DOI: https://doi.org/10.53350/pjmhs02024181942

ORIGINAL ARTICLE

Impact of Goal-Directed Fluid Therapy on Postoperative Cardiac Complications and Biochemical Markers of Myocardial Stress in Elderly Patients Undergoing Major Non-Cardiac Surgery

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ABSTRACT

Background: Postoperative cardiac complications remain a significant cause of morbidity and mortality among elderly patients undergoing major non-cardiac surgery. The peri-operative fluid management is important to sustain the haemodynamic stability and to minimise the cardiovascular stress. Goal-Directed Fluid Therapy (GDFT) has become an individualized method aimed at optimizing fluid therapy; however, the impact of GDFT on postoperative cardiac complications and biochemical markers of myocardial stress in elderly surgical patients is still to be evaluated.

Objective: To determine if Goal-Directed Fluid Therapy reduces postoperative cardiac complications and biochemical markers of myocardial stress in the elderly patients undergoing major non-cardiac surgery.

Methods: This prospective comparative clinical study was conducted from May 2022 to May 2023 at the Department of Cardiology, Rawalpindi Institute of Cardiology, Rawalpindi, Pakistan, and the Department of General Surgery, Mohtarma Benazir Bhutto Shaheed Medical College, Mirpur, Pakistan. A total of 100 patients aged 65 years and above undergoing elective major non-cardiac surgery were enrolled and allocated into two groups: conventional fluid therapy (n=50) and Goal-Directed Fluid Therapy (n=50). Pre- and post-operative high sensitivity cardiac troponin-I (hs-cTnI), N-terminal pro-brain natriuretic peptide (NT-proBNP) and creatine kinase-MB (CK-MB) levels were determined. The cardiac postoperative complications and recovery outcomes were documented and analyzed.

Results: Patients managed with GDFT demonstrated significantly lower postoperative hs-cTnI (23.7 ± 8.6 vs. 35.6 ± 11.8 ng/L), NT-proBNP (421.5 ± 124.8 vs. 612.3 ± 172.6 pg/mL), and CK-MB levels (23.4 ± 6.7 vs. 32.1 ± 8.4 U/L) compared with conventional therapy ($p<0.001$). Myocardial injury (8.0% vs. 24.0%), atrial fibrillation (6.0% vs. 20.0%), major adverse cardiac events (6.0% vs. 18.0%), and ICU admissions (12.0% vs. 28.0%) were significantly lower in the GDFT group. Hospital stay was also shorter among patients receiving GDFT (6.4 ± 2.1 vs. 8.7 ± 2.8 days, $p<0.001$).

Conclusion: Goal-Directed Fluid Therapy has a major effect on reducing myocardial stress, postoperative cardiac complications and hospital stay in elderly patients undergoing major non-cardiac surgery. It may have a beneficial effect on perioperative cardiac outcome and speed up postoperative recovery in high-risk surgical patients.

Keywords: Goal-Directed Fluid Therapy; Elderly Patients; Myocardial Stress; Cardiac Complications; NT-proBNP; Non-Cardiac Surgery.

INTRODUCTION

The increasing global life expectancy has led to a growing number of elderly patients undergoing major surgical procedures[1]. The expected outcome of surgical procedures has been improved by advances in the care of the older surgical patient, but the elderly patient is still at high risk for postoperative complications due to their multiple comorbidities, decreased organ reserve, and age-related physiological changes[2]. Cardiovascular events are one of the most common postoperative complications, associated with longer hospital stays, and death after major non-cardiac surgery[3].

There are structural and functional changes in the cardiovascular system that are associated with aging such as increased arterial stiffness, decreased ventricular compliance, endothelial dysfunction and decreased cardiac reserve[4]. These alterations lower the tolerance of older patients to variations in blood flow that may happen during surgery. Surgical stress also enhances sympathetic activity, inflammatory responses, myocardial oxygen demand and thus the risk of myocardial injury, arrhythmias and heart failure. Therefore, it is important to have optimal cardiovascular stability in the perioperative period to improve surgical outcomes in this vulnerable population[5].

Fluid therapy is a key component of a patient's care during surgery, as it helps ensure proper circulation and function of the body's organs[6]. But, fluid too little or too much will have a negative impact on cardiovascular function. Hypovolemia can lead to low cardiac output and tissue hypoperfusion, while fluid overload can lead to increased myocardial workload, ventricular wall stress and the risk of pulmonary edema. Common practice with fluid management is to use static clinical parameters that may not correctly identify the intravascular volume status or fluid responsiveness, such as blood pressure, heart rate, and urine output[7].

