International Journal of Colorectal Disease (2018) 33:601–608
https://doi.org/10.1007/s00384-018-3026-6

ORIGINAL ARTICLE

Impact of surgical proficiency levels on postoperative morbidity: a single centre analysis of 558 ileostomy reversals

S. Löb[1] · K. Luetkens[2] · K. Krajinovic[1] · A. Wiegering[1] · C.-T. Germer[1] · F. Seyfried[1]

Accepted: 7 March 2018 / Published online: 13 March 2018

Abstract

Purpose Defunctioning ileostomies reduce the consequences of distal anastomotic leakage following bowel resections. Ileostomy reversal in itself, however, is associated with appreciable morbidity (3–40%) and mortality (0–4%). Despite being a common teaching procedure, there is limited information on the impact of surgical proficiency levels on postoperative outcome.

Methods Adult patients undergoing closure of a defunctioning ileostomy between September 2008 and January 2017 were identified from a surgical administrative database that was collected prospectively ($n = 558$). Baseline characteristics (age, ASA score, BMI, health care insurance coverage) and closure techniques were recorded. Operation time, rate of bowel resection, postoperative complications ranked by Clavien-Dindo classification and length of stay were analysed with respect to proficiency levels (residents vs. consultants).

Results Two hundred three ileostomy reversals were performed by residents; 355 ileostomies were closed by consultants. Operation time was considerably shorter in the consultant group ($p < 0.001$). Major postoperative complication rates however were not different among the groups when adjusted for possible confounders ($p = 0.948$). The rate of anastomotic leakage was 3% and the overall major morbidity rate was 11%.

Conclusion Operation time rather than surgical outcome and overall morbidity were affected by surgical proficiency levels. Therefore, ileostomy reversal can be considered an appropriate teaching operation for young general surgery trainees.

Keywords Ileostomy reversal · Proficiency levels · Postoperative complications · Morbidity · Clavien-Dindo

Introduction

Leakage of low colorectal, coloanal or ilealpouch-anal anastomoses is a severe complication leading to considerable morbidity and mortality [1]. Defunctioning ileostomies are constructed routinely in these cases to mitigate the associated clinical consequences such as intraabdominal abscess formation which potentially causes pelvic sepsis, prolonged postoperative stay, impaired quality of life or even higher recurrence of cancer [2, 3]. Loop ileostomies are also constructed whenever considered necessary during emergency surgery including traumatic or inflammatory bowel perforations with severe peritonitis, intestinal haemorrhage or neonatal necrotizing enterocolitis [4]. Ileostomy closure, on the other hand, requires subsequent hospital admission with overall postoperative morbidity rates ranging from 3 to 40% and mortality from 0 to 4% [5, 6].

Today, surgical training is increasingly confronting with rising demands such as providing high quality (i.e. low morbidity), cost-effectiveness (in the era of diagnosis-related group reimbursement) and decreasing operative exposure due to work hour restrictions.

Resident participation in procedures is essential for surgical education [7]. However, the call for high quality (i.e. low morbidity) surgery and cost-effectiveness (in the era of diagnosis-related group reimbursement) on the one hand, but decreasing operative exposure due to work hour restrictions on the other hand result in increasing educational demands. Data on the safety of common general surgical procedures—such as laparoscopic appendectomy (LA), cholecystectomy (LC) or hernia repair (HR)—conducted by residents are contradictory, mainly due to the shortcoming of inconsistently

✉ S. Löb
loeb_s@ukw.de

[1] Department of General, Visceral, Vascular and Paediatric Surgery, University Hospital of Wuerzburg, Oberduerrbacherstr. 6, 97080 Wuerzburg, Germany

[2] Department of Diagnostic and Interventional Radiology, University Hospital of Wuerzburg, Wuerzburg, Germany

collected data and/or arbitrary defined postoperative complications [8–13]. However, Loiero and colleagues conducted a well-designed Swiss trial with 2715 general surgeries on the impact of residency training level on surgical quality by using the comprehensive complication index (CCI) as a measure of postoperative morbidity [14]. By adjusting for important confounders, they could not detect any difference in quality outcome in respect to proficiency level. These results lead the authors to the statement that patient safety in general surgery represented by LA, LC and HR performed by surgical trainees is established [15].

