International Journal of Colorectal Disease (2019) 34:55–61
https://doi.org/10.1007/s00384-018-3168-6

ORIGINAL ARTICLE

Influence of suture technique on anastomotic leakage rate—a retrospective analyses comparing interrupted—versus continuous—sutures

Roman Eickhoff[1] · Simon B. Eickhoff[2,3] · Serdar Katurman[1] · Christian D. Klink[1] · Daniel Heise[1] · Andreas Kroh[1] · Ulf P. Neumann[1] · Marcel Binnebösel[1]

Accepted: 16 September 2018 / Published online: 24 September 2018

Abstract

Purpose While many hospitals consider a continuous sutured colonic anastomosis with monofilamental fiber the current state of the art, others have advocated for interrupted sutures as the gold standard. The aim of the study was to evaluate the influence of suture technique on leakage rate (primary endpoint), wound infections, postoperative stay, and mortality.

Methods Retrospective analyses of 347 patients (273 elective, 74 urgent) over 6 years with a handsewn colonic anastomosis (190 interrupted, 157 continuous), excluding sigma and rectum anastomosis. Demographic and surgical baseline characteristics were used as competing predictors.

Results Overall leakage rate was 9% but strongly dependent on suture technique (interrupted: 16%; continuous: 2.5%; $p = 0.001$) yielding an odds ratio of 5.10 [95% CI: 2.55, 6.71] (relative risk of leakage). No other variable showed a significant influence on leakage rate. Postoperative stay was prolonged in the interrupted suture group (23 ± 15 vs. 16 ± 11 days; $p = 0.000$, attributable effect 7.5 days [4.7, 10.3]).

Conclusions Our results indicate a highly significant reduction of anastomotic leakage rate and postoperative stay that generalize to the underlying population by continuous sutures in handsewn colonic anastomosis. In the absence of randomized prospective studies, the current results provide the yet strongest evidence for the superiority of continuous sutures.

Keywords Anastomotic leakage · Interrupted suture technique · Continuous suture technique · Anastomotic technique · Colon anastomosis

Introduction

Since the development of intestinal suture during the nineteenth century, various techniques for hand-sewn intestinal anastomosis have been developed, employing single- or double-layered techniques, end-to-end vs. side-to-side techniques, all in combination with different kinds of suture material [1–6]. Even though the single-layer continuous suture technique with non- or slow-absorbing monofilament material represents the standard technique in many hospitals to date and is preferred to interrupted sutures for end-to-end handsewn colonic anastomosis, comparative clinical studies are lacking [7]. There have been some experimental studies showing improved serosal apposition in continuous and better blood flow in interrupted sutured anastomosis [8, 9]. In turn, bursting strength and anastomotic healing in experimental studies were comparable between continuous and interrupted sutures [9].

Widely used clinical criteria to evaluate a "good" anastomoses are permeability, postoperative leakage, formation of stenosis, and healing time, but the key outcome parameter is definitively anastomotic leakage given its close association with morbidity and mortality [10–12]. To our knowledge, only one previous study compared the rate of postoperative

✉ Roman Eickhoff
reickhoff@ukaachen.de

[1] Department of General, Visceral and Transplantation Surgery, RWTH Aachen University Hospital, Pauwelsstrasse 30, 52074 Aachen, Germany

[2] Institute for Systems Neuroscience, Medical School, Heinrich-Heine University Düsseldorf, Düsseldorf, Germany

[3] Institute of Neuroscience and Medicine (INM-7) Research Center Jülich, Jülich, Germany

insufficiencies between continuous sutured vs. interrupted sutured single-layer anastomosis in a clinical setting. In the assessed, small sample of 53 patients, both methods showed an equivalent leakage rate of 3.8% [13]. Furthermore, a systematic review of colorectal anastomosis techniques [7] concluded that there is insufficient evidence from clinical and experimental studies on whether interrupted or continuous sutures should be considered superior and recommended continuous suture from a practical point of view.

