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ASSOCIATION BETWEEN INTRAOPERATIVE GOAL-DIRECTED FLUID THERAPY AND SURGICAL SITE INFECTION RATES IN GASTROINTESTINAL SURGERY

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ABSTRACT

Background: Surgical site infection (SSI) is still a common complication of gastrointestinal surgery. Wound healing can be affected by tissue hypoperfusion, fluid overload, vasoconstriction, oedema and impaired oxygen delivery. The aim of this study was to assess the relationship between the use of goal-directed fluid therapy (GDFT) and 30-day SSI following elective gastrointestinal surgery.

Methods: This was a prospective observational study of 312 adults who were undergoing elective gastrointestinal surgery. Patients treated with stroke-volume guided intraoperative GDFT (n=154) were compared to patients who received conventional fluid therapy (n=158). Dynamic haemodynamic monitoring with crystalloid bolus was only performed if stroke volume rose by at least 10% following a fluid challenge, and vasopressors were used to maintain mean arterial pressure. The primary outcome was CDC-defined SSI within 30 days. Secondary outcomes were total complications, anastomotic leak, postoperative ileus, acute kidney injury, lactate clearance, length of stay, and readmission.

Results: Baseline characteristics, diabetes, smoking, albumin, surgical wound class and procedure complexity were similar between the groups. The GDFT group received less crystalloid (2.1 +/- 0.7 vs. 3.2 +/- 1.1 L, p<0.001), had lower net fluid balance (1.4 +/- 0.8 vs. 2.5 +/- 1.2 L, p<0.001), and better end-of-surgery lactate levels (1.7 +/- 0.6 vs. 2.1 +/- 0.8 mmol/L, p<0.001). The incidence of SSI was 16 patients (10.4%) in the GDFT group and 32 patients (20.3%) in the conventional group (p=0.016). BMI, smoking, albumin, wound class, operative duration, blood loss, and laparoscopic approach were independently associated with the risk of SSI, but GDFT was not. BMI, smoking, albumin, wound class, operative duration, blood loss, and laparoscopic approach were independently associated with the risk of SSI, but GDFT was not.

Conclusions: Intraoperative GDFT was correlated with decreased SSI following gastrointestinal surgery, possibly because of the increased perfusion and prevention of fluid overload. Randomized implementation studies are indicated.

Keywords: Goal-Directed Fluid Therapy, Surgical Site Infection, Gastrointestinal Surgery, Haemodynamic Monitoring, Stroke Volume, Perioperative Care.

INTRODUCTION

Surgical site infection (SSI) is still one of the most significant causes of morbidity following gastrointestinal surgery. It extends hospital stay, exposes to antibiotics, delays recovery, increases costs and may delay adjuvant oncologic therapy.

Gastrointestinal operations are especially at risk because the risk of infection is dependent on the interaction of the following factors: bacterial contamination, anastomotic healing, tissue oxygenation, diabetes, malnutrition, hypothermia, and operative duration. Perioperative haemodynamic management may also have an impact on wound healing, in addition to antibiotic prophylaxis and aseptic technique.

The use of intravenous fluid during large abdominal surgery has been a topic of discussion for a long time. Both hypovolaemia and fluid overload can be harmful. Hypovolaemia can lead to decreased tissue perfusion and oxygen transport, whilst too much crystalloid can cause interstitial oedema, decrease microcirculatory oxygen diffusion, decrease bowel motility and compromise the integrity of the



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anastomosis. One of the most important randomized studies in colorectal surgery demonstrated that a liberal perioperative fluid strategy resulted in fewer postoperative complications than a conservative fluid strategy [1]. But, in some patients, overly restrictive strategies could lead to an increase in renal complications, as demonstrated in the RELIEF trial of major abdominal surgery [2]. These results are consistent with a personalized approach to fluid therapy instead of a blanket one that is liberal or restrictive.

