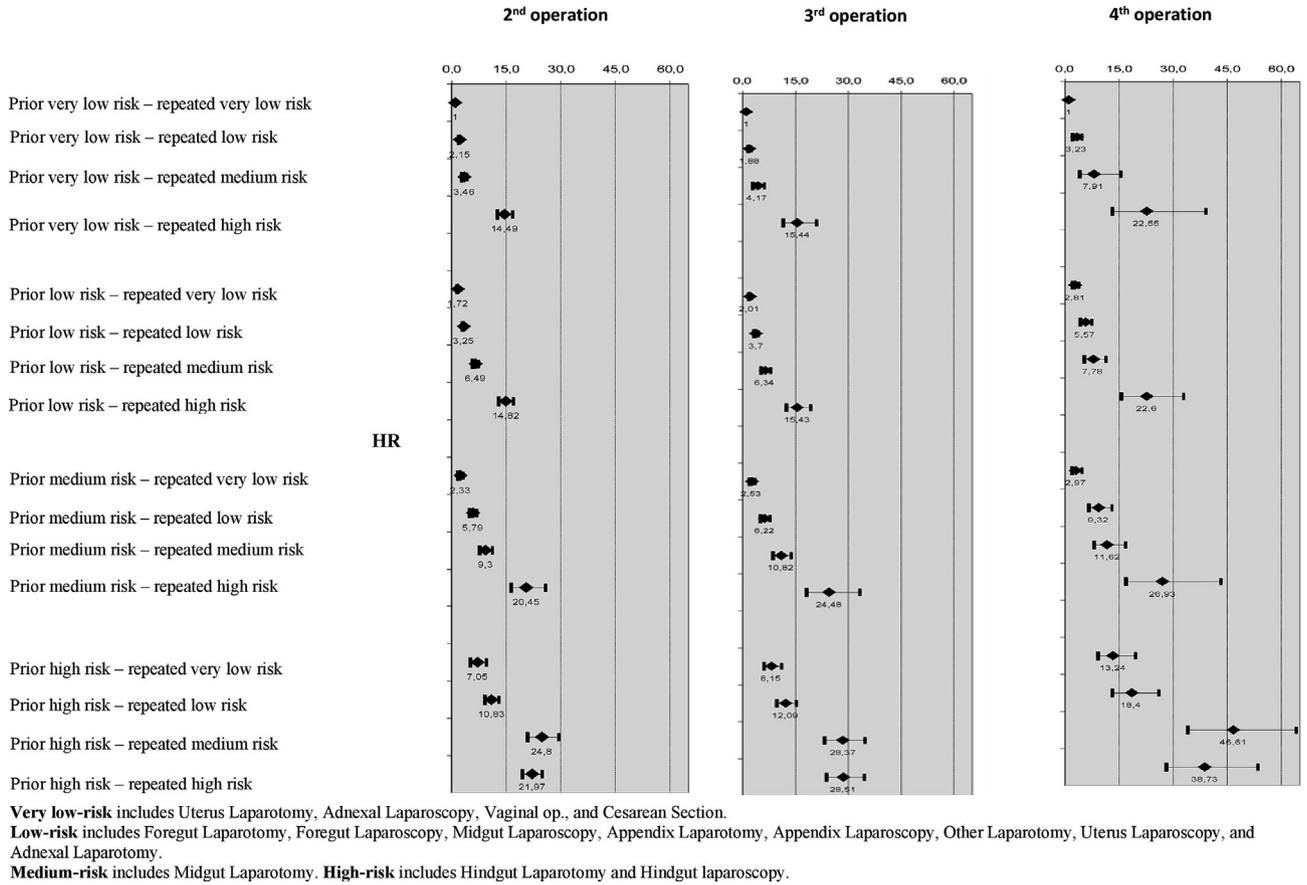
Fig. 3. Risk of incident adhesive bowel obstruction after 2nd, 3rd and 4th abdominal surgery by risk level of bowel obstruction by prior surgery for Danish women from 1984 to 2013. Hazard ratios controlled for calendar time and age.

Incidence of adhesive bowel obstruction

We found that 1.4% of the cohort experienced an episode of adhesive bowel obstruction after their first abdominal operation, ranging from 2.1% after gastrointestinal surgery, 1.0% after gynecological surgery to 0.4% after Cesarean section. This is of the same magnitude as a risk of 2% found in a metanalysis addressing gastrointestinal operations only.[25]

Colorectal surgery constituted 3% of the first operations in our cohort, and was responsible for 19% of the cases of adhesive bowel obstruction and gave the highest risk of adhesive bowel obstruction, which confirms an English study.[1] The prospective Dutch LAPAD follow-up study of 604 patients admitted for elective laparotomy or laparoscopy also identified lower gastrointestinal tract operations as a significant risk factor and found a risk of adhesive bowel obstruction of 6% after a mean follow-up of 46 months compared to our 2.1%. However, 21% of their population had repeated surgery, and the low-risk gynecological operations were not included.[26] Our definition of adhesive bowel obstruction is very restricted as it includes only specific discharge diagnoses and distinct surgical operation codes indicative of adhesive bowel obstruction and may underestimate the true incidence.