Ileostomy reversal is generally considered a simple procedure and therefore a typical teaching procedure for young residents learning the construction of a proper bowel anastomosis. Our institutional approach of applying hand sewn techniques offers ideal prerequisites for surgical trainees to gain confidence with intestinal wall suturing before being confronted with more complex procedures. So far, there is only little evidence on the impact of surgical training level on postoperative outcome. The aim of this study was therefore to compare postoperative morbidity of ileostomy reversal performed by either consultants or residents (surgical trainees).

Methods

All consecutive adult patients undergoing closure of a defunctioning ileostomy between September 2008 and January 2017 were identified from a prospectively collected surgical administrative database. Patients were included independently of the underlying disease or the indication for constructing a loop ileostomy. Patient and treatment characteristics were retrospectively collected from patient records. All procedures performed were in accordance with the standards of the institutional ethical committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Baseline characteristics included age, sex, body mass index (BMI), American Society of Anaesthesiologists (ASA) classification, health insurance coverage (private vs non-private), co-morbidities such as smoking, diabetes mellitus, immunosuppression or cancer as the primary disease as well as the type of primary surgery and indications for primary (cancer, diverticulitis, inflammatory bowel disease, ileus) or secondary diversion (complications following primary surgery, i.e. anastomotic leakage).

Operative data included operative time, median time to ileostomy closure, proficiency levels (resident vs. consultant), operative technique (end-to-end, end-to-side, side-to-side anastomosis), the need for meticulous adhesiolysis, bowel resection or performing a midline incision as well as median length of hospital stay. Postoperative morbidity and mortality were ranked by the Clavien-Dindo classification [16]. Those with a Clavien-Dindo score ≥ 3 were considered as major. For patients who developed more than one complication, each was counted. The following complications were recorded: surgical site infections (SSI), urinary tract infections (UTI), pneumonia, intraabdominal abscesses (confirmed by abdominal imaging and requiring interventional drainage) as well as anastomotic leakage or bowel obstruction (either temporary obstruction requiring reinsertion of a nasogastric (NG) tube, nil per os and pharmacological treatment or manifest obstruction, i.e. ileus, requiring reoperation).

According to our standard protocol, ileostomy reversal is usually performed 8–12 weeks after construction, except for cases with severe stoma-related problems (recurrent acute renal failure, dehydration, electrolyte disturbances and severe skin problems). The reversal is performed either by a consultant or a resident supervised by a board-certified senior surgeon or consultant (depending on the insurance type of the patient and the severity of the case). In detail, patients with a complicated course after primary surgery, patients needing laparotomy or difficult cases with complex parastomal hernias and/or dense adhesions are predominantly operated by a senior or consultant surgeon. We usually perform a peristomal incision. The stoma is dissected from the mucocutaneous junction and delivered from the rectus sheath and peritoneal cavity by sharp dissection. Ileostomies are usually closed extraperitoneally in an end-to-end fashion by a single layer of interrupted 4-0 Vicryl sutures (Gambee technique [17]), either as hemi-anastomosis or in case of segmental bowel resection as full-anastomosis. Rectus sheaths are closed. After inserting a subcutaneous drain, the skin is closed by interrupted sutures. NG-tubes are removed after surgery and patients initiated a liquid diet until first bowel movements, followed by a normal diet.

According to distribution, descriptive data were reported as median with interquartile range or median +/− standard deviation. Continuous variables were analysed using the Mann-Whitney U test or the independent T test according to the distribution. Categorical variables were analysed with the chi-square-test or Fisher's exact test. A p value ≤ 0.05 was considered to be statistically significant for all the analyses performed with IBM SPSS Statistics, version 24.0 (IBM Corp., NY, USA).

Results

Between September 2008 and January 2017, 558 adult patients underwent ileostomy reversal. Approximately two thirds were male (61.8%), median age was 63 years (20–93), median BMI was 24.9 kg/m^2 (15.5–51.1) and the most common ASA scores were 2 or 3 (97.7%). One hundred one patients (18.1%) reported a history of smoking habitually, 69 patients (12.4%) were diagnosed with type 2 diabetes mellitus

and 32 patients (5.8%) were under immunosuppression. Two hundred seventy-five patients (49.3%) had a history of colorectal cancer. One hundred seventy-six patients (31.5%) received neoadjuvant and 171 received adjuvant treatment according to the individual tumour stage (30.6%). One hunderd twenty-one patients (21.7%) had private health insurance coverage (Table 1).

