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ORIGINAL ARTICLE

Perioperative Hemodynamic Optimization Using Goal-Directed Therapy in High-Risk Cardiac Patients Undergoing Major Abdominal Surgery: A Prospective Clinical Study

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ABSTRACT

Background: Patients with high risk for cardiac complications who are undergoing major abdominal surgery are very likely to experience perioperative hemodynamic instability, hypoperfusion, cardiovascular complications, and organ dysfunction after surgery. Goal directed therapy (GDT) is a new personal approach to hemodynamic optimization that is directed toward the goal of improving tissue perfusion and decreasing post operative morbidity.

Objective: To assess the outcome of improving hemodynamic stability and postoperative outcome by implementing a strategy of goal-directed therapy perioperatively in high-risk cardiac patients with major abdominal surgery.

Materials and Methods: The study was conducted at Liaquat University of Medical and Health Sciences, Department of General Surgery and at Dr. Ziauddin Hospital from January 2023 to July 2023. There were 120 high-risk cardiac patients who were undergoing elective major abdominal surgery included. The patients were split into two groups: Goal-Directed Therapy group (n=60) and Conventional Hemodynamic Management group (n=60). Hemodynamic parameters measured were mean arterial pressure, cardiac index, serum lactate, urine output, vasopressor requirement and postoperative clinical outcomes. Data was analyzed statistically with SPSS version 26.0 and statistically significant $p<0.05$ was used.

Results: Goal-directed therapy group had significantly better intraoperative hemodynamic status than the conventional group. The mean arterial pressure and cardiac index were significantly elevated in the GDT group, while the serum lactate and the amount of vasopressors used were significantly reduced. The rate of postoperative cardiovascular complications was 13.3% among GDT patients while it was 35.0% among conventional patients. There was a significant difference between the GDT group and the control group (11.7% vs 30.0%) for acute kidney injury. Patients who received goal-directed therapy also had a significantly shorter ICU stay and hospital stay.

Conclusion: Perioperative goal-directed therapy significantly improves hemodynamic optimization and postoperative recovery in high-risk cardiac patients undergoing major abdominal surgery.

Keywords: Goal-directed therapy; Hemodynamic optimization; Major abdominal surgery; High-risk cardiac patients; Perioperative care; Cardiac index; Postoperative complications

INTRODUCTION

Abdominal surgery in individuals who have a preexisting cardiovascular disorder is a significant perioperative problem and is linked to greater morbidity, longer hospital stay, and higher rates of mortality following surgery[1]. Surgical stress, anesthesia-induced cardiovascular depression, fluid shifts, blood loss, inflammatory activation, and metabolic disturbances may significantly impair tissue perfusion and oxygen delivery in patients with limited cardiac reserve[2]. High-risk cardiac patients often have impaired ventricular function, coronary artery disease, autonomic dysregulation, endothelial dysfunction and impaired physiological adaptability, which increases their vulnerability to perturbations of their haemodynamic status during the perioperative period and to organ dysfunction following surgery[3].

Low blood pressure and poor systemic perfusion in the perioperative period are well known risk factors for adverse postoperative outcomes (APO)[4]. Even brief episodes of intraoperative hemodynamic instability may lead to myocardial ischemia, arrhythmias, acute kidney injury, intestinal hypoperfusion, impaired wound healing, and multiorgan dysfunction[5]. On the other hand, too much fluid can cause pulmonary edema, heart and blood pressure overload, and tissue edema, which could lead to decreased cardiopulmonary function.[6] Therefore, maintaining an optimal balance between adequate intravascular volume and prevention of fluid overload remains a critical objective in perioperative cardiovascular management[7].

Traditionally, perioperative hemodynamic management has relied upon static physiological parameters such as heart rate, central venous pressure, blood pressure, and urine output[8]. The use of these traditional markers, however, has been increasingly questioned, and their accuracy in predicting fluid responsiveness or tissue oxygenation status in critically ill or high-risk surgical patients is increasingly being challenged[9]. Static monitoring methods can be insufficient for identifying occult hypoperfusion when vital signs appear normal, leading to delayed intervention and higher postoperative complication rates[10].

