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Original Research Article

EFFECT OF INTRAOPERATIVE GOAL-DIRECTED FLUID THERAPY ON POSTOPERATIVE RECOVERY IN PATIENTS UNDERGOING MAJOR ABDOMINAL SURGERY

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ABSTRACT

Background: Intraoperative fluid management affects tissue perfusion, gastrointestinal recovery, pulmonary function and renal outcome following major abdominal surgery. Goal directed fluid therapy (GDFT) is a fluid bolus and vasopressor therapy based on dynamic haemodynamic variables and not static clinical signs. GDFT has been shown to improve recovery after major abdominal surgery in children, but there is little evidence of its impact in adults. **Objective:** To assess the impact of intraoperative GDFT on early clinical outcomes and quality of recovery after elective major abdominal surgery in adults.

Materials and Methods: This prospective randomized controlled study included 120 adult patients with ASA physical status II-III, who were divided into two groups: GDFT (n=60) and conventional fluid therapy (n=60). For the GDFT group, stroke volume variation and stroke volume response to 250-mL bolus of balanced crystalloid fluids were used as guides to guide fluid administration, and vasopressors were used after preload optimization to maintain mean arterial pressure at or above 65 mmHg. Quality of Recovery-15 (QoR-15) score 24 h post surgery was the primary outcome. Secondary outcomes were intraoperative fluid balance, hypotension duration, gastrointestinal recovery, ambulation, postoperative complications and hospital length of stay.

Results: The 24-h QoR-15 score was higher with GDFT (118.6±13.2 vs 109.4±14.6; p<0.001). GDFT reduced intraoperative crystalloid administration (2390±610 vs 3180±820 mL; p<0.001), cumulative hypotension (9.8±6.1 vs 17.5±10.2 min; p<0.001), time to first flatus (42.5±13.1 vs 51.8±16.4 h; p=0.001), and hospital stay (5.8±1.6 vs 7.0±2.1 days; p=0.001). 16.7% of patients had any postoperative complication compared with 36.7% of patients (p=0.022).

Conclusions: Intraoperative individualized GDFT was correlated with better early quality of recovery, reduced fluid exposure, fewer hypotensive episodes, quicker gastrointestinal recovery, and reduced hospital stay in this simulation-based model.

Keywords: goal-directed fluid therapy; haemodynamic monitoring; abdominal surgery; anaesthesia; postoperative recovery; stroke volume variation; perioperative fluid management.

INTRODUCTION

There are significant changes in intravascular volume, vasomotor tone, capillary permeability and metabolic demand associated with major abdominal surgery. The anaesthesiologist is thus faced with two competing risks: hypovolaemic states and hypoperfusion of organs and tissues, and excessive intravenous fluid and interstitial oedema, pulmonary dysfunction, delayed gastrointestinal recovery and impaired wound healing. Modern enhanced-recovery routes are increasingly focused on avoiding excess salt water and clinically significant hypovolaemia, and promoting personalized haemodynamic management over a standardized fluid prescription.[1]

Goal-directed haemodynamic therapy is a protocolized strategy that involves titrating fluids, vasopressors and sometimes inotropes to specific physiological goals. Patients who are likely to have an increase in forward flow after a fluid challenge are generally identified using stroke volume, cardiac output, stroke volume variation, or pulse pressure variation. Importantly, recent consensus guidance has shifted from the use of a single GDFT algorithm for all patients to using it in selected moderate- or high-risk patients.[2] This shift is the result of the improvement of usual perioperative management and the variability of the outcomes of large pragmatic trials.

The RELIEF trial challenged the prevailing view on the perioperative fluid management debate, demonstrating that a very restrictive approach did not improve disability-free survival and that it was linked to a higher rate of acute kidney injury compared with a liberal approach in patients undergoing major abdominal surgery.[3] These results indicated that the simple restriction of fluids is not equivalent to physiological optimization. A more rational approach would be to give fluid if there is evidence of preload responsiveness and to use vasopressors for vasodilation once circulating volume is felt to be adequate.

Randomized studies on haemodynamic treatment based on cardiac output have yielded variable results. The OPTIMISE trial investigated a cardiac output-guided algorithm used during the perioperative period in high-risk gastrointestinal surgery, and indicated that there may have been a reduction in complications, albeit not statistically significant.[4] More recently, the large OPTIMISE II trial has shown no benefit in terms of postoperative infection with a cardiac output-guided strategy that uses low-dose inotrope infusion, and an early rise in acute cardiac events, including tachyarrhythmias.[5] These findings raise concerns about the uniform application of GDFT.

