Original article

doi:10.1111/codi.13938

Risk factors for anastomotic leakage following ileosigmoid or ileorectal anastomosis

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Received 21 June 2017; accepted 18 September 2017; Accepted Article online 23 October 2017

Abstract

Aim Reconstruction with an ileosigmoidal anastomosis (ISA) or ileorectal anastomosis (IRA) is a surgical option after a subtotal colectomy. Anastomotic leakage (AL) is a problematic complication and high rates have been reported, but there is limited understanding of the risk factors involved. The aim of this study was to assess the established and potential predictors of AL following ISA and IRA.

Method This was a retrospective cohort study including all patients who had undergone ISA or IRA at three Swedish referral centres for colorectal surgery between January 2007 and March 2015. Data regarding clinical characteristics, treatment and outcome were collected from medical records. Univariate and multivariate logistic regression models were used to determine the association between patient and treatment related factors and the cumulative incidence of AL.

Results In total, 227 patients were included. Overall, AL was detected amongst 30 patients (13.2%). Amongst patients undergoing colectomy with synchronous ISA or IRA (one-stage procedure), AL occurred in 23 out of 120 (19.2%) compared with seven out of 107 (6.5%) after stoma reversal with ISA or IRA (two-stage procedure) ($P = 0.004$). In addition, the multivariate analyses revealed a statistically significantly lower odds ratio for AL following a two-stage procedure (OR 0.10, 95% CI 0.03–0.41, $P = 0.001$).

Conclusions This study confirms high rates of AL following ISA and IRA. In particular, a synchronous procedure with colectomy and ISA/IRA carries a high risk of AL.

Keywords Ileorectal anastomosis, anastomotic leakage, risk factors

What does this paper add to the literature?
This is the largest cohort study reporting on the incidence and risk factors for anastomotic leakage following ileosigmoidal anastomosis or ileorectal anastomosis. A statistically significant increased risk was observed following one-stage procedures.

Introduction

Anastomotic leakage (AL) is a significant complication often needing reoperation and results in poor functional outcomes and increased mortality [1,2]. Indications for sub/total colectomy primarily include severe colitis due to inflammatory bowel disease (IBD), colonic polyposis or multifocal manifestation of high grade dysplasia or colon cancer. After a subtotal colectomy, one surgical option is reconstruction with an ileosigmoidal anastomosis (ISA) or ileorectal anastomosis (IRA) if the rectum is free from major pathology. Another option is an ileal pouch with anal anastomosis. However, there are reports suggesting worse bowel function and decreased female fertility after ileal pouch with anal anastomosis compared to IRA [3–6]. Formation of an ISA or IRA is not considered technically demanding, pelvic dissection is not necessary and there is no tension at the anastomosis which also has an excellent blood supply. However, the reported risk of AL after IRA is high (5.7–23.3%) compared with other anastomoses involving the colon and/or rectum [1,2,7–11]. The lowest leakage rate, 1–8.1%, is seen after ileocolic anastomoses,

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which also involve the small and large bowel [2,7,12,13]. There are no studies, however, analysing potential determinants of the unexpectedly high incidence of AL after ISA and IRA.

The objective of this study was to investigate the risk factors for AL following colectomy with ISA or IRA.

Method

This is a retrospective cohort study investigating predictors for AL following ISA or IRA. The study was conducted at three Swedish referral centres for colorectal surgery (Karolinska University Hospital, Ersta Hospital in Stockholm and Linköping University Hospital) between January 2007 and March 2015. The Regional Ethical Review Board in Stockholm approved the study (2015/176-31/4). The study is reported in accordance with the criteria set out in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), checklist [14].

All patients consecutively registered in the hospitals' databases under the procedural codes JFH00, JFH01 (open and laparoscopic colectomy with IRA), JFC40, JFC41 (open and laparoscopic IRA), JFG29 (closure of enterostomy with IRA) and JFH96 (other colectomy) (Swedish Classification of Surgical Procedures) were eligible. All operation reports were assessed and patients were included if bowel reconstruction with ISA or IRA was confirmed. The definition of the distinction between ISA and IRA was an anastomosis higher than 15 cm above the anal verge. Study patients were followed for 90 days postoperatively.