Goal directed therapy (GDT) is a new form of hemodynamic optimization that is based on individualizing perioperative fluid and cardiovascular support based on dynamic physiologic parameters[11]. The current GDT protocols include ongoing assessment of cardiac index, stroke volume variation, pulse pressure variation, systemic vascular resistance, and oxygen delivery parameters to direct fluid resuscitation and vasoactive therapy[12]. GDT is designed to achieve specific hemodynamic targets to maximize cardiac function, ensure adequate organ perfusion and prevent under-resuscitation and fluid overload.[13]

Numerous studies and meta-analyses from around the world have shown that perioperative GDT can decrease the rates of postoperative complications, intensive care unit admission, length of mechanical ventilation, hospital stay, and health care costs in high-risk surgical patients.[14] Individually optimized hemodynamic

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parameters in tissue have also been correlated with reduced risk of acute kidney injury, postoperative infections, cardiovascular complications and mortality[15]. While these positive results are encouraging, there is still some variation in the way monitoring is done, in institutional protocols, patient characteristics and in the management of peri-operative monitoring in different healthcare settings[16].

The challenge in the developing world is even more difficult in the treatment of high-risk cardiac patients because of the growing incidence of cardiovascular disease, late presentation, polypharmacy and limited resources[17]. Data regarding the effectiveness of goal-directed therapy in regional surgical populations remain limited, especially among patients undergoing major abdominal procedures with significant cardiovascular risk profiles[18]. Assessment of the perioperative optimization strategies, therefore, should be implemented in the local health-care system to enhance evidence-based perioperative care and minimize postoperative complications[19].

In the present prospective clinical study, researchers evaluated the effectiveness of goal-directed therapy around the time of surgery in improving clinical and hemodynamic stability and postoperative outcomes in high-risk cardiac patients undergoing major abdominal surgery[20]. Another objective of the study was to evaluate the effects of individual hemodynamic optimization on cardiovascular complications, renal dysfunction, intensive care unit (ICU) length of stay and general recovery after surgery. [12]

MATERIALS AND METHODS

This prospective clinical study was conducted at the Department of General Surgery, Liaquat University of Medical & Health Sciences, Jamshoro, Sindh, Pakistan, and Dr. Ziauddin Hospital, Karachi, Sindh, Pakistan, from January 2023 to July 2023. The study recruited 120 cardiac patients with high risk who were about to undergo elective major abdominal surgery after obtaining informed written consent. The ethical approval was given by the institutional ethical review committee prior to the data collection.

Patients of either gender, between the ages of 40 and 80 years, who were planned for elective major abdominal surgery, and had their cardiovascular risk documented, were recruited. High-risk cardiac status included presence of ischemic heart disease, prior myocardial infarction, heart failure, reduced left ventricular ejection fraction, history of coronary angioplasty or coronary artery bypass graft, valvular heart disease, or multiple cardiovascular risk factors (hypertension, diabetes mellitus, and chronic kidney disease). Major abdominal surgery consisted of colorectal surgery, gastric surgery, hepatobiliary surgery, pancreatic surgery, small bowel surgery, and surgery of the abdomen that was likely to be longer than 2 hours.

Patients were excluded if they had received emergency surgery, were undergoing minor abdominal surgery, surgery under local anaesthetic, had active sepsis, uncontrolled arrhythmia, had severe pulmonary hypertension, decompensated heart failure, end-stage renal disease on dialysis, pregnancy or if they refused to participate.

The enrolled patients were split into two groups.Patients were split in half. There were 60 patients in Group A, who were receiving perioperative goal directed therapy, and 60 patients in Group B, who were receiving conventional hemodynamic management. Allocation was done per institutional protocol of perioperative management and availability of advanced hemodynamic monitoring.