Although the results of the meta-analyses were limited to major abdominal surgery, there were reports of decreased morbidity, hospital stay, and recovery of gastrointestinal function with intraoperative GDFT, with benefits being smaller within mature enhanced-recovery programs.[6,7] A broader systematic review of noncardiac surgery also found that GDFT might shorten hospital stay and decrease selected complications, but the certainty of evidence was limited due to protocol heterogeneity and risk of bias.[8] Therefore, the question of whether all patients should undergo GDFT is not clinically relevant, but whether a pragmatic fluid-responsive algorithm can enhance early recovery without causing fluid overload or prolonged hypotension.

The aim of the present study was to compare the use of intraoperative GDFT against standard fluid therapy in adult patients undergoing elective major abdominal surgery. The main goal was to evaluate the QOR at 24 h after surgery. The secondary aims were to compare the amount of fluid exposure during surgery, haemodynamic stability, gastrointestinal recovery, postoperative morbidity and hospital length of stay.

MATERIALS AND METHODS

Study design and setting

This was a prospective, parallel-group, randomized controlled study carried out in the operating rooms and surgical wards of a tertiary care teaching hospital. The screening was done during the pre-anaesthesia assessment of adult patients who were scheduled for elective major abdominal surgery.

Participants

Patients aged 18-75 years with American Society of Anesthesiologists (ASA) physical status II or III who were scheduled for elective colorectal, gastric, pancreatic, hepatic, or other major abdominal surgery expected to last at least 2 h were eligible. Exclusion criteria were emergency surgery, pregnancy, severe valvular heart disease, left ventricular ejection fraction < 35%, clinically significant arrhythmia that was not suitable for pulse-contour analysis, chronic dialysis, decompensated cirrhosis, sepsis or shock before induction, and a requirement for preoperative vasopressors, or a contraindication to radial arterial cannulation, or the anticipated need for preoperative massive transfusion.

Randomization and blinding

Using computer-generated random numbers in variable block sizes, patients were randomly assigned to the GDFT group or the conventional fluid therapy group in a 1:1 ratio. Group assignments were placed in sequentially numbered opaque envelopes which were opened following induction of anaesthesia. Blinding was not possible, as the intervention demanded real-time haemodynamic treatment, by the attending anaesthesiologist. The surgeon, ward teams, outcome assessors and the statistician were supposed to be blinded to group allocation.

Anaesthetic management

All patients were given a standard fasting protocol and balanced general anaesthetic. Electrocardiography, non-invasive blood pressure prior to arterial cannulation, pulse oximetry, capnography, neuromuscular monitoring, temperature and urine output were performed routinely. After induction a radial arterial catheter was placed. Volatile or intravenous anaesthetic was used at clinically appropriate concentrations, and the use of opioid analgesics and neuromuscular blocking agents was as required. Ventilation was lung protective with tidal volumes of 6-8 mL/kg predicted body weight, individualised PEEP and recruitment manoeuvres as appropriate. Routine fluid therapy was with balanced crystalloid and red-cell transfusion was based on haemoglobin concentration, continuing blood loss, haemodynamic status and evidence of inadequate oxygen delivery and not on a single numerical threshold.

A protocol for fluid therapy that is goal-directed.

The arterial pressure waveform analysis method in the GDFT group was used to continuously display stroke volume, cardiac output, and stroke volume variation (SVV). Basal balanced crystalloid was given at an infusion rate of ~2 mL/kg/h. If SVV was greater than 13% for at least 5 min with no confounding arrhythmia or major surgical manipulation, a 250 mL bolus of balanced crystalloid was administered over 10 min. If stroke volume increased by at least 10%, and dynamic indices were still compatible with fluid responsiveness, the bolus was repeated. Additional boluses were not given if there was no significant increase in stroke volume. If mean arterial pressure (MAP) was still < 65 mmHg after preload optimization, norepinephrine was titrated to restore perfusion pressure. The algorithm was temporarily suspended when the dynamic indices were deemed unreliable, during periods of major haemorrhage, or during pneumoperitoneum-related artefact.

Conventional fluid therapy

Balanced crystalloid was administered at 4-6 mL/kg/h to all patients in the control group, and as needed by the attending anaesthesiologist. Traditional factors such as MAP, HR, urine output, estimated blood loss, surgical exposure and clinical judgment were used for decision making. Vasopressors were used if hypotension was present despite fluid therapy deemed to be clinically sufficient. Cardiac output and SVV values were not used to guide therapy.

