

Reduced rate of dehiscence after implementation of a novel technique for creating colonic anastomosis in pediatric patients undergoing intestinal anastomosis in a single institute

Yang Yang, MD^a, Bailin Chen, MD^a, Li Xiang, MD, PhD^{a,b,*}, Chunbao Guo, MD, PhD^{a,b,*}

Abstract

We aimed to investigate the new continuous horizontal mattress anastomosis for pediatric patients who underwent emergency or electively laparotomy.

From June 2012 to June 2017, 858 patients undergoing intestinal anastomosis were reviewed retrospectively, including 369 patients with the new continuous horizontal mattress anastomosis and 489 patients with traditional 2 layer interrupted anastomosis, served as control. Propensity score matching was performed to adjust for selected baseline variables. The primary outcome, anastomosis complications and clinical outcomes, including postoperative gastrointestinal function recovery, overall expenditure, and postoperative hospital stay were compared between the 2 groups.

Patients with the new manual anastomosis had advantageous postoperative outcomes than those with the traditional 2 layer interrupted anastomosis. A mean of 11.4 minutes was required to construct the new manual single-layer anastomosis versus 18.5 minutes for the traditional anastomosis ($P < .001$). A reduction trend for postoperative anastomotic complications was indicated in patients receiving horizontal mattress anastomosis (odds ratio [OD] (95% confidence interval [CI]), 0.56 (0.37–0.84); $P = .004$), including peritonitis or abscess (OD [95% CI], 0.56 (0.32–0.98); $P = .026$), anastomotic leakage (OD [95% CI], 0.39 [0.12–1.27]; $P = .088$), and anastomotic strictures ($P = .26$). Mean length of stay was 10.9 ± 2.9 days for the new manual anastomosis group and 11.3 ± 3.5 days for traditional 2-layer anastomosis patients ($P = .12$).

Beneficial effects of the new manual anastomosis were demonstrated in terms of anastomotic complications, and length of hospital stay in the pediatric patients. Furthermore, it is a novel, feasible and safe method that may simplify the surgical procedure in anastomoses.

Abbreviations: CI = confidence interval, OD = odd ratio, POD = postoperative days, WBC = white blood cell.

Keywords: abscess, anastomotic leakage, continuous horizontal mattress anastomosis, two-layer anastomosis

Editor: Leonidas G. Koniaris.

The research was supported by the National Natural Science Foundation of China (No: 30973440, 30770950), and the key project of the Chongqing Natural Science Foundation (CSTC, 2008BA0021, cstc2012jjA0155).

The authors have no conflicts of interest to disclose.

^a Department of Pediatric General Surgery and Liver Transplantation, ^b Ministry of Education Key Laboratory of Child Development and Disorders, Children's Hospital, Chongqing Medical University, Chongqing, P.R. China.

* Correspondence: Li Xiang, Department of Pediatric General Surgery, Children's Hospital, Chongqing Medical University, 136 Zhongshan 2nd Rd., Chongqing 400014, P.R. China (e-mail: xiangyuhuan@126.com), Chunbao Guo, Department of Pediatric General Surgery and Liver Transplantation, Children's Hospital of Chongqing Medical University, 136 Zhongshan 2nd Rd., Chongqing 400014, P.R. China (e-mails: guochunbao@cqmu.edu.cn, guochunbao@foxmail.com).

Copyright © 2019 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

Medicine (2019) 98:19(e15577)

Received: 21 July 2018 / Received in final form: 10 April 2019 / Accepted: 11 April 2019

<http://dx.doi.org/10.1097/MD.00000000000015577>

1. Introduction

Traditional manual anastomosis and surgical staples are commonly used for digestive tract anastomosis, which might be associated with the postoperative complications, including anastomosis leakage, intestinal fistula and stricture, and so on.^[1–3] It was reported that traditional 2 layer anastomosis may be associated with higher risks of anastomosis leakage due to lack of blood supply and an increase of necrotic tissue within the anastomosis.^[1,4] Anastomosis stricture might result from the hyperplasia of granulation tissue and scar formation when irregular and tightly wrapped mucosa suture were performed. In certain cases, with preoperative obstruction of the digestive tract, mucosal edema, thickened muscle layer, the later stitch slacken might allow wound edges to separate, which should be associated with late anastomosis leakage. Another limitation of the traditional method exists the compress soft tissue included in the stitch.^[5,6] Furthermore, partial incisions and tearing should result in leakage and bleeding of the anastomosis. In certain types of surgery, due to special anatomic location and poor exposure of the back wall of the anastomosis, the surgery is more difficult, with increasing the risk of complication accordingly.^[7]