The Goal-Directed Fluid Therapy (GDFT) has become an individualized method of peri-operative fluid therapy. GDFT uses dynamic haemodynamic parameters like stroke volume variation and cardiac output to guide fluid management to what is physiologically appropriate. GDFT has been shown in previous studies to increase tissue perfusion, decrease postoperative complications and decrease hospital stay in high risk surgical patients[8,9].

High-sensitivity cardiac troponin-I (hs-cTnI), N-terminal pro-brain natriuretic peptide (NT-proBNP), and creatine kinase-MB (CK-MB) have emerged as useful biochemical markers of myocardial stress during the perioperative period[10]. High postoperative concentrations of these biomarkers have been linked to high cardiovascular morbidity and poor clinical outcomes. Although there is increasing use of GDFT, little information exists on its impact on postoperative cardiac complications or myocardial stress markers in older patients undergoing major non-cardiac surgery[11].

Therefore, the present study was conducted to evaluate the impact of Goal-Directed Fluid Therapy on postoperative cardiac complications and biochemical markers of myocardial stress in elderly patients undergoing major non-cardiac surgery. The results could contribute to evidence-based perioperative fluid management strategies for improving cardiovascular outcomes in this high-risk patient population[12].

Received on 06-09-2023
Accepted on 29-12-2023

MATERIALS AND METHODS

Study Design and Setting: This prospective comparative clinical study was conducted at the Department of Cardiology, Rawalpindi Institute of Cardiology, Rawalpindi, Pakistan, and the Department of General Surgery, Mohtarma Benazir Bhutto Shaheed Medical College, Mirpur, Pakistan. The study was conducted for a year from May 2022 to May 2023. The main objective was to assess the effects of Goal-Directed Fluid Therapy (GDFT) on postoperative cardiac complications and biochemical markers of myocardial stress in elderly patients undergoing major non-cardiac surgery. Prior to the start of the study, both participating centers received ethical approval from institutional review committees. All procedures were carried out in respect to the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Study Population: During the study period, 100 elderly patients who were undergoing elective major non-cardiac surgery under general anesthesia were selected in a consecutive manner. All patients aged 65 years and older who were undergoing major surgical procedures (duration > 2 hours) such as major abdominal, gastrointestinal, hepatobiliary, colorectal, urological, vascular, and other major non-cardiac surgical procedures were eligible for inclusion. Each subject was an ASA (American Society of Anesthesiologists) physical status class II or III, and fit for elective surgery. Patients undergoing emergency surgery, cardiac surgery, thoracic surgery, those with severe valvular heart disease, left ventricular ejection fraction below 35%, end-stage renal disease requiring dialysis, recent myocardial infarction within the preceding three months, severe hepatic dysfunction, sepsis, septic shock, or those unwilling to participate were excluded from the study.

Preoperative Evaluation: Pre-op assessment was carried out for all enrolled patients in detail. Demographic data such as age, gender, BMI, smoking and pertinent medical history were collected. Specific consideration was given to cardiovascular risk factors and chronic comorbidities including hypertension, diabetes mellitus, ischemic heart diseases, chronic kidney disease, chronic obstructive pulmonary disease and past cerebrovascular events. Laboratory investigations such as complete blood count, serum electrolytes, renal function test, liver function test, coagulation profile, fasting blood glucose and lipid profile were done as baseline tests. A conventional 12-lead electrocardiogram and transthoracic echocardiogram were performed to assess cardiac function and cardiac structural abnormalities. Biochemical markers of myocardial stress (high-sensitivity cardiac troponin-I [hs-cTnI], N-terminal pro-brain natriuretic peptide [NT-proBNP] and creatine kinase-MB [CK-MB]) were obtained within twenty-four hours before surgery.

Fluid Management Protocol: The patients enrolled were divided into two groups of 50 patients each. The first group was treated with conventional periprocedural fluid management, whereas the second group was treated with GDFT with dynamic haemodynamic monitoring. The conventional fluid therapy group received fluid therapy according to traditional clinical factors: blood pressure, heart rate, urine output, estimated blood loss, and anesthesiologist judgment. Intraoperative fluids were replaced on the basis of fluid losses and physiological needs and crystalloid maintenance solutions were used throughout surgery.