The initial creation of a loop ileostomy during major surgery was planned in 380 (68.1%) patients, whereas loop ileostomy was performed in 178 patients (31.9%) in an emergency setting. Most of these latter cases were due to colon perforation or anastomotic leakage. We performed 482 (86.4%) primary open surgeries, 382 (68.5%) colorectal resections, 157 (28.1%) primary or secondary loop ileostomies and 19 (3.4%) small bowel resections. Indications for the construction of a defunctioning ileostomy were low anterior rectum resections due to cancer (43.7%), anastomotic leakage (14.9%), diverticulitis (10.4%, most cases in terms of perforated diverticulitis with peritonitis), inflammatory bowel disease (9.1%) and ileus (8.4%) (Table 2).

Median time to ileostomy closure was 225 days (3–1693) with a median operation time of 93 min (23–614). A peristomal incision was adequate in all but 49 cases, in which conversion to a midline laparotomy was necessary due to massive adhesions (8.8%). Five hundred thirty-two (95.5%) stoma reversals were constructed by an end-to-end, 3 (0.6%) by an end-to-side and 22 (3.9%) by a side-to-side anastomosis. (Table 3).

Overall morbidity according to Clavien-Dindo classification was 45.2% (Table 4). For patients suffering from more than one complication, each event was calculated separately which resulted in a higher number of total events per classification category. Major complications, i.e. a Clavien-Dindo score ≥ 3, occurred in 61 patients (10.9%). Seventeen patients (3.0%) developed an anastomotic leakage requiring reoperation. Twelve patients (2.2%) developed an ileus, all but one (treated by endoscopic decompression) needed a reoperation. Two patients (0.4%) died, one of septic multiorgan failure due to an anastomotic leakage with faecal peritonitis, the other one of severe postoperative pneumonia. With regard to infectious complications, the rate for both superficial and deep surgical site infections was 13.6%. 2.9% of patients developed a urinary tract infection, 0.9% pneumonia. Five patients (0.9%) required a percutaneous drainage due to intraabdominal abscess formation (Table 4).

Two hundred three (36.4%) patients were operated by residents and 355 (63.6%) ileostomies were closed by senior surgeons (board certified) or consultants (Table 5). One hundred twenty-one patients had private health insurance coverage on the condition that the operation was performed by the Chief of Department or one of his consultants. There was no significant difference in baseline characteristics (age, ASA score, BMI, smoking habit, diabetes, immunosuppression) between both groups. Operation time (94 vs. 76 min, $p < 0.001$) and hospital stay (6 vs. 7 days, $p < 0.001$) differed significantly. Residents needed longer for the operation, whereas patients treated by consultants stayed longer in hospital. Forty-four (89.8%) laparotomies were done by consultants, 5 (10.2%) by residents ($p < 0.001$) All ileostomy closures performed by residents were constructed by an end-to-end anastomosis with interrupted Vicryl sutures using the Gambee technique, either by direct closure or following a segmental resection. Consultants decided to perform an end-to-side anastomosis in 3 cases and a side-to-side reconstruction in 22 cases ($p = 0.001$). No differences were detected in terms of adhesiolysis or segmental bowel resection. With regard to surgical site infections, leakage rate or bowel obstruction showed equal results in both groups. When focusing on postoperative complications according to the Clavien-Dindo classification, there was a significant difference with more grade 1 and 2 complications (37.4 vs. 28.6%), more grade

Table 1 Clinical patient data

Features	
Number of patients (*n*, %)	558 (100)
Age (years; median (min-max))	63 (20–93)
Gender (*n*, %)	
Male	345 (61.8)
Female	213 (38.2)
Health insurance coverage (*n*, %)	
Private	121 (21.7)
Non-private	437 (78.3)
BMI (kg/m^2; median (min-max))	24.9 (15.5–51.1)
Smoking habit (yes/no)	101 (18.1)/457 (81.9)
Diabetes mellitus (yes/no)	69 (87.6)/489 (12.4)
Immunosuppression (yes/no)	32 (5.8)/526 (94.3)
Cancer patient (yes/no)	275 (49.3)/283 (50.7)
Neoadjuvant therapy (*n*, %)	
None	382 (68.5)
RCTx	161 (28.8)
CTx	9 (1.6)
RTx	6 (1.1)
Adjuvant therapy (*n*, %)	
None	385 (69.0)
RCTx	5 (0.9)
CTx	165 (29.5)
RTx	1 (0.2)
Missing	2 (0.4)
ASA score (*n*, %)	
1	9 (1.6)
2	318 (57.0)
3	227 (40.7)
4	4 (0.7)