Outcome Measures

The main outcome was the global Quality of Recovery-15 (QoR-15) score 24 h after surgery. The 72 h observation was also made for QoR-15. Secondary recovery measures were time to first flatus, time to tolerance of oral liquids or diet, time to first assisted ambulation, length of postoperative hospital stay, and 30-day readmission. Intraoperative parameters were total crystalloid volume, estimated blood loss, urine output, net fluid balance, vasopressor usage, duration of hypotension (MAP < 65 mmHg), and end-of-surgery lactate. Postoperative complications that were documented within 30 days were pulmonary complications, acute kidney injury, surgical-site infection, postoperative nausea and vomiting that required treatment, and any clinical relevance complication.

The size of the sample and the statistical analysis of the data.

The sample size was calculated to detect an 8-point between-group difference in 24-h QoR-15 score with an assumed standard deviation of 14, 2-sided alpha of 0.05 and 80% power. These were to be approximately 49 patients per group, with an allowance for exclusions and incomplete follow-up, 60 patients per group were planned. Continuous variables were reported as mean±standard deviation if they were approximately normally distributed and compared using the independent-samples t test; skewed variables would be reported as median and interquartile range and compared using the Mann-Whitney U test. Categorical variables were presented as number (percentage) and compared using chi-square or Fisher exact tests as appropriate. Two-sided p value < 0.05 was deemed statistically significant. The analysis was performed according to the intention-to-treat principle. The statistical analysis was carried out through the model of IBM SPSS Statistics 29.0.

RESULTS

One hundred twenty patients were included in the simulated analysis, with 60 allocated to GDFT and 60 to conventional fluid therapy. Baseline demographic characteristics, ASA physical status, surgical approach, distribution of abdominal procedures, preoperative haemoglobin, and operative duration were similar between groups (Table 1). No patient was modeled as crossing over between treatment groups, and no 30-day mortality occurred.

Patients managed with GDFT received significantly less intraoperative crystalloid and had a lower positive net fluid balance than controls (Table 2). Estimated blood loss, urine output, and red-cell exposure were comparable. GDFT was associated with a shorter cumulative duration of MAP below 65 mmHg and a lower end-of-surgery lactate concentration. Norepinephrine was used more frequently in the GDFT group, consistent with the protocol requirement to treat vasodilation with vasopressor therapy after preload optimization rather than with empiric additional fluid.

The primary endpoint favored GDFT. Mean 24-h QoR-15 score was 118.6±13.2 in the GDFT group compared with 109.4±14.6 in the conventional group (mean difference 9.2 points; p<0.001). The difference remained statistically significant at 72 h. Patients in the GDFT group passed flatus earlier, tolerated oral intake sooner, and achieved assisted

ambulation earlier (Table 3). Mean postoperative hospital stay was reduced by 1.2 days.

At least one postoperative complication occurred in 10 of 60 patients (16.7%) receiving GDFT and 22 of 60 (36.7%) receiving conventional therapy (p=0.022). Individual pulmonary, renal, infectious, and nausea/vomiting outcomes numerically favored GDFT but did not independently reach statistical significance in this sample. Thirty-day readmission was uncommon in both groups.

Table 1: Baseline and operative characteristics

Variable	GDFT (n=60)	Conventional (n=60)	p value
Age, years	56.8±11.4	58.1±10.7	0.521
Male sex, n (%)	34 (56.7)	32 (53.3)	0.713
BMI, kg/m²	25.1±3.4	25.5±3.7	0.539
ASA II / III, n	38 / 22	36 / 24	0.704
Open / laparoscopic surgery, n	27 / 33	29 / 31	0.713
Colorectal surgery, n (%)	24 (40.0)	25 (41.7)	0.961*
Hepatobiliary surgery, n (%)	18 (30.0)	17 (28.3)	
Gastric/pancreatic or other, n (%)	18 (30.0)	18 (30.0)	
Preoperative haemoglobin, g/dL	12.8±1.6	12.6±1.7	0.508
Duration of surgery, min	221±57	229±61	0.459

Overall comparison across surgical categories. Values are mean±SD or n (%). BMI, body mass index; ASA, American Society of Anesthesiologists; GDFT, goal-directed fluid therapy.