Although single-layer suture has been confirmed to be tight and safe, similar to double-layer suturing in gastrointestinal anastomosis, and superior to conventional suturing,^[8] for the pediatric patients, due to the small diameter and thin intestinal wall, the implementation of single-layer suture is not so feasible in some pediatric conditions.

Therefore, the identification of a novel manual method with simple and convenient characteristics for reconstruction of pediatric patients is beneficial. In our institute, the whole wall horizontal mattress suture method was piloted used in some patients by some surgeon on duty. By our experiences, the advantage of this approach is its simplicity, and is particularly suited for vessel anastomosis in ischemia or edema tissues. However, the efficacy of this modified continuous suture in different anastomotic locations, like ileal anastomosis, remains unknown. Therefore, we retrospectively compared the selected patients with the whole wall horizontal mattress suture anastomosis and traditional manual anastomosis method and investigated the efficacy of the novel manual method in gastrointestinal anastomosis for pediatric patients. We consider this novel method may simplify the procedures in complex surgery, and reduce the anastomosis complications.

2. Methods

2.1. Patients

This study is a retrospective review of the medical records of a series of patients that underwent intestinal anastomosis on emergency or elective surgery from June 2012 to June 2017 in the Department of General Surgery, Children's Hospital of Chongqing Medical University upon approval by the severance Institutional Review Board, which also granted a waiver of consent because both methods were in common use in our institution and had similar results. We had a local database containing information on all intestinal anastomosis procedures performed in the department. Preoperative data, including demographic data, the clinical and pathological details of all the cases, and pre-existing comorbidities were carefully recorded. All patients requiring primary bowel resection and intestinal anastomosis were considered eligible for entry into the study upon meeting the following inclusion criteria: above the age of

6 months; normal renal and hepatic function; no severe sepsis; no steroid or immunosuppressive medication administration. Exclusion criteria included patients underwent anastomosis involving the stomach, duodenum, or the rectum. Additionally, to minimize severity differences in the study population, patients managed in the intensive care unit (ICU) for more than 3 days were excluded. Treatment-related data included type of operation, operating time, intraoperative blood loss, transfusion rate, and necessity for re-operation were also reviewed.

2.2. Procedures

Bowel preparation and antibiotic prophylaxis were conducted following the standardized criteria. The new manual suture was performed by 2 groups from 2010, using a slowly absorbable monofilament 5-0 (Ethicon Inc, Norderstedt, Germany) suture material under general anesthesia. The affected bowel segment was first removed and sheared as per the standard technique. The end-to-end or end to side construction was performed began at the mesenteric border. The posterior wall was constructed using continued horizontal mattress anastomosis and connell suture for the anterior wall, with all the layers incorporating (Fig. 1). Retention sutures were not used. The edge distance and needle pitch were approximately 2 to 3 mm of each bite. To avoid the anastomosis ischemia, appropriate pressure should be subjected to the suture while render the anastomosis water tight. The edges of the mesentery were conventionally closed. All procedures were performed by senior residents or attending surgeons from the Chongqing Medical University affiliated Children's Hospital. The new suture training was subjected to ensure that all surgeons could correctly perform during emergency surgery. Every surgeon was instructed in documenting the anastomosis time in the patient files. The traditional double-layer interrupted suture was constructed using the same 5-0 silk suture for the inner transmural layer. The outer seromuscular were taken in an interrupted Lembert manner. Operating surgeons and anastomotic category (enteroenteric, colocolic, ileocolic, colorectal, ileorectal, ileoanal, or coloanal) were recorded. The start of the first stitch and ended with cutting the excess material from the last stitch was recorded as the anastomosis time. To evaluate the patency of the anastomosed segment, palpation for the anastomosis using the thumb and the index finger should be