AL was defined as a verified defect in the anastomosis or an abscess close to the anastomosis, in accordance with the definition set by the International Study Group of Rectal Cancer [15]. AL requiring no therapeutic intervention was classified as Grade A, AL treated with therapeutic intervention such as antibiotics or drainage of intraabdominal fluid collection as Grade B, and AL requiring re-laparotomy as Grade C. Antibiotic treatment due to suspected abdominal or unknown infection focus was not regarded as AL. Postoperative mortality was defined as death within 90 days following surgery.

Detailed data on established and potential risk factors for AL in connection with preoperative work-up, intraoperative and surgical measures and postoperative course were collected and investigated for prognostic significance. The Surgical Apgar Score and the Portsmouth Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (P-POSSUM) were calculated [16,17]. Colectomy with ISA or IRA performed in the same procedure was classified as a one-stage procedure, while ISA or IRA after temporary ileostomy was classified as a two-stage procedure. Other possible determinants investigated include preoperative factors [gender, age at surgery, body mass index (BMI)], smoking, the American Society of Anesthesiologists' (ASA) physical status classification, number of comorbidities (diagnoses with active treatment according to the medical records), emergency or elective surgery, indication for surgery (IBD or non-IBD), use of non-steroidal anti-inflammatory drugs, preoperative laboratory data (glomerular filtration rate, serum levels of albumin, creatinine, sodium, potassium and haemoglobin), preoperative systolic blood pressure and heart rate, the presence of rectal mucosal inflammation in patients with IBD, haemodynamic factors (lowest recorded intra-operative body temperature, heart rate, systolic and diastolic blood pressure, mean arterial blood pressure and saturation), procedure related details (laparoscopic or open surgery, conversion from laparoscopic to open procedure, intra-operative blood loss, blood transfusions, duration of surgery, distance from anal verge of the anastomosis, hand sewn or stapled anastomosis, diameter of circular stapler, performance of intra-operative air leak test) and postoperative factors (time at postoperative ward, urine output and lowest mean arterial blood pressure at postoperative ward, pain according to visual analogue scale at the time of discharge from postoperative ward, days to removal of epidural anaesthetic catheter, days to first bowel movement and need for total parenteral nutrition).

Statistics

All analyses were performed using the statistical software programme STATA 12 (StataCorp 2011, College Station, Texas, USA). Continuous variables were reported as median and range. Categorical variables were reported as frequencies and percentages. Wilcoxon rank-sum and Fisher's exact tests were used to compare groups. A logistic regression analysis was performed to assess possible predictors in univariate models with two-sided confidence intervals of 0.95 ($1 - \alpha$). Multivariate models were used to evaluate the confounding effect of potential predictors on the relationship of one/two-stage procedure and circular stapler's diameter with AL. Covariates that resulted in a change of the point estimate larger than 10% were considered confounders and included/excluded stepwise from the final model.

Results

The database search with procedural codes identified 274 eligible patients (Fig. 1). According to the surgical

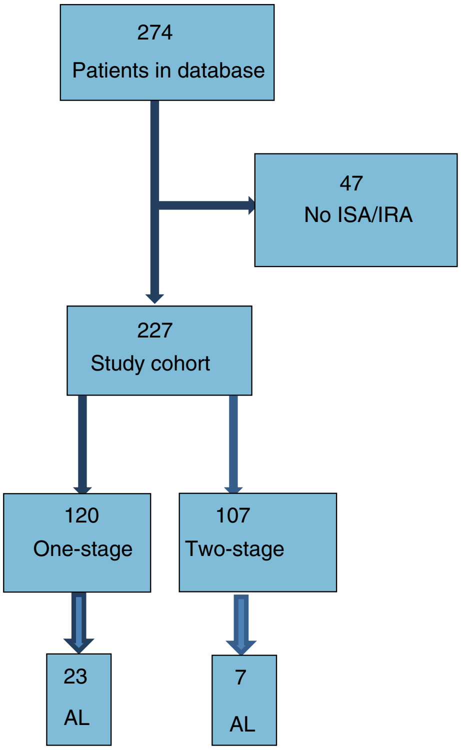

Figure 1 Flowchart.

