Difference between delayed anastomosis and early anastomosis in damage control laparotomy affecting the infusion volume and NPWT output volume: is infusion restriction necessary in delayed anastomosis? A single-center retrospective analysis

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INTRODUCTION

Delayed anastomosis is a treatment strategy that is incorporated into damage control laparotomy (DCL) according to the physiological indicators and intra-abdominal environments of patients who have no intestinal continuity after undergoing only intestinal resection during initial surgery for hollow viscous injury (HVI) or mesenteric injury (MI).1–6

ABSTRACT

Objectives During temporary abdominal closure (TAC) with damage control laparotomy (DCL), infusion volume and negative-pressure wound therapy (NPWT) output volume are associated with the success and prognosis of primary fascial closure. The same may also hold true for anastomosis. The aim of this research is to evaluate whether the difference between early anastomosis and delayed anastomosis in DCL is related to infusion volume and NPWT output volume.

Methods This single-center retrospective analysis targeted patients managed with TAC during emergency surgery for trauma or intra-abdominal sepsis between January 2011 and December 2019. It included patients who underwent repair/anastomosis/colostomy in the first surgery and patients who underwent intestinal resection in the first surgery followed by delayed anastomosis with no intestinal continuity.

Results Seventy-three patients were managed with TAC using NPWT, including 19 cases of repair, 17 of colostomy, and 37 of anastomosis. In 16 patients (trauma 5, sepsis 11) with early anastomosis and 21 patients (trauma 16, sepsis 5) with delayed anastomosis, there was no difference in the infusion volume (p=0.2318) or NPWT output volume (p=0.7128) 48 hours after surgery. Additionally, there was no difference in the occurrence of suture failure (p=0.8428). During the second-look surgery after 48 hours, the anastomosis was further postponed for 48% of the patients who underwent delayed anastomosis. There was no difference in the infusion volume (p=0.0783) up to the second-look surgery between the patients whose delayed anastomosis was postponed and those who underwent delayed anastomosis, but there was a tendency toward a large NPWT output volume (p=0.024) in the postponed delayed anastomosis group.

Conclusion Delayed anastomosis may be managed with the same infusion volume as that used for early anastomosis. There is also the option of postponing anastomosis if the planned delayed anastomosis is complicated.

Level of evidence Therapeutic/Care Management, Level IV.

Key messages

What is already known on this topic?

► Delayed anastomosis is a treatment strategy used in damage control laparotomy (DCL). This research investigates the need to restrict infusion corresponding to delayed anastomosis by evaluating whether the difference between early anastomosis and delayed anastomosis in temporary abdominal closure management using negative-pressure wound therapy (NPWT) is associated with infusion volume and NPWT output volume.

What this study adds?

► This research showed that infusion restrictions were not necessary in delayed anastomosis compared with early anastomosis.

How this study might affect research, practice or policy?

► Improving treatment outcomes for patient management with delayed anastomosis.

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excessive infusion may lead to the development of intestinal edema, which may prevent successful delayed anastomosis or require colostomy to avoid anastomosis. In addition, the NPWT output volume in TAC is an important fluid balance index, and hypoalbuminemia, in which albumin is lost when protein-rich ascites are drained, may pose a risk of anastomotic leakage and present a disadvantage for the success of delayed anastomosis. However, there is little information regarding the differences and relevance of infusion volume and NPWT output volume during TAC for the management of early anastomosis and delayed anastomosis in DCL.

The purpose of this study was to evaluate whether the difference between early anastomosis and delayed anastomosis is related to the volume of fluid infusion and NPWT output in patients who underwent emergency surgery due to external injury or intra-abdominal sepsis and opted for DCL.

METHODS

Target

This retrospective study was conducted at the Iwate Medical University Critical Care Center from 2011 to 2019 with patients who underwent emergency surgery due to HVI/MI caused by abdominal trauma and patients who underwent emergency surgery for lower digestive tract perforation with diffuse peritonitis and peritoneal contamination in the form of intra-abdominal sepsis. The study included patients who underwent repair/anastomosis/colostomy during the first DCL surgery and were managed with TAC using NPWT and patients who had no intestinal continuity after undergoing intestinal resection during the first surgery and were managed with TAC using NPWT. Clinical data and infusion volume, NPWT output, and urine volume up to 48 hours after surgery were extracted from chart review or clinical records review.

The study excluded patients who died within 48 hours after surgery, patients with solid organ injuries without HVI, patients who underwent non-surgical treatment (for MI or intra-abdominal hemorrhage), patients on maintenance dialysis due to chronic renal failure, and patients with iatrogenic injuries. Patients with perforated appendicitis and patients who underwent resurgery with DCL were not included in the study.