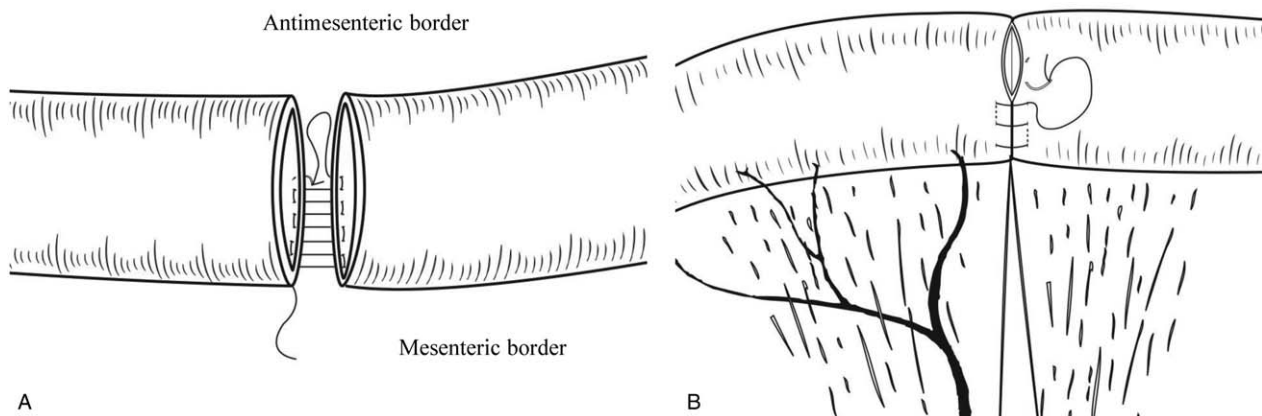


Figure 1. (A) The posterior wall was constructed using the 1-layer continuous horizontal mattress anastomosis from the mesenteric border. The stitches include all layers. (B) The anterior wall was constructed using connell suture with all the layers incorporating. The suture is tied at the antimesenteric border with the end of thread from the posterior wall.

conducted. The whole surgical time was measured from the first skin incision to the last suture placement for all the techniques.

2.3. Postoperative management and follow up

All the patients were subjected to the same postoperative programme, including fluid resuscitation, parenteral nutrition support, perioperative broad-spectrum antibiotics if necessary. Patients were followed daily throughout their hospitalization. The complications and readmissions were recorded by the surgical team. The primary outcome was the occurrence of anastomotic failure, including clinical leakage and stricture during follow-up. Anastomotic leakage was defined as clinical symptoms of leakage, like peritoneal signs, systemic sepsis, fecal and/or charcoal material draining. Anastomotic stricture was defined as anastomotic narrowing those who developed symptoms of outlet obstruction. The postoperative day (POD) for the leak was noted along with the primary method of diagnosis (clinical or radiologic). The surgical and postoperative outcomes were defined as secondary outcomes, including ventilator rates, ICU-stay rates, short-term postoperative complications (eg, burst abdomen, fascia dehiscence), the number of reoperations, and total lengths of hospital stay (the number of days from the day of operation until the date of discharge). Because it is potentially related to the anastomosis, the complication of early ileus, intra-abdominal or pelvic abscesses without fistula were also included in the analysis. Early ileus was defined as more than 1 episode of nausea or vomiting.

2.4. Propensity scores matching and statistical analysis

The propensity scores analyses were done using SPSS 20.0 (IBM, Armonk, NY) or R software 3.1.2 (The R Foundation for Statistical Computing) and the MatchIt package to minimize the effect of potential confounders on selection bias in baseline characteristics. A 1:1 propensity score matching analysis was