reports, 47 did not have bowel reconstruction with ISA/IRA. The remaining 227 patients, 112 women and 115 men, were included in the study. The distribution across the three centres was Karolinska University Hospital *n* = 160, Ersta Hospital *n* = 34 and Linköping University Hospital *n* = 33.

Details of the patient groups are shown in Table 1. There were no age or sex differences between the groups. The main indication for surgery in the 120 patients with colectomy and IRA (one-stage procedure) was colon cancer (*n* = 45, 37.5%), polyposis (*n* = 41, 34.2%) and IBD-associated colitis (*n* = 31, 25.8%). The 107 patients with ISA/IRA at stoma reversal (two-stage procedure) had IBD-associated colitis (*n* = 82, 76.7%), colon cancer (*n* = 10, 9.3%) and polyposis (*n* = 2, 1.9%). Sixteen patients had other diagnoses.

Laparoscopic surgery was used in 31 of 227 (13.7%) patients, with conversion to open surgery in six. The median operating time was 190 min (range 52–643 min). The median intra-operative blood loss was 150 ml (range 0–2700 ml) and 10 patients received blood transfusions. Intra-operative air leakage testing was performed in 119 (52.4%) participants and air leakage was noted in eight (6.7%). Of the latter, six underwent suture repair of the anastomosis and two underwent formation of a new anastomosis within the same operation. None of the patients with positive air leakage test during surgery developed AL postoperatively.

The cumulative incidence of AL was 13.2% (30 of 227). The leakages were detected postoperatively on median day 6 (range 1–26). No patient had AL Grade A, 11 (4.8%) had Grade B and 19 (8.4%) Grade C. An additional 16 study patients (7.0%) were treated with antibiotics for suspected abdominal infection but did not develop a radiologically or clinically evident AL.

The 90-day in-hospital mortality was 0.4%, as one of 227 study patients died on day 52 after surgery due to complications related to AL.

The distribution of exposures between patients with and without AL, as well as a univariate regression analysis of these, is reported in Table 1 (established predictors of AL in colorectal surgery) [13] and Table 2 (potential predictors). The majority of epidemiological/demographic, biochemical, physiological and procedure related factors, listed in Method, were not statistically different for patients with AL compared with patients without AL (Tables 1 and 2, some data not shown). AL was diagnosed in 10.6% (12 of 101) of IBD patients and 15.8% (18 of 114) of non-IBD patients ($P = 0.33$). The cumulative incidence of AL was 19.2% (23 of 120, seven Grade B and 16 Grade C) after one-stage procedures compared with 6.5% (7 of 107, four Grade B and three Grade C) after two-stage procedures ($P = 0.004$). The grade of AL was not statistically different between one- and two-stage procedures ($P = 0.37$). Anastomotic technique (stapled *vs* hand sewn) was not related to AL [11.8% (14 of 119) *vs* 14.8% (16 of 108); $P = 0.56$]. Among patients with stapled anastomoses no leaks were registered after application of a linear cutter (0 of 10). For circular staplers, AL was more common for staplers with a diameter > 30 mm than ≤ 30 mm [33.3% (8 of 24) *vs* 7.5% (6 of 80); $P = 0.003$].

Logistic regression analysis

The univariate logistic regression analysis confirmed the results of the comparisons between the groups. AL was less frequent after a two-stage procedure compared with a one-stage procedure (OR 0.30, 95% CI 0.12–0.72, $P = 0.004$). The use of circular staplers with a diameter smaller than 30 mm resulted in decreased OR for AL (diameter > 30 mm OR 6.17, 95% CI 1.88–20.2). The overall effect of the device's diameter on AL was statistically significant ($P = 0.003$).

