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Effect Of Using Trans-Esophageal Echocardiography Guided Goal-Directed Hemodynamic Therapy Compared To Conventional Hemodynamic Management In Reducing Post-Operative Pulmonary Complications In Elective Major Open Abdominal Surgery Under General Anesthesia

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Background: Pulmonary complications result in a significant rise in morbidity, mortality, and duration of hospitalization, particularly following major upper abdominal operations. The work aimed to reduce the rate of postoperative pulmonary complications (PPCs) following a major abdominal operation.
Methods: This randomized controlled trial study has been performed on 160 cases over the age of eighteen, both sexes, American Society of Anesthesiologists I, II, III physical status, underwent elective major abdominal operation. Cases were categorized to 2 equal groups: Goal-directed therapy (GDT): transesophageal echocardiography (TEE)-guided algorithm and control group: with conventional hemodynamic managing according to standard operating procedures.
Results: Post complications development (pulmonary complications) and intra-operative complication development (hypovolemia and fluid balance) were significantly lesser in in GDT group compared to control group. The duration of hospital stays and need for vasopressors were significantly lesser in GDT group compared to control group ($P<0.05$). Assessing respiratory risk in surgical cases in Catalonia severity, central venous pressure, heart rate, mean arterial blood pressure, oxygen saturation, & physical status were insignificantly variant among the examined groups.

Conclusions: TEE-guided intraoperative hemodynamic management was correlated with a reduced incidence of intraoperative complications in extended, major abdominal surgeries, especially hypovolemia, a lower need for inotrope and a lower frequency of pulmonary complications. It is also beneficial for reducing the length of hospitalization compared to standard care.
Keywords: Trans-Esophageal Echocardiography, Hemodynamic Therapy, Conventional Hemodynamic, Pulmonary Complications, Abdominal Surgery.

Introduction:

Significant morbidity is associated with major abdominal operations. Postoperative complications necessitate invasive therapy and significantly elevate the risk of additional morbidity and mortality in greater than twenty percent of cases [1].

In addition to operative morbidity, nonsurgical complications account for a significant number of complications following surgery. Approximately fifty percent of postoperative complications in upper abdominal surgeries are related to cardiopulmonary adverse reactions [2].

Particularly following major upper abdominal operations, pulmonary complications result in a significant rise in morbidity, mortality, & hospitalization [3].

The outcome of a major abdominal operation is influenced by a variety of factors. Perioperative fluid and hemodynamic control are critical factors. The prevention of fluid overload may decrease the prevalence of postoperative post-operative pulmonary complications following abdominal surgery [4].

Various hemodynamic monitoring procedures such as pulse contour technique, pulmonary artery catheter, TEE were utilized in non-cardiac operation for personalized hemodynamic management. The working group of the Enhanced Recovery after Surgery (ERAS ®) Society advanced an evidence-based algorithm for goal-directed hemodynamic management that involves monitoring of stroke volume & cardiac output [5].

Anesthesiologists have discovered clinical applications for transesophageal echocardiography in other perioperative situations as the intraoperative utilization of the technique has evolved in cardiac surgeries [6].

For more than two decades, perioperative transesophageal echocardiography was utilized for non-cardiac surgical procedures. Its application was increased to help in the diagnosis of life-threatening perioperative disorders including myocardial ischemia, pulmonary embolism, cardiac tamponade, & hypovolemia, and to facilitate resuscitation [7].

The use of TEE for noncardiac operations was recommended. During the perioperative duration, TEE may be a critical tool for monitoring cases with significant comorbidities or if hemodynamic instability is anticipated or happens intraoperatively. Cases with known or suspected cardiovascular compromise, unexplained prolonged hypotension, or unexplained prolonged hypoxemia, in addition to cases with major thoracic or abdominal trauma, are susceptible to the potential benefits of TEE monitoring [8].

We hypothesize that TEE-guided intraoperative hemodynamic management reduces the rate of PPCs following major abdominal surgeries.

The work aimed to diminish the rate of PPCs following major abdominal surgeries & to compare TEE-guided intraoperative hemodynamic management and conventional hemodynamic management in decrease the post-operative pulmonary complications incidence following elective major open abdominal surgeries.