Medical history, cardiovascular evaluation, medication history, physical examination, electrocardiography, echocardiography, complete blood count, renal function tests, liver function tests, serum electrolytes, coagulation profile, and baseline serum lactate were all performed in all patients. Preoperative cardiac risk was evaluated based on clinical history, functional status, echocardiographic results, and American Society of Anesthesiologists physical status classification.

The goal-directed therapy group used the intraoperative parameters of mean arterial pressure, cardiac index, stroke volume variation, pulse pressure variation, urine output and serum lactate. The main hemodynamic targets were maintenance of mean arterial pressure ≥65 mmHg, cardiac index ≥2.5 L/min/m², stroke volume variation below 13%, urine output ≥0.5 mL/kg/hour, and serum lactate below 2 mmol/L. Intravenous fluids were administered in small boluses according to fluid responsiveness. Vasopressors were applied in the event of hypotension despite adequate intravascular volume and inotropic support was started if low cardiac output was suspected.

In the conventional management group, fluid management and vasoactive agents were based on standard clinical parameters (heart rate, noninvasive or invasive blood pressure, central venous pressure when available, urine output, estimated blood loss, clinical judgment of the anesthesiology team). The fluid therapy included balanced crystalloids, colloids when necessary and blood products depending on blood loss and hemoglobin level during the surgery.

All patients received general anesthesia. Electrocardiography, pulse oximetry, capnography, temperature monitoring, urine output monitoring, and invasive arterial blood pressure monitoring (if clinically indicated) were all monitored. Patients were transferred to either the intensive care unit or high-dependency unit after the operation, based on clinical condition and cardiac risk.

The main outcome measures were postoperative cardiovascular complications and the development of acute kidney injury, requirement for postoperative mechanical ventilation, intensive care unit stay, length of hospital stay, and 30-day mortality. The cardiovascular complications were myocardial ischemia, arrhythmias, aggravation of heart failure, hypotensive event needing vasopressor support and post-operative cardiac event. Acute kidney injury was defined as based on the serum creatinine concentration or urine output at a standard clinical definition.

Secondary outcome measures were: intraoperative hemodynamic instability, serum lactate level, total fluid requirement, requirement of vasopressors, blood transfusion requirement, and clinical condition at the end of the surgery. Follow-up was performed during hospitalization and by outpatient follow-up or telephone until 30 days after surgery in all patients.

Data was collected on a structured proforma and analysed using SPSS version 26.0. All quantitative variables were shown as mean ± SD and all categorical variables were shown as frequency and percentage. Comparisons between continuous variables were carried out using independent sample t test and between categorical variables, using chi-square test or Fisher's exact test. Logistic multivariate regression analysis was carried out to determine independent predictors of postoperative complications. A p value of < 0.05 was taken as statistically significant.

RESULTS

A total of 120 high-risk cardiac patients undergoing elective major abdominal surgery were enrolled in the present prospective clinical study. Among them, 60 patients were managed using perioperative goal-directed therapy (GDT group), while the remaining 60 patients received conventional perioperative hemodynamic management (Conventional group). The mean age of all the study subjects was 63.8 ± 10.2 years and most of the subjects were male patients. The majority of study participants had important cardiovascular comorbidities such as hypertension, ischemic heart disease, diabetes mellitus, prior coronary interventions, and low left ventricular ejection fraction.

Pre-surgical demographic and clinical characteristics were analysed for comparability between the two treatment groups. No significant difference was seen in terms of age distribution, gender, prevalence of hypertension, diabetes mellitus, ischemic heart disease, chronic kidney disease, previous coronary artery bypass grafting or percutaneous coronary intervention, and ASA physical

status classification. These results showed that both study groups showed a similar cardiovascular risk profile and a similar burden of peri-operative risk burden before surgery. The most frequent comorbidities in both groups were hypertension, ischemic heart disease and diabetes mellitus. Approximately one-third of the patients in both groups demonstrated reduced left ventricular ejection fraction below 45%, reflecting substantial underlying cardiac dysfunction among the enrolled high-risk surgical population (Table 1).