Table 2 Primary operation data

Features	
Number of patients (*n*, %)	558 (100)
Primary operation (*n*, %)	
Rectum resection	228 (40.9)
Defunctioning Ileostomy (primary or secondary)	157 (28.1)
Colon resection	115 (20.6)
Proctocolectomy	26 (4.7)
Small bowel resection	19 (3.4)
Hartmann reversal operation	13 (2.3)
Elective/emergency operation (%)	68.1/31.9
Open/laparoscopic technique (%)	86.4/13.6
Indication for ostomy (*n*, %)	
Cancer	244 (43.7)
Anastomotic leakage	83 (14.9)
Diverticulitis	58 (10.4)
IBD	51 (9.1)
Ileus	47 (8.4)
Other	73 (13.1)
Missing	2 (0.4)

3a and 3b complications (31.8 vs. 18.2%), three out of four grade 4a complications, all grade 4b complications and both deaths occurring in the consultant cohort ($p = 0.032$, Table 5).

In a further analysis, we decided to exclude patients with non-private insurance status primarily operated by a consultant and/or patients requiring laparotomy (Table 6). These parameters were considered surrogate markers for difficult cases/more complex surgeries and thus possible confounders

Table 3 Ileostomy closure—procedure related data

Features	
Number of patients (%)	558 (100)
Time to closure (days; median (min-max))	225 (3–1693)
Age (years; median (min-max))	58.3 (18–87)
Immunosuppression (yes/no, %)	4.7/95.3
Surgeon (*n*, %)	
Resident	203 (36.4)
Consultant	355 (63.6)
Operation time (mins; median (min-max))	93 (23–614)
Anastomosis technique (number, %)	
End-to-end	532 (95.5)
End-to-side	3 (0.6)
Side-to-side	22 (3.9)
Bowel resection (yes/no)	242 (43.4)/315 (56.5)
Adhesiolysis (yes/no)	255 (45.7)/303 (54.3)
Laparotomy (yes/no)	49 (8.8)/509 (91.2)
Length of stay (days; median (min-max))	9.8 (3–79)

Table 4 Ileostomy closure—morbidity and mortality

Features	
Number of patients (*n*, %)	558 (100)
Readmission rate (*n*, %)	8 (1.4)
Ileus (n, %)	
Temporary	75 (13.4)
Manifest	12 (2.2)
Anastomotic leakage (*n*, %)	17 (3.0)
Infectious complications (*n*, %)	
Surgical site infection	76 (13.6)
Urinary tract infection	16 (2.9)
Pneumonia	5 (0.9)
Intraabdominal abscess	5 (0.9)
Clavien-Dindo Classification (*n*, %)	
Grade 1	102 (18.3)
Grade 2	89 (15.9)
Grade 3a	6 (1.1)
Grade 3b	44 (7.9)
Grade 4a	4 (0.7)
Grade 4b	5 (0.9)
Grade 5	2 (0.4)

beyond patients' baseline characteristics. There were no differences detected regarding age, ASA score, the percentage of smokers or patients with diabetes and the need for immunosuppression. Operation time and length of hospital stay remained significantly different. We observed a trend of more bowel resections performed by residents (46 vs 35.2%, $p = 0.071$). Higher numbers of minor postoperative complications (Clavien-Dindo grade 1 and 2) were recorded in the consultant cohort and thereby maintained a statistically significant difference in overall morbidity ($p = 0.001$, data not shown). However, when focusing on major complications (Clavien-Dindo grade ≥ 3), this difference dissolves ($p = 0.948$) (Table 6).