Treatment strategy

DCL, repair, resection and colostomy

Treatment was conducted at the discretion of the surgeon and not protocolized according to specific injury or perforation site and morphology or contamination status. According to the surgeon’s experience, bleeding and organ injuries in trauma cases and contamination and intestinal edema in intra-abdominal sepsis cases are the main reasons for choosing DCL. Intestinal resection was performed using a stapler. In cases in which delayed anastomosis was selected, the end of the intestinal resection remained stapled, and the intestine was left discontinuous and was directed into the abdominal cavity. No temporary ileostomy or colostomy was created until anastomosis was performed. For delayed anastomosis, second-look surgery was performed 48 hours after the initial surgery to evaluate whether to restore intestinal continuity or create colostomy. Other options included postponing anastomosis with no intestinal continuity and postponing abdominal closure. When TAC was continued, the condition of the intestinal tract was evaluated in a timely manner at the intensive care unit or high-dependency care unit, and the abdomen was closed after anastomosis or colostomy was selected at the discretion of the surgeon. Regarding the anastomosis technique, stapling anastomosis was performed in all cases, and hand-sewn anastomosis was not performed. For resection and anastomosis, a linear cutter (ETHICON, USA) was used. Functional end-to-end anastomosis was performed. Ileostomy was not performed after anastomosis.

Infusion resuscitation

The infusion dose was based on physiological indicators such as heart rate, blood pressure, etc., and the diameter of the inferior vena cava according to ultrasound examination. Infusion up to 48 hours after surgery included basic infusion crystalloid fluid, bolus-administered crystalloid fluid, and albumin preparations. For the crystalloid fluid, acid-treated Ringer’s solution was used. The administration of the albumin preparation was capped at 1 dose of 100 mL. 20% albumin preparation per day. Albumin administration was indicated by the presence or absence of administration rather than by the infusion volume because the dose was limited. There was no protocol for bolus administration of crystalloid solution corresponding to the NPWT output amount. Furosemide was not used for up to 48 hours after surgery. When hemodynamics were unstable even after sufficient infusion (systolic blood pressure less than 90 mm Hg), the administration of 0.05 µg/kg/min of norepinephrine as a vasopressor was started.

Negative-pressure wound therapy

NPWT was performed with a handheld negative pressure system after the abdominal cavity was thoroughly rinsed with saline. The intra-abdominal organs were covered with a sterile vinyl sheet. A 28 Fr gastric catheter was placed on the top of the vinyl sheet, a transparent adhesive film was affixed to the top of the catheter, and TAC was performed with a suction pressure of –30 cm H2O. After that, an elastic band was used to cover the abdomen to prevent the abdominal wall from retracting. During TAC management, sedatives, analgesics, and neuromuscular blocking drugs were administered and controlled based on ventilator monitoring.

The same surgical team handled everything from the diagnosis to the surgery and postoperative management of patients with trauma and sepsis. The operations were performed by general surgeons with the assistance of senior surgeons with extensive experience in DCL and TAC management. Since a senior surgeon always intervenes, starting from the beginning of the surgery, the influence of the surgeon’s experience on the surgery was limited.

Definitions and study outcomes

Patients were classified as follows. Patients who underwent repair/anastomosis/colostomy during the DCL first surgery and were managed with TAC using NPWT were classified as DCL-early, and patients who had no intestinal continuity after intestinal resection during the first surgery and were managed with TAC using NPWT were classified as DCL-delay. Patients who underwent early anastomosis were classified as DCL-early anastomosis, and patients who underwent delayed anastomosis were classified as DCL-delayed anastomosis. Patients were also grouped according to whether they underwent delayed anastomosis during second-look surgery 48 hours after the initial surgery or their delayed anastomosis was postponed.

The important research results were infusion volume and NPWT output up to 48 hours after the initial surgery with early anastomosis and delayed anastomosis.

Secondary results were the delayed anastomosis implementation status and frequency of complications. Complications were
surgical site infection (SSI), intestinal obstruction, and suture failure.

Statistical analysis
All statistical analyses were performed with the statistical package JMP V.11 (SAS Institute, Cary, North Carolina, USA). Continuous variables are expressed as the mean±SD. Categorical variables are expressed as frequency (n, %), as appropriate. Normal distribution of all data was confirmed using the Shapiro-Wilk test. The data were analyzed using the X² test, Wilcoxon rank-sum test, and Kruskal-Wallis test. When a significant difference was found by the Kruskal-Wallis test, the significance of the difference was examined by the Wilcoxon rank-sum test; p values of <0.05 were considered to indicate statistical significance. As this study was a single-centre cohort study with a limited sample size, a sample size power analysis was not performed.

RESULTS
Study population
A total of 109 patients were included in this study (figure 1).

Clinical characteristics of the no-DCL, DCL-early and DCL-delay patients
The no-DCL group included nine patients who underwent repair, eight who underwent colostomy (including one who underwent the Miles technique), seven who underwent small intestine–small intestine anastomosis, six who underwent small intestine–colon anastomosis, and six who underwent colon–colon anastomosis. The DCL-early group included 19 patients who underwent repair, 6 who underwent colostomy (including 3 who underwent the Miles technique), 1 who underwent stomach–small intestine anastomosis, 3 who underwent small intestine–small intestine anastomosis, 2 who underwent small intestine–colon anastomosis, 7 who underwent colon–colon anastomosis, and 3 who underwent colon–rectal anastomosis.

During the second-look procedure, the DCL-delay group included seven patients who underwent ileostomy, four who underwent colostomy, six who underwent small intestine–small intestine anastomosis, five who underwent small intestine–colon anastomosis, eight who underwent colon–colon anastomosis, and two who underwent colon–rectal anastomosis. Of the seven patients who underwent ileostomy, five required total colectomy. The average Injury Severity Score (ISS) for overall trauma was 24.3±10. The average Acute Physiology and Chronic Health Evaluation II (APACHE II) score for overall intra-abdominal sepsis was 30.8±6.7. At the time of DCL, 21 patients (29%) had abdominal packing, including 19 trauma patients and 2 patients with sepsis. No patients were administered hypertonic saline.