Intraoperative hemodynamics showed that patients in the goal-directed group had greater cardiovascular stability than the conventional group. Throughout surgery, mean arterial pressure and cardiac index was higher in GDT group compared to non-GDT group, which was indicative of better circulatory optimization and maintenance of systemic perfusion.

In addition, markers of tissue perfusion and oxygen delivery were significantly improved with the GDT group. Individualized hemodynamic optimization resulted in a significantly lower mean serum lactate concentration, indicating a lower tissue hypoperfusion and a more stable metabolic status during surgery. Urine output was also significantly increased in the GDT group, which was an indication of better renal perfusion and maintenance of intravascular volume status.

A goal-directed therapy was associated with a significantly lower rate of intraoperative hypotension. Likewise, vasopressor use was significantly less in the GDT group, which suggests better control of the hemodynamics and cardiovascular instability in the perioperative period. The need for blood transfusion was also less in the GDT group, but the result was not statistically significant.

In addition, patients in the goal-directed group had a much shorter mechanical ventilation time after surgery. Patients had better postoperative cardiopulmonary recovery, probably due to their better hemodynamic stability and tissue perfusion (Table 2).

The results of the analysis of post-operative outcome showed that there was a significant decrease in morbidity in the perioperative period in patients cared for by goal-directed therapy. Significantly fewer cardiovascular complications such as postoperative arrhythmias, myocardial ischemia, hypotensive events, and exacerbation of heart failure were observed in the GDT group than in the conventional management group.

These postoperative arrhythmias happened a lot less if patients had individualized hemodynamic optimization. Likewise, myocardial ischemic events were seen less frequently in the GDT group, possibly because of better preservation of myocardial perfusion and oxygen delivery during surgery. The results indicate that perioperatively, hemodynamic optimization is important for reducing postoperative cardiovascular stress in high-risk cardiac patients.

Another large postoperative complication that was significantly lower in the GDT group was acute kidney injury. Preservation of renal perfusion and prevention of renal dysfunction during surgery may have been a consequence of maintenance of adequate mean arterial pressure, improved cardiac output, and optimized intravascular volume status.

The need for postoperative ICU admission was considerably reduced in patients in whom goal directed therapy was used. Furthermore, the duration of the ICU stay and the total hospital stay were significantly decreased in the GDT group, which suggested better recovery after surgery and less healthcare burden.

Despite the lower postoperative mortality in patients who had been treated with goal-directed therapy, there was no statistical significance, probably because of the relatively small sample size and the low mortality rate in the study population (Table 3).

Overall, the findings of the present study demonstrated that perioperative goal-directed therapy significantly improved intraoperative hemodynamic stability, enhanced tissue perfusion, reduced postoperative cardiovascular and renal complications, shortened intensive care and hospital stay, and contributed to better postoperative recovery in high-risk cardiac patients undergoing major abdominal surgery.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variables	GDT Group (n=60)	Conventional Group (n=60)	p-value
Mean age (years)	64.1 ± 9.7	63.5 ± 10.6	0.741
Male gender	38 (63.3%)	36 (60.0%)	0.708
Female gender	22 (36.7%)	24 (40.0%)	0.708
Hypertension	44 (73.3%)	46 (76.7%)	0.672
Diabetes mellitus	29 (48.3%)	31 (51.7%)	0.711
Ischemic heart disease	34 (56.7%)	36 (60.0%)	0.713
Reduced ejection fraction (<45%)	20 (33.3%)	22 (36.7%)	0.699
Previous PCI/CABG	15 (25.0%)	17 (28.3%)	0.684
Chronic kidney disease	11 (18.3%)	13 (21.7%)	0.644
ASA Class III/IV	47 (78.3%)	49 (81.7%)	0.645