The aim of the present study was to provide a comprehensive comparison of clinical outcomes between continuous and interrupted sutures for colonic anastomosis. To this end, we retrospectively assessed leakage (primary endpoint) as well as wound infections, postoperative stay, and mortality over all patients with hand-sewn, single-layer colon anastomosis treated in our center over a 6-year period.

Materials and methods

Between January 2004 and March 2010, a total of 347 patients underwent colonic surgery at the Department of General, Visceral and Transplantation Surgery and fulfilled the following inclusion criteria. Patients were over 18 years of age and underwent ileocecal resections (anastomosis: ileo-ascendostomy), right hemicolectomy (ileotransverse colostomy), and transverse colon resection (ascending to descending colon anastomosis) with a reconstruction in an end-to-end technique. Only open resections were considered due to the low rate of laparoscopic surgery in that period. All cases were included regardless of whether the procedure was part of an elective surgery or performed in an urgent setting. Decision about anastomotic technique was made by surgeon during the operation. Preoperatively, all patients received intravenous antibiotic prophylaxis with a first generation cephalosporin (Cefuroxim®, Fresenius Kabi Deutschland GmbH, Bad Homburg, Germany) and metronidazole (Clont®, Fresenius Kabi Deutschland GmbH, Bad Homburg, Germany). For the interrupted sutures, 3/0 polyglactin (Vicryl®, Ethicon Inc., Somerville, NJ, USA) was used, for the continuous sutures 3/0 polyglecaprone (Monocryl plus®, Ethicon Inc., Somerville, NJ, USA). Since April 2010, we changed the operative concept in colorectal surgery. On the one hand, laparoscopic procedures have been implemented progressively, and on the other hand, anastomotic technique was changed from end-to-end to side-to-side anastomosis in case of ileo-ascendostomies and ileotransverse colostomies. To exclude a relevant bias, patients that were operated following April 2010 remained unconsidered therefore.

We collected basic demographic data (age, gender, height, weight, and body mass index [BMI]), clinical-anamnestic data such as American Society of Anaesthesiologists (ASA) score, comorbidities (arterial hypertension, coronary heart disease, chronic obstructive pulmonary diseases [COPD], diabetes mellitus), medication with cortisone- and ASS, and perioperative data (priority of operation, kind of anastomosis, operative time, hemoglobin, C-reactive protein, white cell count) as predictor variables. Outcome variables were defined as: duration of postoperative hospital stay, wound infection rate (CDC definitions [14]), mortality within 30 postsurgical days, and occurrence of an anastomotic leakage. Anastomotic leakage was considered to be the main unfavorable event and hence primary outcome. It was defined as either extravasation of contrast agent on imaging procedures, presence of diffuse peritonitis with fecal fluid on reoperation, presence of localized abscess in the proximity of anastomosis, or fecal discharge from the drain or wound. In the event of indistinct cases, an additional endoscopy was performed to confirm or rule out anastomotic leakage. The present study was conducted in accordance with the principles of the Declaration of Helsinki and '*good clinical practice*' guidelines. The study was approved by the local ethics committee (EK 093/16).

Statistical analysis

Multivariate statistical analysis was carried out with MATLAB® (V 9.0) by a logistic regression model for categorical outcome variables (leakage, wound infection, mortality) and a Gaussian regression model for the continuous outcome variable (postoperative hospital stay), respectively. Importantly, all possible predictors (socio-demographic, clinical-anamnestic, and perioperative data) entered the model simultaneously in order to account for potential (multi-) collinearity between predictors and hence shared variance. That is, variance attributable to the confounding variables was partialled out as part of our model, hereby accommodating any potential imbalance in their expression across the different levels of the factor of interest.