In the multivariate analysis, the prognostic significance of a two-stage procedure compared with a one-stage procedure was confirmed, with an OR of 0.10 (95% CI 0.03–0.41) ($P < 0.001$) in the analysis when adjusted for age, ASA score, preoperative white blood

Table 1 Comparison between the group without AL *vs* the group with AL and univariate regression analysis of predictors of AL in ileosigmoidal and ileorectal anastomoses, according to established predictors in colorectal surgery.

Risk factor	Patients without AL, *n* = 197 (86.8%)	Patients with AL, *n* = 30 (13.2%)	*P**	Odds ratio (95% CI)	*P*†
Gender					
Female	98 (49.8)	14 (46.7)	0.85	1.00 (ref)	0.75
Male	99 (50.2)	16 (53.3)		1.13 (0.52–2.44)	
Age	51 (15–87)	55 (19–88)	0.21	1.02 (0.99–1.04)	0.16
ASA score					
I–II	152 (83.1)	20 (76.9)	0.42	1.00 (ref)	0.45
III–IV	31 (16.9)	6 (23.1)		1.47 (0.55–3.96)	
Missing	14 (7.1)	4 (13.3)			
Number of comorbidities					
0	110 (55.8)	13 (43.3)	0.31	1.00 (ref)	0.38
I–II	76 (38.6)	14 (46.7)		1.56 (0.69–3.50)	
III–IV	11 (5.6)	3 (10.0)		2.31 (0.57–9.36)	
Planning of operation					
Elective	188 (95.4)	28 (93.3)	0.64	1.49 (0.31–7.26)	0.62
Emergent	9 (4.6)	2 (6.7)			
Reason for surgery					
IBD	101 (51.3)	12 (40.0)	0.33	1.00 (ref)	0.25
Non-IBD	96 (48.7)	18 (60.0)		1.58 (0.72–3.45)	
Smoking					
Non-smoker	111 (58.4)	16 (57.1)	0.96	1.00 (ref)	0.97
Previous/irregular smoker	50 (26.3)	8 (28.6)		1.11 (0.45–2.76)	
Active smoker	29 (15.3)	4 (14.3)		0.96 (0.30–3.08)	
Missing	7 (3.6)	2 (6.7)			
BMI (kg/m^2)	24.7 (17.1–38.2)	25.2 (18.2–38)	0.40	1.05 (0.97–1.14)	0.24
Missing	*n* = 4	*n* = 0			
Albumin (g/l)	39 (12–65)	37 (30–46)	0.09	0.95 (0.88–1.03)	0.19
Missing	*n* = 7	*n* = 0			
Operating time (min)	186 (52–643)	212 (98–605)	0.22	1.00 (1.00–1.01)	0.11
Missing	*n* = 0	*n* = 0			
Distance from anal verge					
0–15 cm (IRA)	108 (54.8)	13 (43.3)	0.25	1.00 (ref)	0.24
> 15 cm (ISA)	89 (45.2)	17 (56.7)		1.58 (0.73–3.44)	
Blood loss (ml)	150 (0–2700)	200 (0–2300)	0.39	1.00 (1.00–1.00)	0.20
Missing	*n* = 5	*n* = 1			

Count data presented as frequency (percentage) and continuous data presented as median (range). AL, anastomotic leakage; ASA, American Society of Anesthesiologists; BMI, body mass index; IBD, inflammatory bowel disease; IRA, ileorectal anastomosis; ISA, ileosigmoidal anastomosis.

*Wilcoxon rank-sum test for continuous variables and Fisher's exact test for categorical variables.

†Overall *P* value.

count, operating time and performance of air leakage test. No significant interactions were detected for these covariates. The effect of the circular stapler's diameter was not statistically significant in the final model ($P = 0.156$).