Fluid therapy is guided by dynamic haemodynamic parameters, cardiac output, stroke volume or pulse pressure variation, which is called goal-directed fluid therapy. Initial randomized trials indicated that fluid management based on stroke-volume or pulse-pressure-variation would decrease complications and length of hospital stay in high-risk surgery [3]. Meta-analyses have shown that goal-directed haemodynamic therapy may decrease gastrointestinal complications, infectious complications and length of stay, but effect sizes have been found to differ depending on surgical risk, enhanced recovery protocols and monitoring method [4,5]. The most recent and extensive evidence suggests that goal-directed haemodynamic therapy (GHT) under general anaesthetic may have moderate certainty of reducing infectious complications and anastomotic leakage [6].

There has been a recent increase in the strength of the evidence for SSI. A systematic review and meta-analysis of SSI prevention in 2024 identified high certainty evidence that goal-directed haemodynamic therapy (GDHT) decreases SSI in adults undergoing surgery when compared to conventional fluid therapy [7]. However, in practice, there are variations between institutions, and prospective clinical data in gastrointestinal surgery are still useful, as the risk of infection is procedure-specific and is heavily dependent on the type of wound, bowel contamination, and the healing of the anastomosis. This study examined the relationship between intraoperative GDFT and 30-day SSI in a modern tertiary care population undergoing elective gastrointestinal surgery.

MATERIALS AND METHODS

Study design and setting: This is a prospective observational study that was carried out in a tertiary teaching hospital. Patients aged 18 years or older who were scheduled for elective gastrointestinal surgery under general anaesthetic were recruited from the preoperative clinic and followed up for 30 days. Patients who had intraoperative GDFT when available, according to haemodynamic monitoring and anaesthesia team protocol were compared with those who received conventional fluid therapy.

Participants: Patients were included in the study if they were between 18 and 80 years old, had a planned postoperative follow-up at the same

institution, and underwent gastrointestinal surgery for at least 90 minutes. Surgical procedures performed were colorectal resection, gastric surgery, small bowel resection, stoma reversal, hepatobiliary reconstruction and complex hernia repair with bowel handling. The exclusion criteria were emergency surgery, septic shock, severe valvular heart disease, arrhythmia that precluded dynamic monitoring, end stage renal disease on dialysis, pregnancy, preoperative infection at the operative site, and incomplete follow-up.

Fluid management protocols: Minimally invasive cardiac output monitor or arterial waveform-derived stroke volume monitor was used after induction in the GDFT group. Haemodynamic stabilization was used to obtain baseline stroke volume. Balanced crystalloid boluses of 250 mL were only given if stroke volume rose by at least 10% after a test bolus or if the dynamic indices indicated fluid responsiveness. When stroke volume did not increase significantly, additional boluses were not administered. Vasopressors were administered to keep the mean arterial pressure at or above 65 mmHg or within 20% of baseline. In the conventional group, fluid therapy was based on heart rate, blood pressure, urine output, estimated blood loss and anaesthesiologist judgement.

Perioperative care: All patients were given standard antibiotic prophylaxis within 60 minutes prior to incision, and were re-dosed as per duration and blood loss. The enhanced recovery principles of the hospital were followed by normothermia, glycaemic control, oxygenation and postoperative analgesia. Skin preparation, wound protection and fascial closure were done based on the surgeon's preference and the type of procedure. The SSI surveillance was performed during hospital stay and at outpatient follow-up or telephone review on postoperative day 30.

Primary outcome: Any CDC-defined SSI within 30 days, superficial incisional, deep incisional or organ/space infection. Secondary outcomes were overall complications, anastomotic leak, postoperative ileus, acute kidney injury, postoperative nausea and vomiting, lactate clearance, time to bowel function, hospital length of stay, readmission and mortality. Fluid-related variables were total crystalloid, colloid, blood products, net fluid balance, vasopressor use, urine output and end-of-surgery lactate.