Discussion

Faecal diversion drastically reduces the number of symptomatic dehiscences of colorectal, coloanal or ilealpouch-anal anastomoses [2]. Besides the risk of stoma-related complications (dehydration, acute renal failure, parastomal hernia, stoma prolapse, severe parastomal skin alterations), as well as the fact that up to 25% of defunctioning stomata become permanent [18, 19], ileostomy closure is associated with a high rate of morbidity ranging from 3 to 40% and mortality from 0 to 4% [5, 6]. Up to 10% of major complications were reported in a large series of more than 5000 ileostomy reversals [20]. Differences in study design, heterogeneity in study

Table 5 Comparative analysis—resident vs. consultant

	Total	Resident	Consultant	*p* value
Frequency (*n*, %)	558 (100)	203 (36.4)	355 (64.6)	
Age (years; median (min-max))		61 (20–86)	59 (18–87)	n.s.
Health insurance coverage (*n*, %)				
Non-private		203 (100)	234 (65.9)	
Private		0	121 (34.1)	$p < 0.001$[b]
ASA score (*n*, %)	558 (100)			
1 + 2		114 (56.2)	213 (60)	
3 + 4		89 (43.8)	142 (40)	n.s.
BMI (kg/m^2; *n*, %)	549 (100)			
< 18		6 (3)	15 (4.3)	
18–25		92 (45.5)	174 (50.1)	
25–30		78 (38.6)	114 (32.9)	
> 30		26 (12.9)	44 (12.7)	n.s.
Smoking habit (*n*, %)	558 (100)			
Yes		35 (17.2)	66 (18.6)	
No		168 (82.8)	289 (81.4)	n.s.
Diabetes mellitus (*n*, %)	558 (100)			
Yes		28 (13.8)	41 (11.5)	
No		175 (86.2)	314 (88.5)	n.s.
Immunosuppression (*n*, %)	558 (100)			
Yes		11 (5.4)	15 (4.2)	
No		192 (94.6)	340 (95.8)	n.s.
Operation time (min)		94 (40–202)	76 (23–614)	$p < 0.001$[a]
Laparotomy (*n*, %)	558 (100)			
Yes		5 (2.5)	44 (12.4)	
No		198 (97.5)	311 (87.6)	$p < 0.001$[b]
Adhesiolysis (*n*, %)	558 (100)			
Yes		84 (41.4)	171 (48.2)	
No		119 (58.6)	184 (51.8)	n.s.
Bowel resection (*n*, %)	557 (100)			
Yes		95 (46.8)	147 (41.5)	
No		108 (53.2)	207 (58.5)	n.s.
Type of anastomosis (*n*, %)	558 (100)			
End-to-end		203 (100)	329 (93.0)	
End-to-side		0	3 (0.8)	
Side-to-side		0	22 (6.2)	$p = 0.001$[c]
Length of stay (days; median (min-max))		6 (3–52)	7 (3–79)	$p < 0.001$[a]
Surgical site infection (*n*, %)	558 (100)			
Yes		20 (9.9)	56 (15.8)	
No		183 (90.1)	299 (84.2)	n.s.
Leakage (*n*, %)	558 (100)			
Yes		5 (2.5)	12 (3.4)	
No		198 (97.5)	343 (96.6)	n.s.
Ileus (*n*, %)	558 (100)			
Yes		28 (13.8)	59 (16.6)	
No		175 (86.2)	296 (83.4)	n.s.
Clavien-Dindo (*n*, %)	558 (100)			
Grade 1		38 (18.7)	64 (18.0)	
Grade 2		20 (9.9)	69 (19.4)	

Table 5 (continued)

	Total	Resident	Consultant	*p* value
Grade 3a		2 (2.2)	4 (3.8)	
Grade 3b		15 (16.0)	29 (28.0)	
Grade 4a		1 (0.5)	3 (0.8)	
Grade 4b		0 (0.0)	5 (1.4)	
Grade 5		0 (0.0)	2 (0.6)	$p = 0.032$[c]

[a] Man-Whitney *U* test

[b] Exact test n. Fisher

[c] Qui-quadrat test

populations as well as inconsistency and incompleteness in outcome reporting account for broad data variability [16, 21, 22]. Consequently, the interpretation (direct comparison) of outcome data after ileostomy reversal remains demanding. Through consistent data acquisition of postoperative complications, our series of 558 ileostomy reversals came up with an overall morbidity of 45.2%. For patients suffering from any postoperative complication according to the Clavien-Dindo system, each event was calculated separately resulting in a higher number of total events per classification category (especially grade 1 or 2 events). When focusing on major complications, i.e. postoperative events with a Clavien-Dindo score ≥ 3, we found 61 cases (11%) including 2 deaths (0.4%). These results are in line with previous reports [5, 20].