The average infusion volume up to 48 hours from surgery in all patients who underwent DCL was 11246.5±4305.0 mL, the average NPWT output was 1239.9±712.0 mL, and the average urine volume was 2876.6±2253.1 mL.

In terms of the amount of bleeding during the initial trauma surgery, a significant difference was observed between the no-DCL and DCL-delay groups and between the DCL-early and DCL-delay groups (p=0.0002 and p=0.0004, respectively). In terms of the infusion volume 48 hours after surgery, a significant difference was observed between the no-DCL and DCL-early groups, between the no-DCL and DCL-delay groups, and between the DCL-early and DCL-delay groups (p=0.0001, p=0.0001, and p=0.0128, respectively). There was no difference in the NPWT output or the relaparotomy duration between the DCL-early and DCL-delay groups, and it was possible to achieve PFC in all cases (table 1). Anastomotic leak was observed in a total of six patients, including two in the no-DCL group (one who underwent repair and one who underwent colostomy) and four who underwent DCL (two who underwent repair and two who underwent anastomosis).

Comparison of the early-anastomosis and delayed-anastomosis groups
This category did not include patients who had undergone repair or colostomy. Only patients who underwent intestinal tract resection and anastomosis were included. Among the patients who underwent DCL, 16 underwent early anastomosis, and 21 underwent delayed anastomosis. There was no difference in terms of age, APACHE II score, or ISS. The delayed-anastomosis group included several patients with colon injury due to trauma (p=0.0271). The surgery duration was significantly shorter in the delayed-anastomosis group (p=0.0001). No difference was
Table 1  Clinical characteristics of the no-DCL, and DCL-early and DCL-delay patients

|                              | No-DCL (36) | DCL Early (41) | DCL Delay (32) | P value* |
|------------------------------|-------------|----------------|----------------|----------|
| Age (years)                  | 67.1±17.7   | 64.4±18.7      | 63.8±18.0      | 0.6844   |
| Sex                          |             |                |                |          |
| Male                         | 21 (58%)    | 19 (46%)       | 20 (63%)       | 0.3441   |
| Male                         | 36 (68%)    | 34 (68%)       | 33 (61%)       |          |
| Cause of surgery             |             |                |                |          |
| Trauma                       | 13 (36%)    | 18 (43%)       | 18 (56%)       | 0.2459   |
| Solid organ injury           | 1 (7%)      | 3 (16%)        | 3 (16%)        | 0.7304   |
| Colon injury                 | 3 (23%)     | 4 (22%)        | 14 (77%)       | 0.0008   |
| Lower gastrointestinal perforation | 23 (64%) | 23 (56%)       | 14 (43%)       |          |
| Malignant                    | 9 (39%)     | 3 (13%)        | 3 (21%)        | 0.1166   |
| Benign                       | 14 (61%)    | 20 (87%)       | 11 (79%)       |          |
| Injury Severity Score        | 18.9±9.0    | 25.9±10.3      | 26.6±9.7       | 0.083    |
| APACHE II score              | 25.0±7.6    | 27.8±7.9       | 26.8±7.2       | 0.5117   |
| Surgery start time           |             |                |                |          |
| 08:00–19:00                  | 22 (61%)    | 26 (63%)       | 26 (81%)       | 0.1529   |
| 20:00–07:00                  | 14 (39%)    | 15 (37%)       | 6 (19%)        |          |
| Surgery day                  |             |                |                |          |
| Weekday                      | 23 (64%)    | 32 (78%)       | 24 (75%)       | 0.355    |
| Weekend                      | 13 (36%)    | 9 (22%)        | 8 (25%)        |          |
| Pre-initial surgery          |             |                |                |          |
| Temperature (°C)             | 37.0±0.7    | 36.9±1.0       | 36.7±1.1       | 0.1238   |
| Mean pressure                | 89.7±18.4   | 86.0±20.2      | 84.6±22.2      | 0.656    |
| pH                           | 7.46±0.06   | 7.41±0.07      | 7.41±0.06      | 0.0061   |
| Base excess (mmol/L)         | 0.54±3.9    | -2.42±5.0      | -1.95±4.4      | 0.0087   |
| INR                          | 1.17±0.1    | 1.15±0.2       | 1.21±0.4       | 0.7541   |
| Alb (g/dL)                   | 3.03±0.8    | 3.20±0.9       | 3.19±0.8       | 0.5318   |
| Cre (mg/dL)                  | 0.96±0.8    | 1.34±1.6       | 1.21±1.0       | 0.2705   |
| Post-initial surgery         |             |                |                |          |
| Alb (g/dL)                   | 2.15±0.7    | 2.16±0.6       | 2.18±0.6       | 0.9814   |
| Cre (mg/dL)                  | 0.97±0.6    | 1.22±1.4       | 1.07±0.9       | 0.8556   |
| 48 hours after initial surgery|             |                |                |          |
| Alb (g/dL)                   | 2.05±0.6    | 2.20±0.5       | 2.24±0.4       | 0.4958   |
| Cre (mg/dL)                  | 0.96±0.5    | 1.27±1.3       | 1.22±0.9       | 0.5069   |
| Duration of initial surgery (min) | 180.0±67.1 | 162.3±86.6     | 130.7±46.6     | 0.0101   |
| Trauma                       | 167.5±71.8  | 110.0±55.2     | 114.3±39.1     | 0.0565   |
| Lower gastrointestinal perforation | 187.1±64.8 | 203.3±85.4     | 151.7±48.4     | 0.1696   |
| Bleeding during initial surgery (mL) | 350.9±534.5 | 520.3±509.4   | 1863.6±2090.1 | 0.0002   |
| Trauma                       | 486.0±812.4 | 736.2±646.5    | 2951.3±2200.2  | <0.0001  |
| Lower gastrointestinal perforation | 274.6±278.6 | 351.4±284.3    | 465.0±584.8    | 0.4865   |
| Red blood cell transfusions (mL) | 101.1±233.3 | 122.9±228.3    | 405.0±537.6    | 0.003    |
| Up to 48 hours after the initial surgery |             |                |                |          |
| Total crystalloid administration (mL) | 7601.2±2918.6 | 10084.0±2979.4 | 12736.1±5245.2 | <0.0001  |
| Total NPWT output (mL)       | 1164.7±704.6 | 1336.2±721.1  | 0.2734         |          |
| Total urine output (mL)      | 3005.6±1644.5 | 2545.6±1736.5 | 3300.8±2751.1  | 0.2579   |
| OA duration (day)            | 5.5±3.1     | 4.2±3.1        | 0.0621         |          |
| Primary fascial closure       | 41 (100%)   | 32 (100%)      | N/A            |          |
| Vasopressor infusion         | 13 (36%)    | 14 (34%)       | 13 (40%)       | 0.8468   |
| Alb administration           | 16 (44%)    | 27 (66%)       | 22 (69%)       | 0.0738   |
| Renal replacement therapy    | 3 (8%)      | 13 (31%)       | 14 (43%)       | 0.0036   |
| PMX-DHP                      | 5 (13%)     | 17 (41%)       | 13 (40%)       | 0.0166   |