Discussion

In this cohort study, 227 patients with mainly IBD, polyposis syndromes and colorectal cancer underwent formation of an ISA or IRA. Overall, AL occurred in 30 patients (13.2%). A two-stage procedure was associated with an OR of 0.10 (95% CI 0.03–0.41) for AL compared with a one-stage procedure.

The occurrence of AL in the present study is similar to the findings in a nationwide register study, reporting AL in 13.4% of 178 colon cancer patients undergoing subtotal colectomy [2]. The overall frequency of AL in the 15 667 patients undergoing colorectal resections was 7.5%. Other studies report a frequency of AL after

Table 2 Comparison between the group without AL *vs* the group with AL and univariate regression analysis of potential predictors of AL in ileosigmoidal and ileorectal anastomoses.

Risk factor	Patients without AL, *n* = 197 (86.8%)	Patients with AL, = 30 (13.2%)	*P**	Odds ratio CI)	*P*†
Performed surgery					
One-stage procedure	97 (49.2)	23 (76.7)	0.006	1.00 (ref)	0.007
Two-stage procedure	100 (50.8)	7 (23.3)		0.30 (0.12–0.72)	
Anastomotic technique					
Stapled‡	105 (53.3)	14 (46.7)	0.56	1.00 (ref)	0.50
Hand sewn	92 (46.7)	16 (53.3)		1.30 (0.60–2.82)	
Size circular stapler					
< 30 mm	74 (82.2)	6 (42.9)	0.003	1.00 (ref)	0.003
> 30 mm	16 (17.8)	8 (57.1)		6.17 (1.88–20.2)	
Missing	*n* = 0	*n* = 0			
Testing for air leak					
Yes	100 (50.8)	19 (63.3)	0.24	1.00 (ref)	0.20
No	97 (49.2)	11 (36.7)		0.60 (0.27–1.32)	
Air leakage during test					
Yes	8 (8.0)	0	0.35		N/A
No	92 (92.0)	19 (100)			
Surgical caseload					
≤ 10 performed IRA	162 (82.2)	23 (76.7)	0.46	1.00 (ref)	0.47
> 10 performed IRA	35 (17.8)	7 (23.3)		1.41 (0.56–3.54)	
Surgical approach					
Open	170 (86.3)	26 (86.7)	0.90	1.00 (ref)	0.95
Laparoscopic	22 (11.2)	3 (10.0)		0.89 (0.25–3.19)	
Converted	5 (2.5)	1 (3.3)		1.31 (0.15–11.64)	
Diverting stoma					
Yes	8 (4.1)	0	0.60		N/A
No	189 (95.9)	30 (100)			
Surgical Apgar score	7 (4–10)	7 (4–9)	0.24	0.82 (0.59–1.14)	0.25
Missing	*n* = 8	*n* = 3			
P-POSSUM score					
Physiology score	13 (12–27)	14 (12–18)	0.59	0.99 (0.82–1.20)	0.94
Operative score	11 (8–31)	11 (10–23)	0.56	1.03 (0.89–1.18)	0.72
Missing	*n* = 52	*n* = 9			
Postoperative factors					
Days to removal of EDA	3 (0–14)	3.5 (1–12)	0.33	1.17 (0.98–1.40)	0.08
Missing	*n* = 0	*n* = 0			
Days to bowel movement	2 (0–8)	1.5 (0–6)	0.64	0.94 (0.68–1.30)	0.71
Missing	*n* = 8	*n* = 4			

Count data presented as frequency (percentage) and continuous data presented as median (range). AL, anastomotic leakage; EDA, epidural anaesthesia; IRA, ileorectal anastomosis; N/A, not applicable.
*Wilcoxon rank-sum test for continuous variables and Fisher's exact test for categorical variables.
†Overall *P* value.
‡Includes linear and circular stapler.

ISA and IRA of between 5.7% and 23.3% [1,8–11]. Inconsistency in the definition of AL is a common problem when reviewing the literature [18].

Numerous studies have presented risk factors for AL in colorectal surgery [2,10,13,19,20]. However, the majority are based merely on patients with colorectal cancer. In addition, studies including patients undergoing an IRA have been mixed with other anastomotic sites, making assumptions of specific risk factors for increased leakage after IRA difficult.