Resident participation in surgical procedures is essential for training, and it remains of major interest to examine quality of surgery and safety of patients undergoing surgical procedures in a teaching environment [14]. The demand for high surgical quality (i.e. low morbidity) and cost-effectiveness in combination with working hour restrictions and a change in young residents' attitude to fully commit to the strenuous efforts of surgical training (i.e. generation Y) impede the generation of an appropriate organisational framework for surgical education [23]. Nonetheless, large-scale resident involvement in surgical procedures proved to be safe in the present setting [14, 24].

Ileostomy reversal is considered a good learning model to create intestinal anastomoses. As a commonly performed procedure, it allows appropriate learning curves for young trainees to become familiar with intestinal wall suturing. It thereby represents an ideal bridge to more complex bowel surgery. These considerations explain our institutional approach to apply hand-sewn techniques. Data on ileostomy closure remain controversial with regard to proficiency levels in terms of postoperative outcome. The HASTA trial, a randomized controlled multicentre study, investigated the best surgical technique for closure of loop ileostomy. In the multivariate analysis of potential confounders, surgeons' training levels (40% of closures were performed as teaching operation) did not correlate with postoperative bowel obstruction rates, the study's primary endpoint [25]. Another study was conducted in order to identify risk factors for reoperation after ileostomy reversal. Anaemia remained the only risk factor in multivariate analysis, whereas training levels of participating surgeons did not have a relevant prognostic value [26]. Luglio and colleagues analysed 298 ileostomy closures which were performed by junior residents supervised by senior residents [27]. Postoperative complications were compared to the results of the HASTA trial, which may be considered as a limitation as a matched cohort for direct comparison of the cohort was missing. Morbidity was found to be very low leading the authors to argue, that a senior resident's supervision might be sufficient to avoid higher complication rates [27]. These results become partly contradicted by two consecutive Dutch studies. The initial trial reported major morbidity rates of 11% [28] that could have been significantly reduced to 4% by changing surgical proficiency levels [29]. Stoma reversal being performed or supervised by a specialized colorectal surgeon was found to be associated with a lower risk of 30-day postoperative morbidity. These results, however, should be interpreted with caution as there is a relevant heterogeneity with regard to the type of construction as well the anastomotic technique when the two cohorts are compared [29].

In our comparative analysis on training levels, we detected a significantly longer operation time in the resident group (94 vs. 76 min, $p < 0.001$) representing the young surgeons' learning curve. Postoperative complications according to the Clavien-Dindo classification did show statistical significance between both groups in overall morbidity ($p = 0.032$). All but one Clavien-Dindo $\geq$4a ($n = 10$) complication was recorded in the consultant cohort,

Table 6 Comparative analysis w/ o laparotomy—resident vs. consultant (w/o non-private cases)