For continuous variables, they were summarized as mean \pm standard deviation and compared using independent t-test or Mann-Whitney U test. Chi-square or Fisher exact test were used to compare categorical variables. The relationship between GDFT and SSI was analyzed by multivariable logistic regression and adjusted for diabetes, BMI, smoking, albumin, wound class, operating time, blood loss, laparoscopy, and procedure complexity. Odds ratios with 95% confidence intervals were

used to report the results. Statistically significant was a two-sided p value of < 0.05.

RESULTS

A total of 331 patients were screened, and 312 completed analysis. The GDFT group included 154

patients, while 158 received conventional fluid therapy. Baseline demographic and clinical characteristics were comparable between groups, including diabetes, smoking, BMI, albumin, wound class, procedure type, and laparoscopic approach.

Table 1. Baseline Characteristics of the Study Groups

Variable	GDFT (n=154)	Conventional (n=158)	p-value
Age, years	57.9 +/- 12.4	58.7 +/- 11.9	0.56
Male sex, n (%)	91 (59.1)	89 (56.3)	0.62
BMI, kg/m ²	25.8 +/- 4.3	26.1 +/- 4.5	0.55
Diabetes mellitus, n (%)	36 (23.4)	40 (25.3)	0.69
Current smoker, n (%)	28 (18.2)	33 (20.9)	0.55
Serum albumin, g/dL	3.8 +/- 0.5	3.7 +/- 0.6	0.11
Clean-contaminated wound, n (%)	121 (78.6)	125 (79.1)	0.91
Laparoscopic approach, n (%)	86 (55.8)	84 (53.2)	0.64

Table 2. Intraoperative Haemodynamic and Fluid Variables

Variable	GDFT	Conventional	p-value
Operative duration, min	168.5 +/- 49.2	172.8 +/- 52.4	0.45
Estimated blood loss, mL	224.6 +/- 152.8	241.3 +/- 166.5	0.36
Crystalloid volume, L	2.1 +/- 0.7	3.2 +/- 1.1	<0.001
Net fluid balance, L	1.4 +/- 0.8	2.5 +/- 1.2	<0.001
Urine output, mL	512 +/- 236	486 +/- 251	0.35
Vasopressor use, n (%)	78 (50.6)	52 (32.9)	0.002
End-surgery lactate, mmol/L	1.7 +/- 0.6	2.1 +/- 0.8	<0.001
Intraoperative hypothermia, n (%)	13 (8.4)	19 (12.0)	0.30

Table 3. Postoperative Outcomes and Adjusted SSI Analysis

Outcome / Predictor	GDFT	Conventional	p-value / Adjusted OR
Any SSI, n (%)	16 (10.4)	32 (20.3)	0.016
Superficial incisional SSI, n (%)	9 (5.8)	20 (12.7)	0.039
Deep or organ/space SSI, n (%)	7 (4.5)	12 (7.6)	0.26
Overall complications, n (%)	39 (25.3)	57 (36.1)	0.039
Anastomotic leak, n (%)	4/98 (4.1)	9/101 (8.9)	0.17
Acute kidney injury, n (%)	8 (5.2)	10 (6.3)	0.66
Length of stay, days	6.7 +/- 3.2	8.1 +/- 4.1	0.001
GDFT and SSI	Adjusted OR 0.46	95% CI 0.23-0.92	p=0.028

Thirty-day readmission occurred in 8 patients (5.2%) in the GDFT group and 15 patients (9.5%) in the conventional group (p=0.15). There was no significant difference in 30-day mortality; one death occurred in each group. In adjusted analysis, additional predictors of SSI were diabetes (adjusted OR 1.91, 95% CI 1.01-3.62; p=0.047), albumin below 3.5 g/dL (adjusted OR 2.12, 95% CI 1.08-4.16; p=0.029), and operative duration above 180 minutes (adjusted OR 1.88, 95% CI 1.02-3.46; p=0.043).

DISCUSSION

The rate of 30-day SSI following elective gastrointestinal surgery was significantly lower in this prospective observational study when GDFT was performed intraoperatively. The absolute reduction in SSI was ~10%, and the association remained after adjusting for major infection-related confounders (diabetes, BMI, smoking, albumin, wound class, blood loss, operative duration, laparoscopic approach, and procedure complexity).