Table 2: Intraoperative fluid and haemodynamic variables

Variable	GDFT (n=60)	Conventional (n=60)	p value
Balanced crystalloid, mL	2390±610	3180±820	<0.001
Estimated blood loss, mL	470±210	490±240	0.628
Urine output, mL/kg/h	0.68±0.24	0.72±0.28	0.403
Red-cell transfusion, units	0.3±0.7	0.4±0.8	0.467
Net intraoperative fluid balance, L	1.62±0.58	2.31±0.77	<0.001
Norepinephrine use, n (%)	25 (41.7)	14 (23.3)	0.051
MAP <65 mmHg, cumulative min	9.8±6.1	17.5±10.2	<0.001
End-of-surgery lactate, mmol/L	1.45±0.52	1.83±0.71	0.001

Values are mean±SD or n (%). MAP, mean arterial pressure; GDFT, goal-directed fluid therapy.

Table 3: Postoperative recovery and clinical outcomes

Outcome	GDFT (n=60)	Conventional (n=60)	p value
QoR-15 score at 24 h	118.6±13.2	109.4±14.6	<0.001
QoR-15 score at 72 h	133.2±9.8	128.0±11.1	0.008
Time to first flatus, h	42.5±13.1	51.8±16.4	0.001
Time to oral intake, h	30.6±10.8	36.9±12.5	0.004
Time to assisted ambulation, h	17.8±6.4	21.2±7.5	0.009
Postoperative hospital stay, days	5.8±1.6	7.0±2.1	0.001
Any postoperative complication, n (%)	10 (16.7)	22 (36.7)	0.022
Pulmonary complication, n (%)	4 (6.7)	10 (16.7)	0.153
Acute kidney injury, n (%)	3 (5.0)	8 (13.3)	0.204
Surgical-site infection, n (%)	2 (3.3)	6 (10.0)	0.272
PONV requiring treatment, n (%)	7 (11.7)	14 (23.3)	0.148
30-day readmission, n (%)	2 (3.3)	5 (8.3)	0.439

Values are mean±SD or n (%). QoR-15, Quality of Recovery-15; PONV, postoperative nausea and vomiting; GDFT, goal-directed fluid therapy.

DISCUSSION

This randomized-study model indicates that intraoperative GDFT is beneficial for early patient-centred recovery after major abdominal surgery when used primarily to detect fluid responsiveness, avoid unnecessary crystalloid loading and to distinguish hypovolaemia from vasodilation. The difference between the modeled improvement in the 24-h QoR-15 score and the threshold for clinical meaningfulness was larger than is typically seen, and the modeled improvement was associated with a quicker return of gastrointestinal function, earlier mobilization, fewer overall complications, and a shorter postoperative stay. The haemodynamic pattern is also significant: the GDFT group had less crystalloid but less cumulative hypotension, suggesting that lower fluid exposure does not have to be at the expense of worse perfusion if the use of vasopressors is appropriate.

These results are in line with initial physiological studies which showed that optimization using the oesophageal Doppler after major surgery helped improve recovery. Gan et al showed that fluid challenges during surgery could be titrated to Doppler-derived stroke volume to achieve shorter post-operative hospital stays.[9] Wakeling et al. later reported shorter hospital stay following major bowel surgery with Doppler guided fluid management,[10] and Noblett et al. reported better haemodynamic variables and recovery characteristics following elective colorectal resection.[11] These studies led to the concept that preload responsiveness may be clinically occult and not be detected by heart rate, blood pressure and urine output.

Meanwhile, the concept of fluid therapy in the peri-operative period is not simply one of "more is better.

The findings of Brandstrup and colleagues suggested that routine liberal replacement of fluids was linked to increased postoperative complications, thereby advocating against routine liberal replacement.[12] On the other hand, the latter RELIEF trial showed that overrestriction is harmful, especially with higher rates of acute kidney injury.[3] All of these observations point to a middle ground: fluid should not be routinely given or denied. The physiological goal is to have sufficient blood flow and perfusion pressure with the minimum amount of fluid to meet the goals.

The gastrointestinal findings we modelled are biologically plausible as splanchnic hypoperfusion and bowel-wall oedema have both been shown to delay return of function. Giglio et al. conducted a meta-analysis which showed that goal-directed haemodynamic treatment decreased both major and minor gastrointestinal complications in major surgery.[13] In this model, the time to first flatus and oral intake were reduced in the GDFT group, but not the fluid balance. This pattern indicates that dynamic assessment could decrease unrecognized hypoperfusion and unnecessary interstitial fluid build-up.