In the current study, only the one-stage procedure was a significant predictor of AL. In contrast to previous studies, there was no association between patient related variables such as age, sex, BMI, ASA score, smoking or the number of comorbidities and the risk of AL [2,12,13,19,20]. The absence of these associations may be explained by the facts that IRA is performed primarily in the predominantly young and otherwise healthy group of patients with IBD or polyposis syndromes and that there is no need for pelvic dissection in IRA [13,20–22]. Long operating times [13,19,23], intra-operative blood loss and blood transfusions [8,10,24,25] have been demonstrated to increase the risk for AL in colorectal surgery. These factors presumably reflect intra-operative difficulties, which are rare in IRA. In the present study, with a reasonable median operating time and low blood loss, no such relationship could be identified.

No difference in AL between the use of a stapled or hand sewn anastomosis was identified, which was similar to a Cochrane review identifying no superiority of either technique [25]. The overall effect of the stapler's diameter was not significant in the multivariate analysis and had no confounding effect in the final model. The number of evaluated procedures was limited, and no conclusions regarding stapler diameter and risk of AL can be drawn from the current data.

Intra-operative testing for air leakage was not associated with AL. This method is effective to identify and correct a potential leakage before wound closure, but its role in preventing a leakage is uncertain [13]. The implementation of the laparoscopic technique has been slow in Sweden [26]. No difference in AL between open or laparoscopic surgery was seen in the current study, but the number of laparoscopic procedures was limited. Current evidence reports no clear superiority of either technique regarding AL [13].

There was no difference in AL between ISA and IRA, indicating that the height of the anastomosis is not predictive for the risk of AL. The records of the operations were difficult to analyse in respect of which vessels were divided or preserved. The proximal small bowel end of the anastomosis usually has sufficient perfusion, and tension is seldom an issue. For benign indications, the mesocolon can be transected close to the bowel, leaving the superior rectal artery intact. In colorectal cancer surgery, the impact of a high ligation of the inferior mesenteric artery on AL is not clear [20,27–29]. Likewise, it is uncertain if the perfusion of the distal part of the ISA or IRA is a critical factor in explaining the high risk of AL. It is possible that the perfusion of the rectal stump or remaining sigmoid increases postoperatively after colectomy, which may contribute to our finding of decreased AL in two-stage procedures. Ischaemic conditioning of the gastric conduit has improved mucosal oxygen saturation 4–5 days after oesophageal resection [30].

The two-stage procedure with IRA was carried out mainly in patients with IBD, where the indication would be an inflammatory state considered unsuitable for a primary anastomosis [31]. Crohn's disease is demonstrated to have higher morbidity rates than other indications following surgery with IRA [1]. IBD was not a significant predictor of AL in the present study. Patients selected for a one-stage procedure had mainly colorectal cancers or polyposis syndromes.

Even though great effort has been made to correct for possible bias and confounding by using multiregression models, there may always be factors in retrospective cohort studies that are either hidden or difficult to correct for but that may have an effect on the outcome. Possible confounders that may have influenced the choice of a one- or two-stage procedure could be alcohol consumption and preoperative weight loss, which we were not able to adjust for [13]. Blood loss, operating time and surgical caseload could be regarded as proxies for surgical difficulties and quality, but other unknown factors may exist. The study included patients from three referral centres for colorectal surgery, which may introduce a risk of selection bias. Registration of some of the variables was incomplete. The applied definition criteria for AL may underdiagnose AL (misclassification), as not all patients with abdominal infections had a radiological examination with rectal contrast. Potential misclassification may also have occurred in variables such as ASA scoring, the amount of rectal inflammation and the anastomotic distance from the anal verge, factors that were estimated by different clinicians.

In this study the adjusted OR for the two-stage procedure had a remarkable effect estimate with a narrow CI and consequently a low probability of being caused by chance. When established risk factors for AL in colorectal surgery were analysed, no significant associations were seen. This may be the consequence of a type II error (lack of power) due to the restricted number of patients and events (AL).