Continued
observed in infusion volume, NPWT output, or urine volume 48 hours after the initial surgery. There were no differences in SSI, intestinal obstruction, suture failure, or death within 28 days (table 2). The average time until anastomosis in the delayed-anastomosis group was 72.9 ± 40.9 min. Of the 16 patients with intra-abdominal sepsis, 15 had non-malignant perforations. One patient with malignant perforation was included in the early-anastomosis group. There was no significant difference in total crystalloid administration, total NPWT output, or total urine output (p = 0.3121, p = 0.5312, p = 0.7241, respectively), even after the exclusion of one patient with malignant perforation.

**Comparison of the patients who did or did not undergo delayed anastomosis during second-look surgery**

During second-look surgery performed 48 hours after the initial surgery, anastomosis was performed in 11 patients and postponed in 10 patients. Among the 11 patients who underwent anastomosis during the second-look surgery, 10 underwent a simultaneous procedure to close the abdomen. Regarding the serum albumin value 48 hours after the initial surgery (before second-look surgery), there was no significant difference between the anastomosis group and the group for which anastomosis was postponed. No patients were completely weaned from norepinephrine at the time of the delayed anastomosis (table 3).

**DISCUSSION**

This research showed that there was no difference in the infusion volume and NPWT output volume between early anastomosis and delayed anastomosis during TAC in DCL. The presence or absence of anastomosis during TAC management does not affect NPWT output volume. In patients with delayed anastomosis who received the same infusion volume as the early-anastomosis patients, anastomosis and abdominal closure were possible in all cases, and infusion restrictions were not necessary in delayed anastomosis compared with early anastomosis. However, it is necessary to exercise care when performing delayed anastomosis. When a delayed anastomosis planned for 48 hours after initial surgery is complicated, the surgeon must consider postponing anastomosis instead of performing it forcibly. Moreover, the serum albumin value 48 hours after the initial surgery is not a useful indicator of whether delayed anastomosis should be postponed or conducted.

The drainage of ascites using NPWT during TAC has been shown to be beneficial due to such effects as the reduction of intestinal edema and the lowering of inflammatory mediator levels. However, there are also reports that suggest that NPWT output volume is correlated with infusion volume and is higher in fatal cases. When ascites are drained with NPWT, albumin is lost, which is associated with the failure of PFC after TAC. Moreover, hypoalbuminemia is a potential factor for dilutional hypoalbuminemia caused by infusion resuscitation and is associated with anastomotic leakage after digestive tract surgery. Lofts et al.

**Table 1** Continued

| Comparison of the patients who did or did not undergo delayed anastomosis during second-look surgery |
|------------------------------------------------------|
| Table 1 Continued                                      |
| | No-DCL (36) | Early (41) | Delay (32) | P value* |
| Surgical site infection | 15 (41%) | 20 (48%) | 17 (53%) | 0.6307 |
| Adhesive intestinal obstruction | 1 (3%) | 4 (10%) | 2 (6%) | 0.4594 |
| Anastomotic leak | 2 (6%) | 3 (7%) | 1 (3%) | 0.7381 |
| Death within 28 days | 2 (6%) | 2 (5%) | 1 (3%) | 0.8863 |

Data presented as mean±SD or number of patients with percentage.

*Kruskal-Wallis test or X2 test.