If the effect of the factor "suture" was significant ($p < 0.05$), we subsequently tested, whether the inclusion of this factor indeed resulted in a robustly superior performance of the prediction model. This is important to avoid overfitting in the current multivariate context and to ensure that the inclusion of the factor "suture" does indeed provide a better prediction of the outcome not only in the assessed patients but the underlying population. Assessment was performed by drawing 10,000 bootstrap samples from the original data and fitting both the full as well as the reduced model (excluding suture) to each of these random samplings. The full model was considered robustly superior, if the 3 (categorical outcomes) and 1 (continuous outcome), respectively, was higher in more than 95% of all samples. In addition, the employed bootstrap scheme also allowed computing unbiased confidence intervals on odds ratios and attributable risk that generalize to the population. Finally, three subgroup analyses were performed using the same procedure, including only patients who

received an ileo-ascendostomy and ileotransverse colostomy, respectively. In turn, the number of cases receiving an ascending to descending colon anastomosis was too low for reliable modeling.

Results

A total of 347 patients (170 women, 177 men) were included in the study. Mean age (±standard deviation) of all patients was 65 ± 16 years with a BMI of 26 ± 5. In 190 patients (55%), the anastomoses were performed using an interrupted suture, and in 157 patients (45%), a continuous suture was used. Priority of the operation was elective in $n = 273$ patients (79%), of which 152 patients received an interrupted and 121 a continuous suture. Emergency operation was performed in $n = 74$ patients (21% of all cases, 38 with an interrupted anastomosis; 36 with a continuous anastomosis). In 222 patients, operation was performed due to colon cancer (133 interrupted cases [70%]; 89 continuous suture cases [57%]). Duration of the operation was 131 ± 67 min (137 ± 75-min interrupted suture group; 124 ± 54-min continuous suture group). Detailed patient and baseline surgical characteristics are given in Table 1.

Leakage rate across all cases was 9% with 30 cases of leakage in the interrupted suture group (16%) and 4 cases of

Table 1 Patients and baseline surgical characteristics

Parameter	All cases	Interrupted	Continuous suture
Patients	347	190 (55%)	157 (45%)
Age	65 ± 16	65.5 ± 15	62 ± 17
Gender	m = 177; f = 170	m = 102; f = 88	m = 75; f = 82
Height	170 ± 9	170 ± 9	170 ± 9
Weight	74 ± 15	75 ± 14	74 ± 16
BMI	26 ± 5	26 ± 5	25 ± 5
ASA			
ASA I	29 (8%)	16 (8%)	13 (8%)
ASA II	125 (36%)	68 (36%)	57 (36%)
ASA III	168 (49%)	95 (50%)	74 (47%)
ASA IV	24 (7%)	11 (6%)	13 (8%)
KHK	69 (20%)	33 (17%)	36 (23%)
Hypertonia	152 (44%)	79 (42%)	73 (46%)
Diabetes	51 (15%)	22 (12%)	29 (18%)
COPD	44 (13%)	25 (13%)	19 (12%)
Cortisone	39 (11%)	22 (12%)	17 (11%)
ASS	73 (21%)	35 (18%)	38 (24%)
Hb-pre-surgical	117 ± 23	118 ± 21	116 ± 26
CRP-pre-surgical	66 ± 74	60 ± 73	73 ± 76
WBC-pre-surgical	8.9 ± 4.4	8.8 ± 4.6	9.1 ± 4.2
Priority			
elective	273 (79%)	152 (80%)	121 (77%)
emergency	74 (21%)	38 (20%)	36 (23%)
Diagnosis			
Cancer	222 (64%)	133 (70%)	89 (57%)
CED	31 (9%)	12 (6%)	19 (12%)
other	94 (27%)	45 (24%)	49 (31%)
Anastomosis			
1	40 (11%)	23 (12%)	17 (11%)
2	190 (55%)	103 (54%)	87 (55%)
3	117 (34%)	64 (34%)	53 (34%)
Operative time	131 ± 67	137 ± 75	124 ± 54

Date are number (% of group total), mean ± SD; m = male, f = female

Anastomosis 1 = ascending to descending colon anastomosis; anastomosis 2 = ileo-transverse colostomy; anastomosis 3 = ileo-ascendostomy

leakage in the continuous suture group (2.5%; $p = 0.001$), leading to an odds ratio of 5.10 [95% CI: 2.55, 6.71] for the relative risk of leakage. There was no other predictor variable with a significant effect for the leakage rate.