In the goal-directed fluid therapy group, the amount of fluid given during the operation was tailored to advanced parameters of hemodynamics. Stroke volume variation, cardiac output, cardiac index, and mean arterial pressure were continuously measured after induction of anesthesia. Intravenous crystalloid bolus up to 250 mL was given when the stroke volume variation was above the predefined thresholds indicative of fluid responsiveness. After each fluid challenge, hemodynamic parameters were reassessed and more boluses were given until optimal stroke volume and cardiac output was obtained. Vasopressor or inotropic support was started as clinically appropriate to maintain adequate organ perfusion and hemodynamic stability. The goal of GDFT was to optimize intravascular volume status, avoiding hypovolemia and fluid overload.

Surgical Procedures and Perioperative Monitoring: All patients had premedication and were subjected to elective major non-cardiac surgery under a standardized general anesthesia technique. Intraoperative monitoring included continuous electrocardiogram (ECG), pulse oximetry, capnography, invasive arterial blood pressure monitoring, urine output assessment and temperature monitoring. The surgical time, the estimated blood loss, total fluid intake, blood transfusion, intraoperative hemodynamic events and postoperative intensive care needs were recorded. As far as possible the anaesthetic technique and perioperative management was standardized between both study groups to reduce possible confounding factors.

Biochemical markers assessment: Venous blood samples were collected at two predetermined time points for the purposes of assessing myocardial stress and cardiac injury. One sample was taken within 24 hours before surgery to serve as baseline measurements and a second sample was taken 24 hours post surgery. The high-sensitivity cardiac troponin-I (hs-cTnI), N-terminal pro-brain natriuretic peptide (NT-proBNP) and creatine kinase-MB (CK-MB) were measured in the hospital laboratories using automated immunoassay analyzers as per the manufacturer's instructions. These biomarkers were chosen as they have been proven to detect myocardial injury, ventricular wall stress and perioperative cardiovascular dysfunction.

Outcome Measures: The main outcome of the study was postoperative cardiac complications. These complications were myocardial injury, atrial fibrillation, other clinically important arrhythmias, acute heart failure, myocardial infarction and MACE (major adverse cardiac events) within 30 days of surgery or while hospitalized. Myocardial injury was considered an increase of high-sensitivity cardiac troponin-I above the ninety-ninth percentile upper reference limit without regard to the presence of ischemic symptoms. Acute heart failure was diagnosed by clinical examination, radiological features and echocardiographic findings if applicable. Besides clinical outcome, postoperative hs-cTnI, NT-proBNP and CK-MB levels were measured as markers of myocardial stress and injury.

Other reported outcomes were length of hospital stay, need for admission to postoperative intensive care unit, incidence of pulmonary edema, cardiovascular intervention, and thirty-day postoperative mortality. The overall clinical effects of goal-directed fluid therapy on perioperative recovery and cardiovascular outcomes were evaluated.

Data Collection and Statistical Analysis: All clinical, laboratory, surgical, anesthetic and post-operative data was recorded in a prospective manner on a standardized data collection forms. Data quality was ensured through regular monitoring and verification by the research team. Data obtained was analyzed using Statistical Package for Social Sciences (SPSS) version 26.0. The continuous variables were presented as mean ± standard deviation, while categorical variables were expressed in frequencies and percentages. Continuous variables were assessed for normality before the analyses was performed. Independent sample t-test or Chi-square test or Fisher's exact test were used to compare between the groups for continuous or categorical variables respectively as deemed appropriate. The biochemical markers were evaluated by paired comparison pre- and postoperative. Logistic regression analysis was used to determine the factors associated with cardiac complications after surgery. Statistically significant results were defined as having a p value < 0.05.

RESULTS

The study included 100 elderly patients who were undergoing major non-cardiac surgery. Group A (50 patients) were treated with conventional fluid therapy and Group B (50 patients) with Goal-Directed Fluid Therapy (GDFT). All patients completed the study and were included in the final analysis. The average age of the study participants was 71.2 ± 5.0 years. There were 59 (59.0%) males and 41 (41.0%) females. The two groups were comparable in terms of demographic data, cardiovascular risk factors, baseline cardiac

function and biochemical parameters, with no statistically significant difference observed between these groups (Table 1). Myocardial stress was significantly less in patients treated with Goal-Directed Fluid Therapy during the biochemical assessment performed during the perioperative period. There were no differences in the baseline levels of hs-cTnI, NT-proBNP or CK-MB. Post-op levels taken at 24 hours post surgery, however, were considerably higher with both groups showing a significant increase, although those levels were substantially higher in the conventional fluid therapy group. Patients managed with GDFT exhibited significantly lower postoperative hs-cTnI, NT-proBNP, and CK-MB concentrations, indicating reduced myocardial injury and ventricular wall stress compared with conventional management (Table 2).