Alb, albumin; APACHE II, Acute Physiology and Chronic Health Evaluation II; Cre, creatinine; DCL, damage control laparotomy; INR, international normalized ratio; N/A, not applicable; NPWT, negative-pressure wound therapy; OA, open abdomen; PMX-DHP, direct hemoperfusion with polymyxin B-immobilized fiber.

*Kruskal-Wallis test or X2 test.

Alb, albumin; APACHE II, Acute Physiology and Chronic Health Evaluation II; Cre, creatinine; DCL, damage control laparotomy; INR, international normalized ratio; N/A, not applicable; NPWT, negative-pressure wound therapy; OA, open abdomen; PMX-DHP, direct hemoperfusion with polymyxin B-immobilized fiber.
Table 2  Background factors of early anastomosis and delayed anastomosis in DCL patients

|                      | DCL-early anastomosis | DCL-delay anastomosis | P value * |
|----------------------|-----------------------|-----------------------|-----------|
| **Age (years)**      | 65.6±20.1             | 57.8±19.1             | 0.104     |
| **Sex**              |                       |                       |           |
| Male                 | 8 (50%)               | 12 (57%)              | 0.6658    |
| Cause of surgery     |                       |                       |           |
| Trauma               | 5 (31%)               | 16 (76%)              | 0.0063    |
| Colon injury         | 1 (20%)               | 12 (75%)              | 0.0271    |
| Injury Severity Score| 28.6±11.4             | 27.0±10.2             | 0.8042    |
| APACHE II score      | 28.8±7.6              | 25.0±6.4              | 0.1445    |
| Surgical start time  |                       |                       |           |
| 08:00–19:00          | 9 (56%)               | 18 (86%)              | 0.0456    |
| 20:00–07:00          | 7 (44%)               | 3 (14%)               |           |
| Surgery day          |                       |                       |           |
| Weekday              | 14 (88%)              | 17 (81%)              | 0.6796    |
| Weekend              | 2 (12%)               | 4 (19%)               |           |
| Pre-initial surgery  |                       |                       |           |
| Temperature (°C)     | 37.0±0.9              | 36.6±1.2              | 0.1323    |
| pH                   | 7.39±0.09             | 7.39±0.06             | 0.7129    |
| Base excess (mmol/L) | −1.96±4.2             | −2.44±4.8             | 0.2695    |
| INR                  | 1.20±0.3              | 1.13±0.21             | 0.7381    |
| Alb (g/dL)           | 3.43±0.8              | 3.42±0.8              | 0.9143    |
| Cre (mg/dL)          | 1.17±1.8              | 1.18±0.8              | 0.0399    |
| Post-initial surgery |                       |                       |           |
| Alb (g/dL)           | 2.00±0.4              | 2.30±0.6              | 0.1274    |
| Cre (mg/dL)          | 1.18±1.7              | 0.96±0.7              | 0.7944    |
| 48 hours after initial surgery |       |                       |           |
| Alb (g/dL)           | 2.05±0.3              | 2.38±0.4              | 0.0194    |
| Cre (mg/dL)          | 1.31±1.7              | 1.12±0.7              | 0.5295    |
| Duration of initial surgery (min) | 172.2±48.3          | 108.9±31.4            | 0.0001    |
| Trauma               | 151.0±47.1            | 108.5±32.4            | 0.0474    |
| Lower gastrointestinal perforation | 181.9±47.7           | 110.2±31.4            | 0.0149    |
| Bleeding during initial surgery (mL) | 547.1±582.5         | 2294.0±2391.1         | 0.0553    |
| Trauma               | 1096.8±778.6          | 2991.3±2333.4         | 0.0829    |
| Lower gastrointestinal perforation | 297.2±216.2         | 62.8±29.0             | 0.0234    |
| Red blood cell transfusions (mL) | 105.0±231.4         | 478.0±604.7           | 0.018     |
| Up to 48 hours after the initial surgery |               |                       |           |
| Total crystalloid administration (mL) | 10557.7±2870.9     | 12493.1±5297.0        | 0.2318    |
| Total NPWT output (mL) | 1255.0±588.4         | 1208.1±614.5          | 0.7128    |

Table 2  Continued

|                      | DCL-early anastomosis | DCL-delay anastomosis | P value * |
|----------------------|-----------------------|-----------------------|-----------|
| Total urine output (mL) | 3305.4±2009.1       | 3220.3±1823.3         | 0.9145    |
| OA duration (day)          | 5.4±2.6             | 3.9±3.3              | 0.0301    |
| Vasopressor infusion       | 6 (38%)             | 8 (38%)              | 0.9705    |
| Alb administration         | 10 (63%)            | 15 (71%)             | 0.5654    |
| Renal replacement therapy  | 3 (19%)             | 7 (33%)              | 0.3224    |
| PMX-DHP                  | 8 (50%)             | 6 (29%)              | 0.183     |
| Postoperative complications |                   |                       |           |
| Surgical site infection   | 5 (31%)             | 10 (48%)             | 0.315     |
| Adhesive intestinal obstruction |               |                       |           |
| Anastomotic leak           | 1 (6%)              | 1 (5%)               | 0.8428    |
| Death within 28 days       | 1 (6%)              | 0                    | 0.2455    |

Data presented as mean±SD or number of patients with percentage. *Wilcoxon rank-sum test or Χ² test.