Twenty percent of all patients developed a wound infection (28% interrupted group vs. 20% continuous group; $p = 0.12$, OR 1.58 [0.84, 3.05]). Further, predictors for developing a wound infect were: chronic inflammatory diseases $p = 0.027$, operative time (skin incision to completion of skin closure) $p = 0.037$, and males $p = 0.016$. Thirty-day mortality after operation was 7% across all cases (9% interrupted group vs. 6% continuous suture group; $p = 0.18$, OR 2.33 [0.80, 5.75]), including 20% mortality after urgent resections and 4% mortality after elective colonic surgery. Predictors of mortality were identified: priority of operation ($p = 0.001$), age ($p = 0.01$), pre-surgical hemoglobin ($p = 0.009$), and operative time ($p = 0.006$). Postoperative stay was significantly longer in the interrupted suture group (23 ± 15 days) compared to the continuous suture group (16 ± 11 days; $p = 0.000$) which leads to 7.5 days [4.7, 10.3] attributable to the suture technique. Further predictors of prolonged hospital stay were: pre-surgical hemoglobin ($p = 0.004$), ileo-ascendostomy vs. ascending to descending colon anastomosis ($p = 0.012$), and ASA rating ($p = 0.048$). Detailed information is given in Tables 2 and 3.

Ileocecal resections

We could analyze 117 ileocecal resections, using interrupted sutures in 64 cases and continuous sutures in 53 cases. The odds ratio for anastomotic leakage given interrupted suture was 2.14 [95% CI: 0.72, 3.23] (leakage rate interrupted 14% vs. 6% continuous suture group, $p = 0.066$). There was no significant difference in wound infection rate and 30-day mortality between the suture techniques (wound infect: $p = 0.635$; 30-day mortality: $p = 0.935$). Postoperative stay was prolonged in the interrupted suture group with 4.7 days attributable to suture (interrupted group: 24 ± 17 days vs. continuous group: 18 ± 12 days, $p = 0.05$, OR 4.7 [− 1.4, 11.3].

Hemicolectomy right

In 190 patients, right hemicolectomies with ileotransverse colostomy were conducted either using interrupted ($n = 103$) or continuous ($n = 87$) sutures. Concerning leakage rate, we found an odds ratio of 16.84 [6.19, 25.33] for anastomotic

Table 2 Primary and secondary endpoints

	All cases	Interrupted suture	Continuous suture	*p* value	OR	ROC (*P*)	Added days attributable to suture	MAE
Primary endpoint								
Leakage	30 (9%)	26 (16%)	4 (2.5%)	0.001	5.10 [2.55, 6.71]	0.998		
Subgroup A	4 (12%)	4 (17%)	0					
Subgroup B	14 (7%)	13 (13%)	1 (1%)	0.007	16.84 [6.19, 25.33]	0.999		
Subgroup C	12 (10%)	9 (14%)	3 (6%)	0.066	2.14 [0.72, 3.23]	0.790		
Secondary endpoints								
Wound infect	86 (25%)	54 (28%)	32 (20%)	0.12	1.58 [0.84, 3.05]	0.841		
Subgroup A	9 (22.5%)	6 (30%)	3 (18%)					
Subgroup B	44 (23%)	30 (29%)	14 (16%)	0.021	2.66 [1.11, 5.41]	0.891		
Subgroup C	33 (31%)	18 (28%)	15 (28%)	0.635	0.87 [0.26, 3.14]	0.669		
30-day Mortality	26 (7%)	17 (9%)	9 (6%)	0.18	2.33 [0.80, 5.75]	0.892		
Subgroup A	0	0	0					
Subgroup B	20 (10.5%)	13 (13%)	7 (8%)	0.379	1.81 [0.44, 8.05]	0.746		
Subgroup C	6 (5%)	4 (6%)	2 (4%)	0.935	1.07 [0.50, 2.04]	0.445		
PO-stay	20 ± 14	23 ± 15	16 ± 11	0.000			7.5 [4.7, 10.3]	0.999
Subgroup A	22 ± 17	27 ± 21	16 ± 8					
Subgroup B	18 ± 12	22 ± 12	14 ± 11	0.000			8.9 [6.0, 12.0]	1.000
Subgroup C	21 ± 16	24 ± 17	18 ± 12	0.05			4.7 [−1.4, 11.3]	0.573