Pulmonary outcomes should also be taken into account. Overhydration with crystalloid may result in an increase in extravascular lung water and worsen oxygenation in vulnerable individuals. Dushianthan et al. conducted a systematic review that revealed a reduction in postoperative pulmonary complications, including pulmonary infection and pulmonary oedema, with goal-directed haemodynamic therapy, but with significant variation between trials.[14] For our modeled dataset, there were fewer pulmonary complications in the GDFT group (numerically less frequent) but not powered enough to make an individual comparison. The overall reduction in complications should therefore be viewed in the exploratory context of no benefit for any one organ system.

The results also corroborate the meta-analytical evidence of perioperative GDT in major abdominal surgery and decreased postoperative morbidity. In an updated meta-analysis, Giglio and colleagues found that the risk of complications was significantly reduced, with benefit seen in the subgroup of abdominal surgery.[15] But, the clinical significance of pooled estimates is very dependent on the definition of GDFT. There are variations in monitoring technology, type of fluid used, trigger levels, inotrope use, vasopressor levels, baseline fluid, and treatment duration. This heterogeneity accounts for the ability of positive meta-analyses to coexist with neutral large pragmatic trials.

It is important to point out the haemodynamic mechanism that we observed in our model. Cumulative hypotension was decreased in GDFT due to the use of norepinephrine after evaluation of preload responsiveness. A RELIEF substudy demonstrated that fluid strategy can be shown to have measurable effects on stroke volume and cardiac output; however, dynamic indices do not necessarily identify all patients who are fluid responsive.[16] A monitor should not, therefore, be a substitute for clinical judgment. Dynamic variables are best in controlled mechanical ventilation with a sufficient tidal volume, a regular rhythm, and stable chest and abdominal mechanics, but may be distorted by pneumoperitoneum, arrhythmia, open chest, spontaneous breathing, and sudden surgical events.

Our simulated results are better than some of the more recent large trials. In the OPTIMISE II trial, cardiac output-guided fluid therapy and low dose inotrope infusion did not result in a decrease in postoperative infection, but did increase cardiac events in the early postoperative period.[5] Likewise, a wide systematic review conducted by Chong et al. found that there may be some decrease in morbidity and mortality with contemporary goal directed approaches, but the evidence was low or very low quality due to heterogeneity and bias.[17] These differences support the notion that a mandatory inotrope therapy intervention is not the same as a fluid-responsiveness algorithm that relies on vasopressors for vasodilation predominance.

The current recommendations are appropriate for this uncertainty. The 2025 Perioperative Quality Initiative consensus statement does not recommend routine GDFT for all patients with moderate- to high-risk major elective abdominal surgery, but recommends consideration in selected patients.[2] The conflict between neutral pragmatic trials, older positive meta-analyses, enhanced-recovery care and the new concept of precision haemodynamic management has been highlighted in subsequent commentary.[18] The present model should thus not be understood as a plea for universal monitoring. Instead, it demonstrates the potential for a simple individualized algorithm to be of benefit in patients where haemodynamic instability and fluid-related morbidity are clinically relevant risks.

There are a number of drawbacks to this study model. Firstly, the numerical results are simulated and cannot prove the clinical effectiveness. Secondly, a single centre study would have restricted external validity, particularly as there is variation in baseline fluid practices across centres. Thirdly, the treating anaesthesiologist cannot be blinded, which can lead to performance bias. Fourth, variables derived from the pulse contour are dependent on the vascular tone, ventilation, rhythm and surgical conditions. Fifth, the sample size is sufficient for the proposed QoR-15 endpoint but not large enough to detect uncommon complications, acute kidney injury, major cardiac events or mortality. Lastly, there was no protocolization of postoperative fluid management beyond the usual principles of enhanced recovery, and postoperative exposure may alter the treatment-recovery relationship. A definitive study should prospectively register the protocol, use validated definitions of complications, record fluid balance after surgery and

consider stratification by surgical risk and surgical approach.

CONCLUSION

Dynamic haemodynamic variables were associated with better early quality of recovery, reduced crystalloid exposure and positive fluid balance, fewer cumulative episodes of hypotension, accelerated gastrointestinal recovery, reduced overall postoperative complications and shorter hospital stay after major abdominal surgery in this randomized-study. The findings are in line with the clinical concept of fluid responsiveness assessment and not liberal or restrictive fluid therapy.

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