Conclusion

The 13.2% rate of AL in this study represents a high frequency of leakage after a relatively straightforward surgical procedure in a reasonably young and healthy patient population. Our findings suggest that previously identified risk factors for AL in bowel surgery may not have the same importance in patients selected for ISA or IRA. The two-stage procedure has the disadvantage of a temporary stoma but seems to be associated with a decreased risk of AL.

Acknowledgements

Financial support was provided through the Regional Agreement on Medical Training and Clinical Research (ALF) between Stockholm Community Council and Karolinska Institutet, the Bengt Ihre Foundation and the Bengt Ihre Research Fellowship. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contributions

All authors contributed to the conception and design of the study, analysis and interpretation of data, drafting or critically revising the article and final approval of the version to be published.

Conflicts of interest

No conflict of interest is reported.

References

1 Elton C, Makin G, Hitos K, Cohen CR. Mortality, morbidity and functional outcome after ileorectal anastomosis. *Br J Surg* 2003; **90:** 59–65.
2 Bakker IS, Grossmann I, Henneman D *et al.* Risk factors for anastomotic leakage and leak-related mortality after colonic cancer surgery in a nationwide audit. Long-term outcome of colectomy and ileorectal anastomosis for Crohn's colitis. *Br J Surg* 2014; **101:** 424–32; discussion 432.
3 Scoglio D, Ahmed Ali U, Fichera A. Surgical treatment of ulcerative colitis: ileorectal vs ileal pouch–anal anastomosis. *World J Gastroenterol* 2014; **20:** 13211–8.
4 Waljee A, Waljee J, Morris AM, Higgins PD. Threefold increased risk of infertility: a meta-analysis of infertility after ileal pouch anal anastomosis in ulcerative colitis. *Gut* 2006; **55:** 1575–80.
5 Aziz O, Athanasiou T, Fazio VW *et al.* Meta-analysis of observational studies of ileorectal versus ileal pouch–anal anastomosis for familial adenomatous polyposis. *Br J Surg* 2006; **93:** 407–17.
6 Olsen KO, Juul S, Bulow S *et al.* Female fecundity before and after operation for familial adenomatous polyposis. *Br J Surg* 2003; **90:** 227–31.
7 Platell C, Barwood N, Dorfmann G, Makin G. The incidence of anastomotic leaks in patients undergoing colorectal surgery. *Colorectal Dis* 2007; **9:** 71–9.
8 Boccola MA, Buettner PG, Rozen WM *et al.* Risk factors and outcomes for anastomotic leakage in colorectal surgery: a single-institution analysis of 1576 patients. *World J Surg* 2011; **35:** 186–95.
9 Hyman N, Manchester TL, Osler T, Burns B, Cataldo PA. Anastomotic leaks after intestinal anastomosis: it's later than you think. *Ann Surg* 2007; **245:** 254–8.
10 Alves A, Panis Y, Trancart D, Regimbeau JM, Pocard M, Valleur P. Factors associated with clinically significant anastomotic leakage after large bowel resection: multivariate analysis of 707 patients. *World J Surg* 2002; **26:** 499–502.
11 O'Riordan JM, O'Connor BI, Huang H *et al.* Long-term outcome of colectomy and ileorectal anastomosis for Crohn's colitis. *Dis Colon Rectum* 2011; **54:** 1347–54.
12 2015 European Society of Coloproctology collaborating group. The relationship between method of anastomosis and anastomotic failure after right hemicolectomy and ileocaecal resection: an international snapshot audit. *Colorectal Dis* 2017; **19:** O296–O311.
13 McDermott FD, Heeney A, Kelly ME, Steele RJ, Carlson GL, Winter DC. Systematic review of preoperative, intraoperative and postoperative risk factors for colorectal anastomotic leaks. *Br J Surg* 2015; **102:** 462–79.
14 von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; **370:** 1453–7.
15 Rahbari NN, Weitz J, Hohenberger W *et al.* Definition and grading of anastomotic leakage following anterior resection of the rectum: a proposal by the International Study Group of Rectal Cancer. *Surgery* 2010; **147:** 339–51.
16 Gawande AA, Kwaan MR, Regenbogen SE, Lipsitz SA, Zinner MJ. An Apgar score for surgery. *J Am Coll Surg* 2007; **204:** 201–8.
17 Tekkis PP, Kocher HM, Bentley AJ *et al.* Operative mortality rates among surgeons: comparison of POSSUM and p-POSSUM scoring systems in gastrointestinal surgery. *Dis Colon Rectum* 2000; **43:** 1528–32, discusssion 1532–4.
18 Bruce J, Krukowski ZH, Al-Khairy G, Russell EM, Park KG. Systematic review of the definition and measurement of anastomotic leak after gastrointestinal surgery. *Br J Surg* 2001; **88:** 1157–68.
19 Buchs NC, Gervaz P, Secic M, Bucher P, Mugnier-Konrad B, Morel P. Incidence, consequences, and risk factors for anastomotic dehiscence after colorectal surgery: a prospective monocentric study. *Int J Colorectal Dis* 2008; **23:** 265–70.
20 Trencheva K, Morrissey KP, Wells M *et al.* Identifying important predictors for anastomotic leak after colon and rectal resection: prospective study on 616 patients. *Ann Surg* 2013; **257:** 108–13.
21 Pommergaard HC, Gessler B, Burcharth J, Angenete E, Haglind E, Rosenberg J. Preoperative risk factors for anastomotic leakage after resection for colorectal cancer: a systematic review and meta-analysis. *Colorectal Dis* 2014; **16:** 662–71.