DCL, damage control laparotomy; INR, international normalized ratio; NPWT, negative-pressure wound therapy; OA, open abdomen; PMX-DHP, direct hemoperfusion with polymyxin B-immobilized fiber.
Table 3  Background factors of patients performing or postponing delayed anastomosis during second-look surgery

| Measure                                      | Performing delayed anastomosis (11) | Postponing delayed anastomosis (10) | P value * |
|----------------------------------------------|-------------------------------------|--------------------------------------|-----------|
| Age (years)                                  | 52.0±20.3                           | 64.2±16.3                            | 0.0977    |
| Cause of surgery                             |                                     |                                      | 0.0967    |
| Trauma                                       | 10                                  | 6                                    |           |
| Lower gastrointestinal perforation           | 1                                   | 4                                    |           |
| Injury Severity Score                        | 24.3±10.6                           | 31.5±8.6                             | 0.1585    |
| APACHE II score                              | 21.2±5.0                            | 29.1±5.3                             | 0.0066    |
| Duration of initial surgery (min)            | 99.3±20.9                           | 119.4±38.3                           | 0.2597    |
| Bleeding during initial surgery (mL)         | 2539.4±2319.1                       | 2024.1±2564.1                        | 0.4386    |
| 48 hours after initial surgery               |                                     |                                      |           |
| pH                                           | 7.39±0.06                           | 7.38±0.04                            | 0.9719    |
| Base excess (mmol/L)                         | 2.09±2.64                           | −0.83±3.71                           | 0.0725    |
| INR                                          | 1.22±0.21                           | 1.46±0.19                            | 0.0136    |
| Alb (g/dL)                                   | 2.49±0.54                           | 2.27±0.38                            | 0.2016    |
| Cre (mg/dL)                                  | 0.87±0.31                           | 1.39±0.97                            | 0.2448    |
| P/F ratio                                    | 420.5±120.7                         | 276.0±106.2                          | 0.0112    |
| CRP (mg/dL)                                  | 9.44±7.34                           | 14.89±7.35                           | 0.0448    |
| Up to 48 hours after the initial surgery     |                                     |                                      |           |
| Total crystalloid administration (mL)         | 10407.0±4359.2                      | 14787.9±5483.3                       | 0.0783    |
| Total NPWT output (mL)                       | 959.0±460.3                         | 1482.0±666.8                         | 0.024     |
| Total urine output (mL)                      | 4040.6±1958.9                       | 2318.1±1182.0                        | 0.0317    |
| Sites of anastomosis                         |                                     |                                      |           |
| Small intestine–small intestine              | 3                                   | 3                                    |           |
| Small intestine–colon                        | 4                                   | 1                                    |           |
| Colon–colon                                  | 4                                   | 4                                    |           |
| Colon–rectal                                 | 2                                   |                                      |           |
| Time until anastomosis (min)                 | 46.4±2.8                            | 102.1±43.7                           | 0.0006    |
| OA duration (day)                            | 2.1±0.3                             | 5.9±4.0                              | 0.0002    |
| Vasopressor infusion                         | 3 (27%)                             | 5 (50%)                              | 0.2841    |
| Alb administration                           | 9 (81%)                             | 6 (60%)                              | 0.269     |
| Renal replacement therapy                    | 1 (9%)                              | 6 (60%)                              | 0.0134    |
| PMX-DHP                                      | 1 (9%)                              | 5 (50%)                              | 0.0382    |
| Postoperative complications                  |                                     |                                      |           |
| Surgical site infection                      | 3 (27%)                             | 7 (70%)                              | 0.0502    |
| Adhesive intestinal obstruction              | 2 (18%)                             | 0 (0%)                               | 0.1563    |
| Anastomotic leak                             | 0 (0%)                              | 1 (10%)                              | 0.2825    |

Data presented as means±SD or number of patients with percentage. *Wilcoxon rank-sum test or X2 test.

CONCLUSIONS

Compared with patients who underwent early anastomosis, those for whom delayed anastomosis was selected during DCL do not necessarily require infusion restrictions for the purpose of anastomosis. The presence or absence of anastomosis during TAC management does not affect the NPWT output volume, and both early anastomosis and delayed anastomosis can be managed with the same infusion volume. However, in cases in which the planned delayed anastomosis is complicated, it is necessary to postpone anastomosis rather than perform it.

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pressure (suction amount) was −75 mm Hg. In this study, the median value of NPWT output up to 48 hours after surgery was 1080 mL. The NPWT output was less than that in the previously mentioned report. Our suction pressure setting was −30 cmH\textsubscript{2}O (1 mm Hg=1.36 cmH\textsubscript{2}O), and low pressure management was considered one of the factors for this comparably low output. Our suction pressure setting was maintained at a low pressure to avoid excessive suction of ascites and to maintain physiological ascites absorption in the abdominal cavity. This study showed that the presence or absence of anastomosis does not impact NPWT ejection volume; however, since the NPWT output volume is predicted to depend on the suction pressure, it is necessary to consider the difference in suction pressure.