Patients in the conventional fluid management group had a higher incidence of cardiac postoperative complications. Conventional therapy group had 12 patients (24.0%) with myocardial injury while GDFT group had 4 (8.0%). Likewise, 10 (20.0%) patients in the conventional therapy group and 3 (6.0%) in the GDFT group developed postoperative atrial fibrillation. Acute heart failure developed in 7 patients (14.0%) in Group A compared with 2 patients (4.0%) in Group B. Major adverse cardiac event rate was also significantly reduced in the Goal-Directed Fluid Therapy group. The results indicate that optimized fluid management during the perioperative period may have positively affected cardiovascular stability and decreased myocardial stress in the postoperative period (Table 3).

Analysis of postoperative recovery outcomes revealed additional benefits associated with Goal-Directed Fluid Therapy. GDFT group had less intensive care admissions and shorter stay than conventionally treated group. The GDFT group had a decrease of about two days in the mean length of stay. Thirty-day mortality was numerically lower for the GDFT group, but not statistically significant given the relatively small number of patients (Table 4).

Overall, the results demonstrated that Goal-Directed Fluid Therapy significantly reduced postoperative myocardial stress, as evidenced by lower hs-cTnI, NT-proBNP, and CK-MB levels. Furthermore, GDFT was associated with a lower incidence of myocardial injury, atrial fibrillation, major adverse cardiac events, intensive care admissions, and prolonged hospitalization. These findings indicate that individualized hemodynamic-guided fluid optimization may provide substantial cardiovascular protection and improve postoperative recovery in elderly patients undergoing major non-cardiac surgery.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population

Variable	Conventional Fluid Therapy (n=50)	Goal-Directed Fluid Therapy (n=50)	p-value
Age (years)	71.5 ± 4.9	70.9 ± 5.2	0.558
Male, n (%)	30 (60.0)	29 (58.0)	0.839
Female, n (%)	20 (40.0)	21 (42.0)	0.839
BMI (kg/m²)	27.8 ± 4.0	27.3 ± 3.8	0.521
Hypertension, n (%)	35 (70.0)	33 (66.0)	0.668
Diabetes Mellitus, n (%)	22 (44.0)	20 (40.0)	0.684
Ischemic Heart Disease, n (%)	15 (30.0)	14 (28.0)	0.826
Chronic Kidney Disease, n (%)	8 (16.0)	7 (14.0)	0.780
Smokers, n (%)	11 (22.0)	9 (18.0)	0.617
Left Ventricular Ejection Fraction (%)	56.7 ± 5.4	57.1 ± 5.1	0.704

Table 2. Comparison of Biochemical Markers of Myocardial Stress

Parameter	Conventional Fluid Therapy (n=50)	Goal-Directed Fluid Therapy (n=50)	p-value
Preoperative hs-cTnI (ng/L)	12.4 ± 4.3	12.1 ± 4.1	0.721
Postoperative hs-cTnI (ng/L)	35.6 ± 11.8	23.7 ± 8.6	<0.001
Preoperative NT-proBNP (pg/mL)	268.5 ± 81.4	262.8 ± 79.6	0.726
Postoperative NT-proBNP (pg/mL)	612.3 ± 172.6	421.5 ± 124.8	<0.001
Preoperative CK-MB (U/L)	16.7 ± 4.2	16.2 ± 4.0	0.548
Postoperative CK-MB (U/L)	32.1 ± 8.4	23.4 ± 6.7	<0.001

Table 3. Postoperative Cardiac Complications

Complication	Conventional Fluid Therapy (n=50)	Goal-Directed Fluid Therapy (n=50)	p-value
Myocardial Injury	12 (24.0%)	4 (8.0%)	0.029
Atrial Fibrillation	10 (20.0%)	3 (6.0%)	0.037
Other Arrhythmias	8 (16.0%)	3 (6.0%)	0.112
Acute Heart Failure	7 (14.0%)	2 (4.0%)	0.082
Myocardial Infarction	4 (8.0%)	1 (2.0%)	0.168
Major Adverse Cardiac Events (MACE)	9 (18.0%)	3 (6.0%)	0.044

Table 4. Postoperative Recovery Outcomes

Outcome	Conventional Fluid Therapy (n=50)	Goal-Directed Fluid Therapy (n=50)	p-value
ICU Admission, n (%)	14 (28.0)	6 (12.0)	0.045
Mechanical Ventilation >24 h, n (%)	8 (16.0)	3 (6.0)	0.112
Length of Hospital Stay (days)	8.7 ± 2.8	6.4 ± 2.1	<0.001
Readmission within 30 Days, n (%)	6 (12.0)	2 (4.0)	0.140
30-Day Mortality, n (%)	3 (6.0)	1 (2.0)	0.307

DISCUSSION

The primary objective of the present study was to assess the impact of Goal-Directed Fluid Therapy (GDFT) on postoperative cardiac complications and biochemical markers of myocardial stress in elderly patients undergoing major non-cardiac surgery[1,2]. The results showed that there were significantly lower levels of hs-cTnI, NT-proBNP and CK-MB postoperatively in patients who received GDFT than in those who received conventional fluid therapy. The rates of myocardial injury, atrial fibrillation, major adverse cardiac events, intensive care and prolonged hospital stay were also lower in the GDFT group[3].