accomplished using a multivariable logistic regression model with demographic and clinical variables with potential biases related to the PGE1 treatment. The selected variables entered into the propensity model included demographic data information, laboratory values, treatment protocols, lesion location, type of surgery, as well as ICU admissions. Matching without replacement was performed based on the estimated propensity score of each patient with no replacement, and a 0.1 caliper width. We also evaluated the interaction among all pretest covariates. The generalized additive model was used to check linear assumption in propensity scores (PS) model. Our propensity score model discriminated well between PGE1 treatment patients and controls, thus matching 278 PGE1 treatment patients to 278 controls. The characteristics of both the horizontal mattress suture method patients and controls were compared before and after propensity scores matching. The demographic and surgical outcomes data were analyzed using SPSS software, version 11.5 (IBM). The Mann–Whitney *U* test and Chi-square or Fisher exact test were used to analyze continual and categorical variables, respectively. To elucidate the risk factors for postoperative complications, cross-tabulation (odds ratio [OR]) or multivariate analysis (risk ratio) was performed using the logistic regression model. The statistical significance was evaluated using a 2-tailed 95% confidence interval (CI), and statistical significance was established if *P* < .05.

3. Results

3.1. Patient characteristics

During the study period of the analysis, a total of 858 pediatric anastomosis were assessed for eligibility, including 369 (63.0%) received the whole wall mattress-suture and 489 (37.0%) preceding the implementation of the new technique. The baseline features of the pediatric patients according to the whole wall

Table 1
Baseline demographics of eligible patient and preoperative variables.

	Total population			Propensity matched population		
	Horizontal mattress suture (369)	Traditional 2 layer (489)	<i>P</i> -values	Horizontal mattress suture (359)	Traditional 2 layer (359)	<i>P</i> -values
Age, yr	5.7 ± 1.9	5.7 ± 1.8	.85	5.7 ± 1.9	5.7 ± 1.8	.78
Male: female	214: 155	318: 171				
Albumin (g/L, normal range, 35–50)	33.2 ± 3.8	33.1 ± 3.6	.64	33.2 ± 3.8	33.2 ± 3.6	.84
Hemoglobin, g/L	104.0 ± 14.6	102.5 ± 15.2	.15	103.6 ± 14.6	102.1 ± 14.6	.16
WBC, 109/L	16.3 ± 4.3	16.3 ± 4.2	.95	16.2 ± 4.3	16.4 ± 4.3	.63
CRP	23.3 ± 7.3	23.2 ± 7.4	.93	23.4 ± 3.4	23.5 ± 3.4	.94
Operative time, min	74.7 ± 10.3	75.8 ± 10.1	.18	75.2 ± 6.8	75.6 ± 7.3	.34
Operative blood loss, mL	22.6 ± 5.4	22.9 ± 5.3	.23	22.7 ± 4.5	22.8 ± 4.7	.35
Transfused patients, N (%)	136 (36.9)	191 (39.1)	.51	133 (31.5)	116 (32.3)	.11
Emergency surgery, N (%)	214 (58.0)	300 (61.3)	.32	211 (58.8)	213 (59.3)	.47
ICU admissions, N (%)	98 (26.6)	124 (25.4)	.37	95 (26.5)	87 (24.2)	.27
Second operation, N (%)	94 (25.5)	116 (23.7)	.55	92 (25.6)	90 (25.1)	.47
Causes of operation, N (%)						
Intussusception	155 (42.0)	212 (43.4)	.37	153 (42.6)	142 (39.6)	.22
Trauma	41 (11.1)	82 (16.8)	.012	41 (11.4)	49 (13.6)	.22
Perforation	73 (19.8)	90 (18.4)	.34	69 (19.2)	78 (21.7)	.23
Obstruction/strangulation	100 (27.1)	105 (21.5)	.034	96 (26.7)	90 (25.1)	.34
Surgical types, N (%)						
Small bowel resection and anastomosis	219 (59.3)	269 (55.0)	.12	213 (59.3)	202 (56.3)	.23
Colon resection and right hemicolectomy	150 (40.7)	220 (45.0)		146 (40.7)	157 (43.7)	

CRP = C-reactive protein, ICU = intensive care unit.

Table 2
Surgical outcomes in the matched population.