Time trend

During the study period the risk of adhesive bowel obstruction increased 33–43% in spite of an increased use of the laparoscopic approach, which seems to be associated with a lower risk of adhesive bowel obstruction compared to open operations. In contrast,

Scott FI et al. found a stable rate of small bowel obstruction in the United States in almost the same period (1988–2007).[27]

The risk of adhesive bowel obstruction is probably affected by several factors including patient selection, surgical experience and diagnostic methods. As the total number of both gastrointestinal and gynecological operations declined with time, surgically treated cases may have more severe diseases associated with a higher risk of long term complications. Increased use of new diagnostic methods as CT scanning with a higher diagnostic sensitivity than conventional x-ray, may result in increased frequency of surgical treatment of patients with symptoms of bowel obstruction. Improved perioperative treatment may also lead to increased use of surgical treatment of bowel obstruction in patients with significant comorbidities.

Finally, the changed diagnostic criteria for adhesive bowel obstruction after 1996 could cause an overestimation of the rate of adhesive bowel obstruction hereafter. However, even if the same criterias had been used throughout the study period, the risk of adhesive bowel obstruction still increased by 21% during the last decade, indicating that other factors may have an impact. (Appendix S8).

Strengths and limitations

This study is a population-based study with an extended follow-up of 37 years and is based on the validated National Patient Registry,[19,21] which provides information keyed to the individual, consequently the study collects details of each individual's history of surgery. The registers also allow exclusion of all women with a

malignant diagnosis, ensuring that risk estimates of bowel obstruction were preceded by operations on benign indications only.

Hospital treatment is free of charge in Denmark, and both public and private hospitals report to the National Patient Registry by law, which tends to minimize selection bias that arise from unequal access to medical treatment observed in other countries. Furthermore, the Danish population is relatively stable, has only grown 10% in 37 years, and only two percent of the cohort emigrated during the study period.

Cohort studies have a potential time bias due to left truncation. In the present study, the surgical history of the women entering the study in 1977 was unknown, and their first operation within the study period might have been proceeded by earlier surgeries. In order to reduce this bias, we excluded all women with either abdominal surgery or adhesive bowel obstruction in the seven-year observational period between 1977 and 1984. As the median time between the first and second operation was 4.8 years, and the interval between the following operations was even shorter, we reduced the impact of left truncation, but a residual left truncation will tend to overestimate the risk estimates of bowel obstruction.

This observational cohort study does not allow comparison of the risks of laparoscopic and open surgical procedures due to possible selection bias. The laparoscopic approach is probably more often used in the healthier and younger patients with less complicated operations, while the open operations may represent more technically difficult operations including cases initialized by the laparoscopic approach but converted to open access.

Conclusion

We found that gastrointestinal surgery was associated with a higher risk of adhesive bowel obstruction than gynecological and obstetric surgery, and that colorectal surgery had the highest risk. Throughout the study the laparoscopic procedures were associated with a lower risk than laparotomy, but the overall risk of bowel obstruction increased over the years despite an increase in laparoscopy.

The risk after repeated surgeries was more dependent on the anatomical site of the disease than the number of surgeries. This knowledge can be useful in the shared decision-making process for benign operations.

Disclosure of interests

The authors declare no disclosure of interests.

Details of ethics approval

This report does not involve human or animal subjects, nor medical records, thus Ethics Approval is not necessary.

Contribution to authorship

CN, LN, AS, MS and EL did the initial planning and development of the methods of the study. CN and MS undertook the selection of the operative and the diagnostic codes and the abstraction of data from the NPR assisted by AS, LN and EL. MSJ, MO and CA did the initial preparation of data for review. All authors participated in the review of data and the planning of the analyses. MSJ did the statistical analyses. CN drafted the paper and all authors were involved in editing of all subsequent drafts with CN as coordinator of the drafts and the final paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.10.035.