22 Kang CY, Halabi WJ, Chaudhry OO *et al*. Risk factors for anastomotic leakage after anterior resection for rectal cancer. *JAMA Surg* 2013; **148:** 65–71.
23 Konishi T, Watanabe T, Kishimoto J, Nagawa H. Risk factors for anastomotic leakage after surgery for colorectal cancer: results of prospective surveillance. *J Am Coll Surg* 2006; **202:** 439–44.
24 Leichtle SW, Mouawad NJ, Welch KB, Lampman RM, Cleary RK. Risk factors for anastomotic leakage after colectomy. *Dis Colon Rectum* 2012; **55:** 569–75.
25 Neutzling CB, Lustosa SA, Proenca IM, da Silva EM, Matos D. Stapled versus handsewn methods for colorectal anastomosis surgery. *Cochrane Database Syst Rev* 2012; **2:** Cd003144.
26 Swedish Colorectal Cancer Register (SCRCR). http://www.cancercentrum.se/globalassets/cancerdiagnoser/tjock–och-andtarm-anal/kvalitetsregister/rapporter-2017/kolon 2016.pdf (in Swedish; accessed 25 August 2017).
27 Rutegard M, Hemmingsson O, Matthiessen P, Rutegard J. High tie in anterior resection for rectal cancer confers no increased risk of anastomotic leakage. *Br J Surg* 2012; **99:** 127–32.
28 Komen N, Slieker J, de Kort P *et al*. High tie versus low tie in rectal surgery: comparison of anastomotic perfusion. *Int J Colorectal Dis* 2011; **26:** 1075–8.
29 Titu LV, Tweedle E, Rooney PS. High tie of the inferior mesenteric artery in curative surgery for left colonic and rectal cancers: a systematic review. *Dig Surg* 2008; **25:** 148–57.
30 Bludau M, Holscher AH, Vallbohmer D, Gutschow C, Schroder W. Ischemic conditioning of the gastric conduit prior to esophagectomy improves mucosal oxygen saturation. *Ann Thorac Surg* 2010; **90:** 1121–6.
31 Hwang JM, Varma MG. Surgery for inflammatory bowel disease. *World J Gastroenterol* 2008; **14:** 2678–90.