	Horizontal mattress suture (359)	Traditional 2 layer (359)	P-values
Anastomosis time, min, n=20	11.4±2.1	18.5±2.4	<.001
Regular diet tolerated within POD 4, N (%)	75 (20.9)	91 (25.3)	.092
CRP at POD 5 (mg/L, normal value: 0–8)	15.8±3.6	15.7±3.8	.46
Overall expenditure, Chinese Yuan, n=20	22695.7±5092.9	22824.8±5116.3	.74
Postoperative hospital stay, d	9.0±1.4	9.0±1.3	.39

CRP = C-reactive protein, POD = postoperative days.

mattress-suture or traditional anastomosis are summarized in Table 1. There were no significant differences with regard to age, sex, ICU admissions, and operative magnitude between the 2 groups. The operative magnitude was evaluated by measurement of operative time, estimated blood loss, and total units of blood transfused within the 24-hour perioperative period. The amount of blood loss and transfused blood were equally distributed between the 2 groups. In addition, there were no significant differences in location of the anastomosis between the 2 groups. There were significant differences in causes of operation between the 2 groups, suggesting that, in this observational study, there were systematic differences in baseline characteristics between the patients with the whole wall mattress-suture and traditional double-layer interrupted suture. Under PS-matching, the continuous and categorical variables were very similar and comparable between the 2 anastomosis groups. Most surgical procedures were emergency exploratory laparotomy, including small bowel resection, colon resection, and right hemicolectomy with the following anastomosis.

The time required for construction of the anastomosis was recorded for 20 cases of the 2 groups respectively. The mean time required for the horizontal mattress suture was significantly lesser (11.4±2.1 minutes) than for traditional 2 layer anastomosis (18.5±2.4 minutes) ($P < .001$) (Table 2). The average surgical time in the horizontal mattress suture anastomosis group was 93.0±17.1 minutes and in the 2-layer anastomosis group was 95.4±18.2 minutes ($P = .067$). Following the surgery, there were no significant differences between the 2 groups in terms of the regular diet tolerated (0.092), C-reactive protein at POD 5 ($P = .24$), and albumin ($P = .11$), which should reflect the

postoperative inflammation and nutritional status. No differences in hospital stay ($P = .12$), was noted between the 2 groups (Table 2).

According to established criteria, the type and frequency of postoperative complications were summarized in detail in Table 3. Almost one-fifth of patients had postoperative complications, the incidence of all of the postoperative anastomotic complications did not differ significantly between the 2 groups ($P = .16$). There were no statistically significant differences between the 2 groups for surgical wound infection ($P = .34$), severe bleeding ($P = .36$), anastomotic strictures ($P = .26$), and sepsis ($P = .40$) which should be subjected to surgical intervention. Reintervention rates were 7.0% and 10.9% ($P = .044$), due to leakage, hemoperitoneum, and pelvic abscess, which should be associated with the anastomosis complications. No patient with postoperative bleeding or stenosis required another operation. Readmission rates also did not differ significantly between groups ($P = .20$).

Although the generally leak rate was quite similar, a reduction trend for postoperative anastomotic leakage in patients receiving the continued horizontal mattress anastomosis was indicated when stratified for ileocolonic anastomosis, with a OR of 0.25 (95% CI [0.05–1.17]; $P = .053$), representing a trend toward a 75% relative risk reduction for the complications. Overall, leaks were diagnosed at a mean of 5.7 days postoperatively (range, 3–9 days). Furthermore, a reduction in peritonitis or abscess (OR, 0.56 [95% CI] [0.32–0.98]; $P = .026$) was noted in patients receiving the new anastomosis method, of which some could be managed by percutaneous drainage.

Table 3
Postoperative complications in the matched population.

	Horizontal mattress suture (359)	Traditional 2 layer (359)	P-values	Odds ratio (95% CI)
Total complications (at least 1 complication), N (%)	71 (19.8)	83 (23.1)	.16	
Sepsis, N (%)	7 (1.9)	9 (2.5)	.40	
Anastomotic complications	42 (11.7)	69 (19.2)	.004	0.56 (0.37–0.84)
Peritonitis or abscess, N (%)	21 (5.8)	36 (10.0)	.026	0.56 (0.32–0.98)
Anastomotic leakage, N (%)	4 (1.1)	10 (2.8)	.088	0.39 (0.12–1.27)
Ileal anastomosis	2 (0.6)	2 (0.6)	.69	
Ileorectal anastomosis	2 (0.6)	8 (2.2)	.053	0.25 (0.05–1.17)
Incision dehiscence, N (%)	9 (2.5)	8 (2.2)	.50	
Severe bleeding	3 (0.8)	5 (1.4)	.36	
Chylous leakage	6 (1.7)	4 (1.1)	.38	
Surgical wound infection, N (%)	56 (15.6)	61 (17.0)	.34	
Reintervention	25 (7.0)	39 (10.9)	.044	0.61 (0.36–1.04)
Anastomotic strictures	18 (5.0)	23 (6.4)	.26	
Hospital readmission, N (%)	46 (12.8)	55 (15.3)	.20	

CI = confidence interval.