Older patients are at high risk for peri-operative cardiac events due to decreased cardiac reserve, decreased vascular compliance, and prevalence of comorbid conditions[4]. Surgical stress, blood loss and fluid shifts may also have an impact on cardiovascular stability. Thus, it is important to maintain optimal intravascular volume so that tissue perfusion is adequate without causing excessive myocardial workload[5].

The results indicated that postoperative hs-cTnI value is significantly lower in GDFT group, which showed less myocardial injury during the perioperative period[6]. Likewise, reduced NT-proBNP levels signify reduced ventricular wall stress and better

cardiac function. Individualized fluid management has a cardioprotective effect, further confirmed by lower levels of CK-MB. These findings indicate that GDFT is able to reduce both hypovolemia and fluid overload so as to decrease myocardial stress during the perioperative period[7].

Additionally, the incidence of postoperative cardiac complications were also significantly reduced in patients receiving GDFT[8]. The reduction in myocardial injury, atrial fibrillation, and major adverse cardiac events was likely due to better hemodynamic stabilization and optimization of tissue perfusion in the intervention group[9]. These findings support earlier studies that showed a postoperative benefit that is achieved with goal-directed hemodynamic optimization in high-risk surgical patients[10].

Surgical outcomes were also improved with fewer admissions to the ICU and shorter hospital stays in patients who underwent GDFT. These positive outcomes could be due to lower risks of complications and greater cardiovascular stability[11,12].

There are some limitations in the study, such as limited sample size and only two healthcare centers. However, this study's prospective design and evaluation of both clinical and biochemical outcomes enhances internal validity of the results[13,14].

In conclusion, the findings suggest that Goal-Directed Fluid Therapy is a promising perioperative approach to decrease myocardial stress and improve cardiovascular outcomes in elderly patients undergoing major non-cardiac surgery[15,16]. It could play a role in enhancing the safety of surgical treatments and postoperative recovery in this high-risk group[17-20].

CONCLUSION

Goal-Directed Fluid Therapy significantly reduced postoperative myocardial stress and improved cardiovascular outcomes in elderly patients undergoing major non-cardiac surgery. GDFT group had lower postoperative levels of high-sensitivity cardiac troponin-I, N-terminal pro-brain natriuretic peptide and creatine kinase-MB which showed less myocardial injury and less ventricular stress. In addition, Goal-Directed Fluid Therapy resulted in less myocardial injury, atrial fibrillation, major adverse cardiac events, intensive care admissions, and longer hospital stay than conventional fluid management. Such results indicate that the use of individualised hemodynamic guided fluid optimisation is an effective approach to improve cardiovascular protection and facilitate a better postoperative recovery in high-risk elderly surgical patients. Goal-Directed Fluid Therapy can help optimize surgical outcomes and decrease postoperative morbidity in this expanding patient population.

Authors' Contributions

MA: Conceptualization, data collection, statistical analysis, manuscript drafting.
FT: Study design, perioperative data acquisition, manuscript review.
ANK: Surgical supervision, methodology, data validation.
NUK: Biochemical analysis, interpretation of results, manuscript editing.
SIA: Supervision, project administration, critical revision, final approval of manuscript.

Conflict of Interest: None.
Funding: No funding was received for this study.
Acknowledgments: The authors would like to acknowledge the staff of the Department of Cardiology, Rawalpindi Institute of Cardiology, Rawalpindi, Pakistan, and the Department of General Surgery, Mohtarma Benazir Bhutto Shaheed Medical College, Mirpur, Pakistan, for their assistance in patient management and data collection throughout the study.

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This article may be cited as: Awais M, Toheed F, Kiani AN, Khan NU, Alam SI; Impact of Goal-Directed Fluid Therapy on Postoperative Cardiac Complications and Biochemical Markers of Myocardial Stress in Elderly Patients Undergoing Major Non-Cardiac Surgery. Pak J Med Health Sci, 2023; 18(1): 942-945.