Table 2: Intraoperative Hemodynamic and Perfusion Parameters

Parameters	GDT Group (n=60)	Conventional Group (n=60)	p-value
Mean arterial pressure (mmHg)	75.6 ± 6.9	68.8 ± 8.4	<0.001
Cardiac index (L/min/m²)	2.8 ± 0.4	2.3 ± 0.5	<0.001
Serum lactate (mmol/L)	1.9 ± 0.5	3.0 ± 1.0	<0.001
Urine output (mL/kg/hr)	0.92 ± 0.24	0.61 ± 0.19	<0.001
Intraoperative hypotensive episodes	10 (16.7%)	25 (41.7%)	0.003
Vasopressor requirement	14 (23.3%)	29 (48.3%)	0.004
Blood transfusion requirement	12 (20.0%)	18 (30.0%)	0.208
Mechanical ventilation duration (hours)	8.1 ± 2.9	14.2 ± 5.3	<0.001

Table 3: Postoperative Clinical Outcomes

Outcomes	GDT Group (n=60)	Conventional Group (n=60)	p-value
Postoperative cardiovascular complications	8 (13.3%)	21 (35.0%)	0.005
Arrhythmias	6 (10.0%)	16 (26.7%)	0.018
Myocardial ischemic events	4 (6.7%)	11 (18.3%)	0.048
Acute kidney injury	7 (11.7%)	18 (30.0%)	0.014
Postoperative ICU admission	18 (30.0%)	33 (55.0%)	0.006
ICU stay (days)	2.7 ± 1.0	4.5 ± 1.9	<0.001
Hospital stay (days)	8.4 ± 2.5	11.6 ± 3.7	<0.001
Reintubation requirement	3 (5.0%)	9 (15.0%)	0.071
30-day mortality	2 (3.3%)	7 (11.7%)	0.082

DISCUSSION

The present prospective clinical study evaluated the effectiveness of perioperative goal-directed therapy in high-risk cardiac patients undergoing major abdominal surgery and demonstrated that individualized hemodynamic optimization significantly improved perioperative cardiovascular stability and postoperative clinical outcomes[1]. Patients receiving goal-directed therapy had less intraoperative hypotension, higher cardiac index, lower lactate levels, less vasopressor use, and fewer postoperative cardiovascular and renal complications than patients who received conventional perioperative management[2].

Major abdominal surgery has a very strong physiological impact that is accompanied by inflammatory activation, sympathetic nervous system stimulation, redistribution of the body's intravascular fluid, metabolic changes, and increased myocardial oxygen consumption[3]. These changes in patients with underlying cardiovascular disease can lead to myocardial ischemia, arrhythmias, low cardiac output states, tissue hypoperfusion, and multiorgan dysfunction[4]. Effective maintenance of systemic perfusion and oxygen delivery therefore remains essential for improving postoperative recovery in high-risk surgical populations[5].

One of the most important findings of the present study was the significantly improved intraoperative hemodynamic stability observed among patients receiving goal-directed therapy[6]. The GDT group had better maintenance of mean arterial pressure and cardiac index during surgery, and less intraoperative hypotensive episodes with significance[7]. These observations suggest that dynamic hemodynamic monitoring can help identify circulatory compromise earlier, and may help guide timely intervention to prevent severe tissue hypoperfusion[8].

Traditional perioperative fluid management strategies frequently rely on static parameters such as blood pressure, heart rate, and central venous pressure[9]. But, traditional parameters may not be representative of preload responsiveness or real tissue perfusion.[10] Dynamic parameters including cardiac index and stroke volume variation provide more accurate assessment of intravascular volume status and cardiac performance, thereby enabling individualized fluid administration and vasopressor support[11]. In the current study, utilization of these advanced monitoring strategies likely contributed to improved circulatory optimization and reduced cardiovascular stress[12].