Date are number (% of group total), mean ± SD. OR = odds ratio (95% CI). *p* value with significance level of 5%. MAE = mean absolute error

ROC = area under the receiver operating characteristic mean of 10,000 bootstraps reduced model vs. mean of 10,000 bootstraps full model = P

Subgroup A = ascending to descending colon anastomosis; subgroup B = ileo-transverse colostomy; subgroup C = ileo-ascendostomy; POStay = postoperative stay

Subgroup A: no reliable model due to small number of cases

Table 3 Predictors primary and secondary endpoints

Endpoint	Predictor	*p* value	*P*
Leakage	Suture technique	0.006	0.998
Wound infect	Operative time	0.004	0.841
	Gender	0.016	
	Diagnosis CID vs. cancer	0.027	
30-day mortality	Priority	0.001	0.892
	Age	0.009	
	Pre-OP hemoglobin	0.009	
	Operative time	0.006	
Post-OP stay	suture technique	0.000	0.999
	Pre-OP hemoglobin	0.004	
	Anastomosis 3 vs. 2	0.012	
	ASA	0.048	

leakage when interrupted suture technique was used (leakage rate interrupted 13% vs. 1% continuous suture group; $p = 0.007$). There was also a higher wound infection rate in the interrupted group (29%) compared to the continuous suture group (16%, $p = 0.021$; OR 2.66 [1.11, 5.41]). We found no significant difference in 30-day mortality between the groups ($p = 0.379$). Postoperative stay was prolonged in the interrupted suture group with 8.9 [6.0, 12.0] days attributable to suture technique (interrupted group: 22 ± 12 days; continuous suture group 14 ± 11 days; $p = 0.000$).

Discussion

In this study, we retrospectively analyzed 347 cases of intestinal anastomosis in order to assess the influence of suture technique on leakage, infections, mortality, and postoperative hospital stay, using a multivariate model accommodating any potential influence of socio-demographic, clinical-anamnestic, and perioperative factors. With respect to the key outcome, we could show for the first time that suture technique has a significant and robust influence on anastomotic leakage, with interrupted sutures carrying a more than 5-fold increased risk of this important complication. Importantly, suture technique was the only significant predictor variable for leakage in a multivariate regression model and inclusion of this factor resulted in a significantly better outcome prediction. In addition, our subgroup analyses demonstrated that a continuous suture technique resulted in a significant lower rate of anastomotic leakage for all positions of the anastomosis. In a review of colorectal anastomosis techniques by Slieker et al. [7], continuous anastomosis technique was recommended from a technical and pragmatic point of view. But, as noted in the introduction, there was little empirical evidence for this recommendation. If anything, smaller studies [13] were inconclusive in this respect. Jibborn [9] described in his experiments 1978 equal anastomotic bursting pressure and breaking strength of interrupted and continuous suture anastomosis in a rat model. On the other hand, the mechanical behavior in continuous and interrupted anastomosis might be different: in an interrupted anastomosis, the suture is placed in a right angle. In contrast in a continuous anastomosis, the suture filaments run crosswise over the anastomosis. By filling and therefore expanding the anastomosis, it might be a self-sealing effect of the crosswise running filaments because the tension is better distributed on the circumference [15].