4. Discussion

In the present study, we used the continuous single-layer anastomosis in the posterior wall of the digestive tract in 359 cases involving ileal anastomosis and assessed the technically possible to perform in terms of anastomotic leak, time required to construct the anastomosis, and length of hospital stay. For ileal colon anastomosis, the anastomotic leak incidence was lower compared to that observed with traditional 2-layer anastomotic techniques. The study showed that this new anastomosis method is technically possible to perform, and the novel anastomosis appears to be more superior than traditional sutures.

The ultimate test of the suitability of a technique for intestinal anastomosis is its ability to heal without leakage. The leakage complication has catastrophic consequences for the patient's health as well as the cost of care, so play an important role for the intestinal anastomosis.^[9-11] A large number of patients ultimately found to have an anastomotic leak develop a more insidious presentation, often with low-grade fever, prolonged ileus, or failure to thrive.^[9,12] A postoperative abscess was also caused by a small anastomotic leak.^[9] Our results demonstrated that the total complications, in the new manual technique group was 19.8% and the anastomotic complication rate, including postoperative abscess, leakage, and strictures was 11.7%, which was lower than that recorded in the traditional technique group and previous studies, providing evidence for the advantage of the current technology. Undoubtedly, among various types of anastomosis, the continuous suture is the tightest. The single-layer anastomosis is as strong as double-layer suturing and ensures mechanical integrity.^[13,14] Also, tissue viability is emphasized regarding the surgical technique of gastrointestinal anastomosis. Blood flow is always reduced in the suture line compared with the normal mucosa.^[15,16] Of all the anastomosis studied, the blood flow of the suture line decreased from the single-layer manual to the 2-layer manual to the stapled suture.^[17,18] But for pediatric patients, the single-layer anastomosis is really difficult to perform for the so thin of the intestinal wall and some challenging surgical positions. In our institute, a double-layer anastomosis was generally performed in a continuous fashion. Upon the technique improvement, the current horizontal mattress running stitches technique with a single monofilament suture is a safe technique in view of the low incidence of abscess, leakage, and stricture. Additionally, it is easily learn for performance and generalizable to the general surgical population, like specialists of vascular, general, gastrointestinal, and gynecological surgical specialties. The development of strictures is closely associated with the diameter of the anastomosis and the thickness of the wall. By contrast, in the single-layered technique this is prominently avoided, as only 1 layer of sutures is incorporated, which may reduce the incidence of anastomotic strictures. Our result supported this speculation.

In the double-layered anastomotic, even the single anastomotic, the submucosal vascular plexus might be strangulated for the continuous anastomotic, furthermore, it is certainly possible to create an ischemic continuous anastomosis by applying too much tension in vertical suture.^[19] This is avoided in the current technique, as the horizontal suture is just taken sparing mucosa close together without strangulation and hence causing lower damage to the submucosal vascular plexus. In contrast, this can easily occur to the tissue enclosed by an interrupted suture.^[20] In addition, the current suture might be more favorable in favor of the adjustment excess extension to equilibrate with surrounding

areas of less tension by minute movements of tissue. Another factor is related to the slick properties of a continuous monofilament plastic suture line, which may be able to expand and contract depending on intraluminal forces. This may explain the lack of anastomotic stenoses and leak in the current cases.