Another clinically significant observation was the markedly lower serum lactate concentration among patients managed with goal-directed therapy[13]. Elevated serum lactate is widely recognized as an indicator of tissue hypoxia and impaired oxygen delivery[14]. Persistent perioperative hyperlactatemia has been associated with increased postoperative complications, prolonged intensive care admission, and mortality[15]. The lower lactate concentrations in the GDT group suggest better tissue perfusion and more efficient use of oxygen during surgery[16].

The incidence of postoperative cardiovascular complications including arrhythmias and myocardial ischemic events was significantly lower among patients receiving goal-directed therapy[17]. High-risk cardiac patients are particularly vulnerable to perioperative myocardial injury due to fluctuations in preload, afterload, and myocardial oxygen demand[18]. Cardiovascular optimization of hemodynamics to each patient's needs may reduce myocardial stress and maintain coronary perfusion to minimize postoperative cardiac complications[19].

Another important complication which was significantly lower in the goal-directed therapy group was acute kidney injury[20]. Renal dysfunction following major surgery is frequently associated with prolonged hypotension, reduced renal blood flow, systemic inflammation, and inadequate tissue perfusion[6]. Maintenance of adequate cardiac output and mean arterial pressure likely contributed to preservation of renal perfusion and prevention of postoperative renal injury in the present study[8]. Additionally, GDT patients had improved urine output which suggests better perioperative renal hemodynamic stability[11].

The findings of the current study also demonstrated significantly shorter intensive care unit stay and overall hospital stay among patients managed with goal-directed therapy[14]. Less postoperative complications and improved organ perfusion may have helped to shorten postoperative recovery and avoided longer intensive monitoring[16]. These findings are clinically important because shorter hospitalization not only improves patient recovery but may also reduce healthcare expenditure and hospital resource utilization[18].

Although postoperative mortality was lower in the GDT group, statistical significance was not achieved, likely due to the relatively limited sample size and low overall mortality rate[13]. However, the global decrease in postoperative morbidity is a clear sign of a positive effect of perioperative hemodynamic optimization in this high-risk surgery population.

The present study has several strengths including prospective data collection, inclusion of high-risk cardiac patients, and comprehensive evaluation of perioperative hemodynamic parameters and postoperative outcomes[17]. But some caveats should also be noted. The study was carried out in two tertiary care centres with a relatively modest sample size, with the possibility of generalisations of the findings being limited[19]. In addition, long-term postoperative cardiovascular outcomes were not evaluated. Perioperative outcomes may also have been influenced by the surgical complexity and anesthetic management, despite the uniform institutional management of these patients[20].

The results of the present study add to the existing body of literature indicating that the strategy of goal-directed therapy in the perioperative period is an effective method of achieving hemodynamic optimization and minimizing postoperative complications in the high-risk cardiac surgical patient undergoing major abdominal surgery[12].

CONCLUSION

Perioperative goal-directed therapy is associated with better intra-operative haemodynamic stability and post-operative outcome in high-risk cardiac patients undergoing major abdominal surgery. Dynamic hemodynamic monitoring leads to individual cardiovascular optimization, reduced intraoperative hypotension, lower serum lactate levels, lower postoperative cardiovascular and renal complications and shorter intensive care and hospital stay.

Goal-directed hemodynamic management strategies could improve postoperative outcomes and perioperative safety in high-risk surgical patients with cardiovascular comorbidities. Advanced monitoring of hemodynamics and timely correction of circulatory instability can be important in minimising the peri-operative morbidity and enhance surgical outcome.

The results of this multicenter study warrant further multicenter studies with larger sample sizes and longer follow-up periods to validate the results and provide standardized protocols for goal-directed therapy perioperatively in high-risk cardiac patients for major abdominal surgery.

Authors' Contributions: NAD, NA, and JA conceptualized and designed the study. RMR and AUHP supervised perioperative data collection and clinical monitoring. AK and AN participated in patient assessment, postoperative follow-up, and data acquisition. LNK performed statistical analysis and manuscript drafting. All authors critically revised and approved the final manuscript.

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