References

1. Menzies D, Ellis H. Intestinal obstruction from adhesions–how big is the problem? *Ann R Coll Surg Engl*. 1990 Jan;72(1):60–63.
2. Ouaïssi M, Gaujoux S, Veyrie N, et al. Post-operative adhesions after digestive surgery: their incidence and prevention: review of the literature. *J Vis Surg*. 2012 Apr;149(2):e104–e114.
3. Ellis H. The clinical significance of adhesions: focus on intestinal obstruction. *Eur J Surg Suppl*. 1997;577:5–9.
4. Stewart RM, Page CP, Brender J, Schwesinger W, Eisenhut D. The incidence and risk of early postoperative small bowel obstruction. A cohort study. *Am J Surg*. 1987 Dec;154(6):643–647.
5. Bizer LS, Liebling RW, Delany HMGM. Small bowel obstruction: the role of nonoperative treatment in simple intestinal obstruction and predictive criteria for strangulation obstruction. *Surgery*. 1981;89(4):407–413.
6. Jeppesen M, Tolstrup M-B, Gögenur I. Chronic pain, quality of life, and functional impairment after surgery due to small bowel obstruction. *World J Surg*. 2016;40(9):2091–2097.
7. McCarthy JR, Guy TS. Totally endoscopic robotic mitral valve surgery. *AORN J*. 2016;104(4):293–306.
8. Awonuga AO, Saed GM, Diamond MP. Laparoscopy in gynecologic surgery: adhesion development, prevention, and use of adjunctive therapies. *Clin Obstet Gynecol*. 2009;52(3):412–422.
9. Steiner HL, Strand EA. Surgical-site infection in gynecologic surgery: pathophysiology and prevention. *Am J Obstet Gynecol*. 2017;217(2):121–128.
10. Semm K. Pelviscopic surgery: a key for conserving fertility. *Ann N Y Acad Sci*. 1991;626:372–398.
11. ten Broek RPG, Kok- Krant N, Bakkum EA, Bleichrodt RP, van Goor H. Different surgical techniques to reduce post-operative adhesion formation: a systematic review and meta-analysis. *Hum Reprod Update*. 2013;19(1):12–25.
12. Polymeneas G1, Theodosopoulos T, Stamatiadis A, Kourias E. A comparative study of postoperative adhesion formation after laparoscopic vs open cholecystectomy. *Surg Endosc*. 2001;(1):41–43. jan 15.
13. Lower AM, Hawthorn RJS, Clark D, et al. Adhesion-related readmissions following gynaecological laparoscopy or laparotomy in Scotland: an epidemiological study of 24 046 patients. *Hum Reprod*. 2004 Aug;19(8):1877–1885.
14. Leung TTW, Dixon E, Gill M, Moulton KM, Maclean AR. Bowel obstruction following appendectomy. *Ann Surg*. 2009;250(1):51–53.
15. Parker MC, Ellis H, Moran BJ, et al. Postoperative adhesions: ten-year follow-up of 12,584 patients undergoing lower abdominal surgery. *Dis Colon Rectum*. 2001 Jun;44(6):822–829. discussion 829-30.
16. Ellis H, Moran BJ, Thompson JN, et al. Adhesion-related hospital readmissions after abdominal and pelvic surgery: a retrospective cohort study. *Lancet*. 1999 May 1;353(9163):1476–1480.
17. Okabayashi K, Ashrafian H, Zacharakis E, et al. Adhesions after abdominal surgery: a systematic review of the incidence, distribution and severity. *Surg Today*. 2014;44(3):405–420.
18. Lynge E, Sandegaard JL, Rebolj M. The Danish national patient register. *Scand J Publ Health*. 2011;39:30–33. January 2011.
19. Lidegaard Ø, Vestergaard C, Hammerum M. Kvalitetsmonitorering ud fra data i Landspatientregisteret. *Ugeskr læger*. 2009;171(6):412–415.
20. Nickelsen T. Datavaliditet og dækningsgrad i Landspatientregistret. *Ugeskr læger*. 2001;164(1):33–37.
21. Schmidt M, Schmidt SAJ, Sandegaard JL, Ehrenstein V, Pedersen L, Sørensen HT. The Danish National patient registry: a review of content, data quality, and research potential. *Clin Epidemiol*. 2015;7:449–490.
22. Lower AM, Hawthorn RJS, Clark D, et al. Adhesion-related readmissions following gynaecological laparoscopy or laparotomy in Scotland: an epidemiological study of 24 046 patients. *Hum Reprod*. 2004 Aug 1;19(8):1877–1885.
23. Ha GW, Lee MR, Kim JH. Adhesive small bowel obstruction after laparoscopic and open colorectal surgery: a systematic review and meta-analysis. *Am J Surg*.

2016;212(3):527–536.

24. Yamada T, Okabayashi K, Hasegawa H, et al. Meta-analysis of the risk of small bowel obstruction following open or laparoscopic colorectal surgery. *Br J Surg.* 2016;103(5):493–503.

25. ten Broek RPG, Issa Y, Santbrink EJP Van, et al. Burden of adhesions in abdominal and pelvic surgery : systematic review and met-analysis. *BMJ.*

2013;347:f5588. October.

26. Strik C, Stommel MWJ, Schipper LJ, Van Goor H, Ten Broek RPG. Long-term impact of adhesions on bowel obstruction. *Surgery.* 2016;159(5):1351–1359.

27. Scott FI, Osterman MT, Mahmoud NN, Lewis JD. Secular trends in small-bowel obstruction and adhesiolysis in the United States: 19882007. *Am J Surg.* 2012;204(3):315–320.