In the present study, the mean time documented in constructing the whole wall horizontal mattress suture anastomosis was 11.4 minutes, whereas that for double-layered anastomosis was 18.4 minutes. Continuous suture contributes to reduced surgical time, but to ensure a safe anastomosis, a sufficient amount of tissue cutting must be handled with caution and we carefully pruned the edges of intestinal with a healthy blood supply to keep tissue viability, which has been found to closely correlate with anastomosis complications. All this may ultimately prolong surgery time. Nevertheless, the whole time saved in experienced hands by creating the single-layer anastomosis was about 7 minutes, including bowel preparation, although there was no significant difference in whole surgical time between the new manual and traditional suture technique. Others also experienced the same significant difference between the single continuous and 2 layer anastomosis.^[9,11,21]

Considering the fact that most of the patients were on emergency basis, with some degree of hemodynamical instability, it can be more preferably to reduce the time of anesthesia, some risk factors of surgical concern may require both rapidity and security of the anastomosis. Multiple anastomosis is more prominent in pediatric surgery.^[22] Due to limited physiologic reserve and compensatory responses, prolonged operative time may cause serious problems in a neonate suffering from NEC or multiple bowel atresia. It is also indicated that gastrointestinal function recovery faster with the new single-layer method, then the traditional suture, although further studies would be required to confirm this point. In experimental setting, a decreasing number of inflammation and fibroblast cells were identified in the suture line in the novel manual suture group compared with the conventional manual suture groups, which might cause disturbed anastomotic healing contributing to leakage and stricture formation, which may explain the gastrointestinal function recovery and rarity of anastomotic complication.^[23-25]

There are several weaknesses to this study. This was a single center, retrospective study with inherent risk of selection bias, therefore should be cautious for generalization. The study takes place over a long time period so the 2 study groups might be different in the patient composition, because there have likely been many practice changes within both the surgery and the ICU divisions, leading to different care practices between study patients. In practice, although there is no executable guideline, we are inclined to perform the current technology in some patient prone to intestinal edema, which might be associated with long procedure time, more fluid loss and tend to transfer into ICU care. To limit the influence of residual confounding variables on the actual effects of this modified anastomotic method, we performed propensity score matching analysis to generate comparison groups with similar baseline factors. Following the PS matching, this discrepancy is eliminated and comparable, as indicated by the standardized mean differences and *P*-value. The other weakness of the study is its relatively small sample size. It is therefore difficult to detect a significant difference in leakage rates based on our data. A power analysis including large sample size with a multi-institutional trial would be necessary in the future. Therefore, our results need to be carefully interpreted. However, our results and those in the literature are consistent and reassuring.

In conclusion, this new single-layer continuous anastomosis in the posterior wall of the digestive tract is a novel, feasible and safe method that may simplify the surgical procedure in anastomoses, while reducing the anastomosis complications and postoperative hospital stay. For these reasons, we believe the modified single layer continuous anastomosis is superior to the 2-layer interrupted technique and can be safely introduced into a surgical training program.

Acknowledgments

We thank Prof. Xianqing Jin for providing technical assistance and for insightful discussions during the preparation of the manuscript. We thank Dr Xiaoyong Zhang at the Wistar Institute, USA, for help with the linguistic revision of the manuscript.

Author contributions

Qin Deng, Qiankun Geng, Yang Yang designed, analyzed the data, and evaluate the manuscript. Yan Tang performed the statistic measurement and analyzed the data. Chunbao Guo analyzed the data, and wrote the paper.

Data curation: Li Xiang.

Funding acquisition: Chunbao Guo.

Methodology: Yang Yang.

Software: Bailin Chen.

Supervision: Chunbao Guo.