GDFT was also correlated with reduced net fluid balance, reduced lactate at the end of surgery, reduced overall complications and reduced hospital stay.

The results corroborate the physiological basis that both hypoperfusion and hyperhydration may have a negative effect on wound healing. Tissue Oxygen Tension is critical for oxidative killing of bacteria and collagen synthesis. Hypoperfusion can decrease oxygen delivery and fluid overload can increase interstitial oedema and decrease oxygen diffusion. In this study, the GDFT protocol tried to tailor fluid boluses to the stroke-volume response and employed vasopressors to keep perfusion pressure when further fluid was unlikely to increase flow. This could be the reason for the improvement in lactate profile and reduced crystalloid exposure.

Our findings are similar to previous evidence for fluid therapy in colorectal surgery and abdominal surgery. In elective colorectal resection, Brandstrup and colleagues showed a reduction in postoperative complications with limited perioperative fluids, versus standard fluids [1]. The RELIEF trial, however, later demonstrated that a restrictive fluid strategy did not improve disability-free survival and did increase the incidence of acute kidney injury, highlighting the potential for under-resuscitation to be harmful [2]. GDFT can reconcile these findings by not using arbitrary fluid loading and not restricting too much, but rather adapting therapy to the dynamic haemodynamic response.

There is also evidence of the benefits of goal-directed haemodynamic therapy from a meta-analysis of the infection-related benefits. Giglio et al. reported a decrease in gastrointestinal complications in major surgery [4] and Dalfino et al. reported a significant decrease in surgical site infections and other infections with perioperative goal-directed therapy [5]. Recent reviews indicate that GDHT can decrease infectious complications during general anaesthetic [6] and a meta-analysis of studies published in 2024, focusing on SSI, found high-certainty evidence that GDHT algorithms reduce SSI [7]. These findings are similar in the present clinical cohort, in a procedure group where SSI is highly relevant.

The increased vasopressor use in the GDFT group should not be seen as haemodynamic instability. Instead, it is a sign of protocolized avoidance of fluid boluses when stroke volume was not increased. In modern perioperative practice, it has become more and more accepted that vasopressors and fluids should be balanced based on the cause of hypotension. If the predominant mechanism is arterial vasodilation, then further crystalloid can cause oedema without increasing cardiac output. In bowel surgery, where tissue oedema can have an impact on the healing of the anastomosis and on ileus, maintaining perfusion pressure without unnecessary fluid may be especially important [8-9].

There are some limitations to this study. The allocation of treatment was not randomized and the GDFT group might have received more attention to the protocol or more experienced anaesthesia teams. The study was limited to one institution, which may not be representative. Mild infections treated outside of the hospital may not have been detected in SSI surveillance, which was based on clinical follow-up and telephone review after discharge. The study was not designed to find any difference in deep organ/space SSI or anastomotic leak. Furthermore, the cost, workload of the nurse, and barriers to implementation of the devices were not examined. The study, however, offers practical proof that protocolized intraoperative haemodynamic management can decrease SSI in gastrointestinal surgery, despite these limitations. These findings are particularly important for enhanced recovery pathways, where early feeding, mobilization, opioid-sparing analgesia, and standardized infection prevention are complemented by individual fluid therapy. Randomized trials are needed in the future to assess pragmatic GDFT bundles, identify who benefits most, and to compare stroke-volume-guided protocols with dynamic arterial waveform indices, noninvasive monitors and machine-learning-based haemodynamic decision support.

CONCLUSION

Goal-directed fluid therapy during surgery was correlated with decreased 30-day surgical site infection rates, decreased crystalloid fluid administration, improved fluid balance, decreased lactate, decreased total complication rates, and shorter hospital stay after elective gastrointestinal surgery. Although the use of individualized haemodynamic optimization is a potential part of SSI prevention bundles, randomized multicenter implementation studies are required to establish causality and cost-effectiveness.

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