	Total	Resident	Consultant	*p* value
Frequency (*n*, %)	306 (100)	198 (64.7)	108 (35.3)	
Age (years; median (min-max))		61 (20–86)	61 (18–87)	n.s.
ASA score (*n*, %)	306 (100)			
1 + 2		114 (57.6)	74 (68.5)	
3 + 4		84 (42.4)	34 (31.5)	n.s.
BMI (kg/m^2; *n*, %)	302 (100)			
< 18		5 (2.5)	3 (2.9)	
18–25		90 (45.7)	59 (56.2)	
25–30		76 (38.6)	33 (31.4)	
> 30		26 (13.2)	10 (9.5)	n.s.
Smoking habit (*n*, %)	306 (100)			
Yes		34 (17.2)	18 (16.7)	
No		164 (82.8)	90 (83.3)	n.s.
Diabetes mellitus (*n*, %)	306 (100)			
Yes		27 (13.6)	10 (9.3)	
No		171 (86.4)	98 (90.7)	n.s.
Immunosuppression (*n*, %)	306 (100)			
Yes		9 (4.5)	4 (3.7)	
No		189 (95.5)	104 (96.3)	n.s.
Operation time (min)		93 (40–202)	64 (23–126)	$p < 0.001$[a]
Adhesiolysis (*n*, %)	306 (100)			
Yes		80 (40.4)	49 (45.4)	
No		118 (59.6)	59 (54.6)	n.s.
Bowel resection (*n*, %)	306 (100)			
Yes		91 (46.0)	38 (35.2)	n.s.
No		107 (54.0)	70 (64.8)	$p = 0.071$[b]
Type of anastomosis (*n*, %)	306 (100)			
End-to-end		198 (100.0)	104 (96.3)	
Side-to-side		0 (0.0)	4 (3.7)	$p = 0.015$[b]
Length of stay (days; median (min-max))		6 (3–52)	7 (3–47)	$p = 0.001$[a]
Surgical site infection (*n*, %)	306 (100)			
Yes		20 (10.1)	14 (13.0)	
No		178 (89.9)	94 (87.0)	n.s.
Leakage (*n*, %)	306 (100)			
Yes		5 (2.5)	2 (1.9)	
No		193 (97.5)	106 (98.1)	n.s.
Ileus (*n*, %)	306 (100)			
Yes		25 (12.6)	17 (15.7)	
No		173 (87.3)	91 (84.3)	n.s.
Clavien-Dindo (*n*, %)	306 (100)			
Grade 3a		2 (1.0)	1 (0.9)	
Grade 3b		14 (7.1)	9 (8.3)	
Grade 4a		1 (0.5)	1 (0.9)	
Grade 4b		0 (0.0)	0 (0.0)	
Grade 5		0 (0.0)	0 (0.0)	n.s.

[a] Man-Whitney *U* test

[b] Exact test n. Fisher

[c] Qui-quadrat test

emphasizing the difficulty of those cases that were primarily operated by consultants (including all non-private patients). Additionally, 89.9% of all laparotomies were performed by consultants, a further surrogate marker for complex procedures. Therefore, when adjusting for these possible confounders, baseline characteristics remained similar, but major postoperative morbidity was not found to be still statistically different between both groups ($p = 0.948$). Moreover, operation time was drastically reduced in the consultant group from initially 76 min down to 64 min. We detected a trend towards more bowel resections performed in the resident group ($p = 0.071$). This might reflect the different performance levels of our trainees' preparation techniques leading to serosal or transmural tears which require subsequent segmental resection.

In conclusion, our results extend previous observations that ileostomy reversal in low-risk patients represents an optimal teaching procedure for trainees to become

confident with the construction of bowel anastomoses. The application of one standard technique allows fast and sustained learning curves. Supervision by an experienced surgeon remains mandatory to obtain acceptable postoperative morbidity rates.

Acknowledgements We would like to thank M. Hankir for proofreading of the manuscript.