The purpose of performing early anastomosis during the initial surgery and selecting TAC is to move the patient to intensive care with the aim of controlling rapid bleeding and contamination, shorten the surgery time to the greatest possible extent, and encourage early physiological optimization. However, it is necessary to reconsider some matters, such as the need for TAC with early anastomosis and whether patients for whom early anastomosis is possible might not have been selected for delayed anastomosis. Regarding DCL, overuse\textsuperscript{32} and increased risk of abdominal complications\textsuperscript{33} have also been pointed out. In addition, it is necessary to recognize that delayed anastomosis itself can have negative impacts; reports have described it as a disadvantageous treatment strategy\textsuperscript{34} and have raised the possibility of ongoing peritonitis\textsuperscript{33} increased anastomotic leakage if PFC is not possible during second-look surgery,\textsuperscript{16} and other factors. For anastomosis, we chose stapling anastomosis, which is less dependent on the practitioner’s experience. However, it should be remembered that hand-sewn anastomosis is safe and is superior in situations such as intestinal edema.

This study has several limitations. First, our data were based on a limited number of diseases and cases, and this was a retrospective analysis of data obtained from a single facility. Since the study was not randomized, the results are limited, and there is a risk of bias. Second, the albumin value included in the ascites drained from NPWT was not measured, and therefore, the amount of albumin lost could not be clarified. Third, there are no clear criteria regarding the decision to perform or postpone delayed anastomosis. It is necessary to establish objective treatment selection criteria that do not depend on the subjective judgment of the surgeon. Fourth, patients with trauma and patients with sepsis are not completely comparable. This study reports a restricted result. In the future, reconsideration to address multiple limitations is required.
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REFERENCES
1. Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. Ann Surg 1983;197:532–5.
2. Rotondo MF, Schwab CW, McGonigal MD, Phillips GR, Fruchterman TM, Kauder DR, Latenser BA, Angood PA. ‘Damage control’: an approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma 1993;35:375–82. discussion 82-3.
3. Miller PR, Chang MC, Hoth JJ, Holmes JH, Meredith JW. Colonic resection in the setting of damage control laparotomy: is delayed anastomosis safe? Am Surg 2007;73:606–9. discussion 09-10.
4. Ordoñez CA, Pino LF, Badiel M, Sánchez AI, Loaiza J, Ballestas L, Puyana JC. Safety of performing a delayed anastomosis during damage control laparotomy in patients with destructive colon injuries. J Trauma 2011;71:1512–8. discussion 17-8.
5. Sharpe JP, Magnotti LJ, Fabian TC, Crock MA. Evolution of the operative management of colon trauma. J Trauma Acute Care Surg 2017;82:e10092.
6. Tatebe GC, Jennings A, Tatebe K, Handy A, Prappati P, Smith M, Du T, Ogola GO, GDPR RR, Duane TM, et al. Traumatic colon injury in damage control laparotomy: a multicenter trial: it is safe to do a delayed anastomosis? J Trauma Acute Care Surg 2017;82:742–9.
7. Ferrara A, MacArthur JD, Wright HK, Modlin JM, McMillen MA. Hypothermia and acidosis worsen coagulopathy in the patient requiring massive transfusion. Am J Surg 1990;160:515–8.
8. Rotondo MF, Zonis DH. The damage control sequence and underlying logic. Surg Clin North Am 1997;77:761–77.
9. Moore EE, Burch JM, Francisco RJ, Offner PJ, Biffi WL. Staged physiologic restoration and damage control surgery. World J Surg 1998;22:1184–91. discussion 90-1.
10. Perathoner A, Klaus A, Mühlmann G, Obenwalder M, Margeiret R, Kalka-Ritsch R. Damage control with abdominal vacuum therapy (VAC) to manage perforated diverticulitis with advanced generalized peritonitis—a proof of concept. Int J Colorectal Dis 2010;25:767–74.
11. Sohn M, Iesalnieks I, Agha A, Steiner P, Hochrein A, Pratschke J, Ritsch P, Aigner F. Perforated Diverticulitis with Generalized Peritonitis: Low Stoma Rate Using a “Damage Control Strategy.” World J Surg 2018;42:1389–95.
12. Tartaglia D, Costa G, Camilli A, Castronico M, Andreano M, Lanza M, Fransvea P, Russelli P, Rimini M, Galatioto C, et al. Damage control surgery for perforated diverticulitis: saves lives and reduces omentum. World J Emerg Surg 2019;14:19.
13. Smith JW, Garrison RN, Matheson PI, Franklin GA, Harbrecht BG, Richardson JD. Direct peritoneal resuscitation accelerates primary abdominal wall closure after damage control surgery. J Am Coll Surg 2010;210:5:658–64. 64-7.
14. Huang Q, Zhao R, Yue C, Wang W, Zhao Y, Ren J, Li N, Li Jshou. Fluid volume overload negatively influences delayed primary facial closure in open abdomen management. J Surg Res 2014;187:122–7.