References

- Leahy J, Schoetz D, Marcello P, et al. What is the risk of clinical anastomotic leak in the diverted colorectal anastomosis? *J Gastrointest Surg* 2014;18:1812–6.
- Reinke CE, Showalter S, Mahmoud NN, et al. Comparison of anastomotic leak rate after colorectal surgery using different databases. *Dis Colon Rectum* 2013;56:638–44.
- Slieker JC, Daams F, Mulder IM, et al. Systematic review of the technique of colorectal anastomosis. *JAMA Surg* 2013;148:190–201.
- Shogan BD, Carlisle EM, Alverdy JC, et al. Do we really know why colorectal anastomoses leak? *J Gastrointest Surg* 2013;17:1698–707.
- Morse BC, Simpson JP, Jones YR, et al. Determination of independent predictive factors for anastomotic leak: analysis of 682 intestinal anastomoses. *Am J Surg* 2013;206:950–5.
- Wong NY, Eu KW. A defunctioning ileostomy does not prevent clinical anastomotic leak after a low anterior resection: a prospective, comparative study. *Dis Colon Rectum* 2005;48:2076–9.
- Li GC, Xu Y, Zhang YC, et al. Efficacy of single-layer continuous suture of the posterior wall in anastomosis involving a difficult location of the digestive tract. *Oncol Lett* 2014;8:1567–74.
- Burch JM, Franciose RJ, Moore EE, et al. Single-layer continuous versus two-layer interrupted intestinal anastomosis: a prospective randomized trial. *Ann Surg* 2000;231:832–7.
- Hyman N, Manchester TL, Osler T, et al. Anastomotic leaks after intestinal anastomosis: it's later than you think. *Ann Surg* 2007;245:254–8.
- Harris LJ, Moudgill N, Hager E, et al. Incidence of anastomotic leak in patients undergoing elective colon resection without mechanical bowel preparation: our updated experience and two-year review. *Am Surg* 2009;75:828–33.
- Hyman NH, Osler T, Cataldo P, et al. Anastomotic leaks after bowel resection: what does peer review teach us about the relationship to postoperative mortality? *J Am Coll Surg* 2009;208:48–52.
- Placer C, Enríquez-Navascués JM, Elorza G, et al. Preventing complications in colorectal anastomosis: results of a randomized controlled trial using bioabsorbable staple line reinforcement for circular stapler. *Dis Colon Rectum* 2014;57:1195–201.
- Law WL, Bailey HR, Max E, et al. Single-layer continuous colon and rectal anastomosis using monofilament absorbable suture (Maxon): study of 500 cases. *Dis Colon Rectum* 1999;42:736–40.
- Facy O, De Blasi V, Goergen M, et al. Laparoscopic gastrointestinal anastomoses using knotless barbed sutures are safe and reproducible: a single-center experience with 201 patients. *Surg Endosc* 2013;27:3841–5.
- Hamzaoğlu I, Karahasanoğlu T, Aydin S, et al. The effects of hyperbaric oxygen on normal and ischemic colon anastomoses. *Am J Surg* 1998;176:458–61.
- Pommergaard HC, Achiam MP, Burcharth J, et al. Impaired blood supply in the colonic anastomosis in mice compromises healing. *Int Surg* 2015;100:70–6.
- Chung RS, Hitch DC, Armstrong DN. The role of tissue ischemia in the pathogenesis of anastomotic stricture. *Surgery* 1988;104:824–9.
- Chung RS. Blood flow in colonic anastomoses. Effect of stapling and suturing. *Ann Surg* 1987;206:335–9.
- Orsay CP, Bass EM, Firfer B, et al. Blood flow in colon anastomotic stricture formation. *Dis Colon Rectum* 1995;38:202–6.
- Orak I, Güneren E, Yildiz L. A hemodynamic study of the effects of arterial anastomoses with interrupted simple versus horizontal mattress sutures on rat epigastric flap perfusion. *Ann Plast Surg* 2006;57:84–8.
- Herrle F, Diener MK, Freudenberg S, et al. Single-layer continuous versus double-layer continuous suture in colonic anastomoses—a randomized multicentre trial (ANATECH Trial). *J Gastrointest Surg* 2016;20:421–30.
- Ordorica-Flores RM, Bracho-Blanchet E, Nieto-Zermeño J, et al. Intestinal anastomosis in children: a comparative study between two different techniques. *J Pediatr Surg* 1998;33:1757–9.
- Buch N, Glad H, Svendsen P, et al. An intraluminal prosthesis may improve healing of a one-layer colonic anastomosis: an experimental study in pigs. *Eur J Surg* 2002;168:165–71.
- Ballantyne GH, Burke JB, Rogers G, et al. Accelerated wound healing with stapled enteric suture lines. An experimental study comparing traditional sewing techniques and a stapling device. *Ann Surg* 1985;201:360–4.
- Ho YH, Ashour MA. Techniques for colorectal anastomosis. *World J Gastroenterol* 2010;16:1610–21.