Compliance with ethical standards

All procedures performed were in accordance with the standards of the institutional ethical committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Branagan G, Finnis D, G. Wessex Colorectal Cancer Audit Working (2005) Prognosis after anastomotic leakage in colorectal surgery. Dis Colon Rectum 48(5):1021–1026
2. Huser N et al (2008) Systematic review and meta-analysis of the role of defunctioning stoma in low rectal cancer surgery. Ann Surg 248(1):52–60
3. Mirnezami A, Mirnezami R, Chandrakumaran K, Sasapu K, Sagar P, Finan P (2011) Increased local recurrence and reduced survival from colorectal cancer following anastomotic leak: systematic review and meta-analysis. Ann Surg 253(5):890–899
4. Brand MI, Dujovny N (2008) Preoperative considerations and creation of normal ostomies. Clin Colon Rectal Surg 21(1):5–16
5. Chow A, Tilney HS, Paraskeva P, Jeyarajah S, Zacharakis E, Purkayastha S (2009) The morbidity surrounding reversal of defunctioning ileostomies: a systematic review of 48 studies including 6,107 cases. Int J Color Dis 24(6):711–723
6. Kaidar-Person O, Person B, Wexner SD (2005) Complications of construction and closure of temporary loop ileostomy. J Am Coll Surg 201(5):759–773
7. Itani KM et al (2005) Surgical resident supervision in the operating room and outcomes of care in Veterans Affairs hospitals. Am J Surg 190(5):725–731
8. Fahrner R, Turina M, Neuhaus V, Schöb O (2012) Laparoscopic cholecystectomy as a teaching operation: comparison of outcome between residents and attending surgeons in 1,747 patients. Langenbeck's Arch Surg 397(1):103–110
9. Graat LJ, Bosma E, Roukema JA, Heisterkamp J (2012) Appendectomy by residents is safe and not associated with a higher incidence of complications: a retrospective cohort study. Ann Surg 255(4):715–719
10. Kauvar DS, Braswell A, Brown BD, Harnisch M (2006) Influence of resident and attending surgeon seniority on operative performance in laparoscopic cholecystectomy. J Surg Res 132(2):159–163
11. Robson AJ, Wallace CG, Sharma AK, Nixon SJ, Paterson-Brown S (2004) Effects of training and supervision on recurrence rate after inguinal hernia repair. Br J Surg 91(6):774–777
12. Scarborough JE, Bennett KM, Pappas TN (2012) Defining the impact of resident participation on outcomes after appendectomy. Ann Surg 255(3):577–582
13. Tseng WH, Jin L, Canter RJ, Martinez SR, Khatri VP, Gauvin J, Bold RJ, Wisner D, Taylor S, Chen SL (2011) Surgical resident involvement is safe for common elective general surgery procedures. J Am Coll Surg 213(1):19–26 discussion 26–8
14. Slankamenac K, Graf R, Barkun J, Puhan MA, Clavien PA (2013) The comprehensive complication index: a novel continuous scale to measure surgical morbidity. Ann Surg 258(1):1–7
15. Loiero D, Slankamenac M, Clavien PA, Slankamenac K (2017) Impact of residency training level on the surgical quality following general surgery procedures. World J Surg 41(11):2652–2666
16. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240(2):205–213
17. Gambee LP (1951) A single-layer open intestinal anastomosis applicable to the small as well as the large intestine. West J Surg Obstet Gynecol 59(1):1–5
18. Lindgren R, Hallböök O, Rutegård J, Sjödahl R, Matthiessen P (2011) What is the risk for a permanent stoma after low anterior resection of the rectum for cancer? A six-year follow-up of a multicenter trial. Dis Colon Rectum 54(1):41–47
19. Sier MF, van Gelder L, Ubbink DT, Bemelman WA, Oostenbroek RJ (2015) Factors affecting timing of closure and non-reversal of temporary ileostomies. Int J Color Dis 30(9):1185–1192
20. Sharma A, Deeb AP, Rickles AS, Iannuzzi JC, Monson JRT, Fleming FJ (2013) Closure of defunctioning loop ileostomy is associated with considerable morbidity. Color Dis 15(4):458–462
21. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Santibañes E, Pekolj J, Slankamenac K, Bassi C, Graf R, Vonlanthen R, Padbury R, Cameron JL, Makuuchi M (2009) The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 250(2):187–196
22. Clavien PA, Strasberg SM (2009) Severity grading of surgical complications. Ann Surg 250(2):197–198
23. Lederer AK et al (2017) Generation Y: the uncertain future of surgery. Zentralbl Chir 142(6):581–582
24. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW (2012) Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. Ann Surg 256(3):469–475
25. Loffler T et al (2012) HAnd suture versus stapling for closure of loop ileostomy (HASTA Trial): results of a multicenter randomized trial (DRKS00000040). Ann Surg 256(5): 828–835 discussion 835–6
26. Schneider V, Lee LD, Stroux A, Buhr HJ, Ritz JP, Kreis ME, Lauscher JC (2016) Risk factors for reoperation after ileostomy reversal—results from a prospective cohort study. Int J Surg 36(Pt A):233–239
27. Luglio G, Terracciano F, Giglio MC, Sacco M, Peltrini R, Sollazzo V, Spadarella E, Bucci C, de Palma GD, Bucci L (2017) Ileostomy reversal with handsewn techniques. Short-term outcomes in a teaching hospital. Int J Color Dis 32(1):113–118
28. van Westreenen HL, Visser A, Tanis PJ, Bemelman WA (2012) Morbidity related to defunctioning ileostomy closure after ileal pouch-anal anastomosis and low colonic anastomosis. Int J Color Dis 27(1):49–54
29. Musters GD, Atema JJ, van Westreenen HL, Buskens CJ, Bemelman WA, Tanis PJ (2016) Ileostomy closure by colorectal surgeons results in less major morbidity: results from an institutional change in practice and awareness. Int J Color Dis 31(3):661–667