15. Tan W, Huang Q, Yao Z, Huang M, Yang F, Zhao Y, Li J. A preliminary prospective study of patients who underwent vacuum-assisted and mesh-mediated fascial traction techniques for open abdomen management with negative fluid therapy: an observational study. Medicine 2019;98:e16617.
16. Lofts TJ, Elfon PA, Bala TM, Rosenthal MD, Croft CA, Walters MS, Smith RS, Moore AM, Brakenridge SC. The impact of standardized protocol implementation for surgical damage control and temporary abdominal closure after emergent laparotomy. J Trauma Acute Care Surg 2019;86:670–8.
17. Lofts TJ, Jordan JR, Croft CA, Smith RS, Elfon PA, Moore FA, Mohr AM, Brakenridge SC. Characterization of hypoaalbuminemia following temporary abdominal closure. J Trauma Acute Care Surg 2017;83:650–6.
18. Lai C-C, You J-F, Yeh T-Y, Chen J-S, Tang R, Wang J-Y, Chin C-C. Low preoperative serum albumin in colon cancer: a risk factor for poor outcome. Int J Colorectal Dis 2011;26:473–81.
19. Parhasarathy M, Greensmith M, Bowers D, Groot-Wassink T. Risk factors for anastomotic leakage after colorectal resection: a retrospective analysis of 17 518 patients. Colorectal Dis 2019;19:288–9–8.
20. Huang J, Zhou Y, Wang C, Yuan W, Zhang Z, Chen X, Zhang X. Logistic regression analysis of the risk factors of anastomotic fistula after radical resection of esophageal-cardiac cancer. Thorac Cancer 2017;8:666–71.
21. Kubiak BD, Albert SP, Gatto LA, Snyder KP, Maier KG, Vieux CJ, Roy S, Nieman GF. Peritoneal negative pressure therapy prevents multiple organ injury in a chronic porcine sepsis and ischemia/reperfusion model. Shock 2010;34:525–34.
22. Roberts DJ, Zygun DA, Grendar J, Ball CG, Robertson HL, Ouellet J-J, Cheatham ML, Kirkpatrick AW. Negative-pressure wound therapy for critically ill adults with open abdominal wounds: a systematic review. J Trauma Acute Care Surg 2012;73:629–39.
23. Hu P, Uhlich R, Gleason F, Kerby J, Bosange P. Impact of initial temporary abdominal closure in damage control surgery: a retrospective analysis. World J Emerg Surg 2018;13:43.
24. Cheatham ML, Demetriadis D, Fabian TC, Kaplan MJ, Miles WS, Schreiber MA, Holcomb JB, Bocchiocchi G, Sarani B, Rotondo MF. Prospective study examining clinical outcomes associated with a negative pressure wound therapy system and Barker’s vacuum packing technique. World J Surg 2015;37:2018–30.
25. Ryan AM, Hearty A, Pickard RS, Cunningham A, Rowley SP, Reynolds JV. Association of hypoaalbuminemia on the first postoperative day and complications following esophagectomy. J Gastrointest Surg 2007;11:1355–60.
26. Hübner M, Mantziari S, Demartines N, Pralong F, Coti-Bertrand P, Schäfer M. Postoperative albumin drop is a marker for surgical stress and a predictor for clinical outcome: a pilot study. Gastroenterol Res Pract 2016;2016:8743187.
27. Lofts TJ, Jordan JR, Croft CA, Smith RS, Elfon PA, Mohr AM, Moore FA, Brakenridge SC. Temporary abdominal closure for trauma and intra-abdominal sepsis: different patients, different outcomes. J Trauma Acute Care Surg 2017;82:345–50.
28. Chiara G, Cimbamassi S, Biffi W, Leppaniemi A, Henry S, Scalma TM, Catena F, Ansaloni L, Chieregato A, de Blasio E, et al. International consensus conference on open abdomen in trauma. J Trauma Acute Care Surg 2016;80:173–83.
29. Chabot E, Ninlra R. Open abdomen critical care management principles: resuscitation, fluid balance, nutrition, and ventilator management. Trauma Surg Acute Care Open 2017;2:e000063.
30. Lofts TJ, Elfon PA, Bala TM, Rosenthal MD, Croft CA, Smith RS, Moore FA, Mohr AM, Brakenridge SC. Hypertonic saline resuscitation after emergent laparotomy and temporary abdominal closure. J Trauma Acute Care Surg 2018;84:350–7.
31. Germonos S, Gourgiotis S, Villias C, Bertucci M, Dimopoulos N, Salemis N. Damage control surgery in the abdomen: an approach for the management of severe injured patients. Int J Surg 2008;6:246–52.
32. Hatch QM, Osterhout LM, Podbielski J, Koarza RA, Wade CE, Holcomb JB, Cotton BA. Impact of closure at the first take back: complication burden and potential overutilization of damage control laparotomy. J Trauma 2011;71:1503–11.
33. George MJ, Adams SD, McNutt MK, Love JD, Albarado R, Moore LJ, Wade CE, Cotton BA, Holcomb JB, Harvin JA. The effect of damage control laparotomy on major abdominal complications: a matched analysis. Am J Surg 2018;216:56–9.
34. Ott MM, Norris PR, Diaz JJ, Collier BR, Jenkins KM, Gunter OL, Morris JA. Colon anastomosis after damage control laparotomy: recommendations from 174 trauma colectomies. J Trauma 2011;70:595–602.
35. Sohn MA, Agha A, Steiner P, Hochrein A, Komm M, Ruppert R, Ritsch P, Aigner F, Iesalnieks I. Damage control surgery in perforated diverticulitis: ongoing peritonitis at second surgery predicts a worse outcome. Int J Colorectal Dis 2018;33:871–8.
36. Anjaria DJ, Ullmann TM, Lawrey R, Livingston DH. Management of colonic injuries in the setting of damage control laparotomy: one shot to get it right. J Trauma Acute Care Surg 2014;76:594–8. discussion 98-100.