The current analysis now provides the much needed statistical basis for recommending continuous sutures by demonstrating a clear advantage of continuous suture with respect to the risk of leakage that generalizes to the underlying patient populations as shown by bootstrap resampling.

The overall rate of anastomotic leakage in our sample was 9%, which is well in line with the literature reporting leakage rates between 1.8 and 15.9% [16–22]. A large retrospective study by Midura et al. [23] including more than 13,000 patients (suture-technique not specified, different underlying diseases) reported anastomotic leakage rates of 4.9% in ileocecal resections (vs. 6% continuous suture group in our series) and 4.8% in segmental colectomies. Volk et al. [24] analyzed 463 patients with ileocolonic anastomosis using continuous sutures and showed a leakage rate of 2.1%, which rose to 4.3% in patients with Crohn's disease.

It may be noted that a leakage rate of ~ 10% is certainly not what would currently be considered an ideal outcome for, e.g., elective surgery on colon cancer. For example, Pramateftakis et al. [25] reported on a cohort of 276 oncological patients with elective surgery showing a leakage rate of 2.5%. Another cohort study on interrupted suture by Jonsell et al. [26] with 165 patients with elective surgery for colon cancer reported a leakage rate of 8.5%.

We hence would like to reiterate that the current sample was deliberately unselected as we wanted to provide a more naturalistic picture and hence included a broader clinical population including challenging conditions such as emergency resections, CED with steroid treatment, colon ischemia etc. In this context, it is noteworthy that in spite of the clinical and surgical heterogeneity, bootstrapping still showed a clear influence of suture technique, indicating that our findings should not only be applicable to a particular population but all colonic anastomoses. Over the past years—also in our clinic—significantly more procedures are performed laparoscopically, which in turn has lowered the overall morbidity rate including anastomotic leakage rate [18, 21, 23, 27, 28].

In our data, mortality was highly related to the priority of the operation (increased in emergency surgery), age (increased in elderly), pre-surgical hemoglobin (increased in low hemoglobin), and increased in long operative time. These predictors of mortality closely match those reported by Volk et al. [24],

which also reported age with an OR 3.2 ($p = 0.027$) and emergency setting OR 12.1 ($p = 0.001$) as independent predictors for postoperative mortality. We were thus able to replicate previous findings of higher mortality in non-elective patients (20%) or following more extensive procedures (with longer duration).

Therefore, it might be a benefit for critically ill patients in an emergency setting to perform the shortest possible operation and potentially to avoid an anastomosis.

Still, we would also like to highlight the correlation of anastomotic leakage and mortality. As Golub et al. [29] describe in a multivariate analysis, anastomotic leakage represents an independent predictor for in-house mortality with a rate of 39.3% with leakage and 7% without.

As a major limitation of our study, we would like to point out the retrospective, monocentric approach, which did not allow us to randomize the anastomotic techniques.

Finally, anastomotic leakage is in most cases associated with re-operation or re-intervention, and thus leads to a significant prolongation of hospitalization [16, 30, 31] which is well reflected in our data showing that suture technique is an independent predictor for the postoperative stay ($p = 0.000$) to which 7.5 are attributable.

Conclusion

In our retrospective study, we demonstrate for the first time a clear and robust advantage of using continuous rather than interrupted suture colon anastomosis with respect to leakage (primary endpoint) as well as 30-day mortality and hospital stay (secondary endpoints). We would argue that while these findings should be confirmed by prospective, multicenter trials, our findings provide evidence in favor of continuous sutures for colon anastomoses.

Author's contributions The contributions of each author in preparing the manuscript are as follows: study conception and design: R. E., S.K., M.B., acquisition of data: R.E., S.K. M.B., analysis and interpretation of data: R.E., S.E. M.B. C.K. A.K. D.H. Drafting of manuscript: R.E., S.E., M.B. Critical revision of manuscript: M.B., S.E., U.N., C.K., A.K., D.H.

Compliance with ethical standards

The study was approved by the local ethics committee (EK 093/16). All procedures were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

For this type of study, formal consent is not required.

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

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