Patients & Methods:

This randomized controlled trial research has been performed on 160 cases over the age of eighteen, both sexes, American Society of Anesthesiologists (ASA) I, II, III physical status, who underwent major elective abdominal surgeries (characterized as procedures that are expected to continue for more than two hours or that result in a blood loss of more than 500 milliliters) [9] and underwent benign & cancer resections on the pancreas, liver, small bowel, biliary tree, rectum, colon, bladder, abdominal aorta, & kidneys. The research was conducted with the approval of the Ethical Committee Suez Canal University, Ismailia, Egypt. The cases provided written consent that was informed.

Exclusion criteria were emergency operation, morbid obesity (body mass index (BMI)>forty), esophageal pathologies (such as varices), which are a contraindication to an esophageal probe, gastric or esophageal surgeries, pregnancy, coagulopathy and severe valvular regurgitation.

Randomization and blindness

cases were randomly categorized into 2 equal groups utilizing a computerized randomization programmed. In order to conceal the randomization sequence, opaque envelopes with numerical identifiers were opened on the day of operation to demonstrate the group classification: Group A (GDT): TEE-guided algorithm and group B (control group): with conventional hemodynamic managing according to standard operating procedures. Physicians, nurses, & surgeons on the inpatient unit were unaware of their assigned groups during the postoperative duration.

All patients were subjected to history taking, anesthetic assessment, laboratory examinations [prothrombin time (PT), complete blood count (CBC), partial tissue thromboplastin time, and international normalized ratio (INR), random blood sugar and other investigations according to the patient's conditions such as kidney function test or liver function test] and radiological investigations [Electrocardiogram (ECG) and echocardiography].

Interpretation of ARISCAT score: low risk <26 points, intermediate risk 26_44 points & high risk ≥45 points].

Intra-Operative Technique:

Insertion of wide bore cannula in the upper limb and arterial cannula for frequent samples of arterial blood gases (ABG). Patients were monitored intraoperatively by non-invasive oscillometric arterial blood pressure (NIBP), ECG, pulse oximeter; end-tidal CO_2, end-tidal isoflurane. Pre-induction heart rate, diastolic, systolic, & mean blood pressure and oxygen saturation were documented as baseline values. For all subjects, an epidural catheter has been located in sitting position at interspaces T9/10, T10/11, or T11/12 by an 18G Tuohy needle (Perifix ®, B BRAUN, Germany) utilizing the paramedian approach & hanging drop technique before general anaesthesia. All patients were pre-oxygenated with FiO_2 100% to attain FeO_2 greater than 60% before induction of anaesthesia. Induction of anaesthesia was done with intravenous Fentanyl 2 μg/kg and propofol 2 mg/kg. Rocuronium 0.6 mg/kg was administered for mechanical ventilation via endotracheal tube. Anaesthesia was maintained by 1.0 - 1.2 MAC isoflurane and was adjusted to preserve the mean arterial pressure & heart rate within twenty percent of pre-induction values. Initial ventilator settings were tidal volume of 6-8ml/kg of predicted body weight, respiratory rate of 12-14 breath/min and was adjusted to keep normocapnia, FiO_2 was adjusted to maintain $SPO_2 \geq 92\%$, PEEP 5 cmH_2O in pressure-controlled volume guaranteed ventilation mode, using GE, Avance anaesthesia station. Central Venous line (CVL) was inserted in right Internal Jugular Vein using ultrasound and baseline measurement was recorded. Epidural injection 10ml of 0.125% bupivacaine with 2 mg morphine was started before the start of the surgery. In the two groups, the intraoperative maintenance rate of Ringer's Acetate was 6ml/kg/hr.

In Goal-directed therapy (GDT) group, directly subsequent the induction of anaesthesia a TEE probe (6Tc-RS, GE health care, Chicago, IL) connected to Ultrasound (Vivid I, GE health care, Chicago, IL) was placed in the esophagus after well lubrication. All participants enrolled in GDT group underwent uneventful placement of the TEE probe. TEE derived haemodynamic data was obtained before the start of surgery as a baseline measurement. Subjects who were randomized to the Goal-directed therapy group was controlled regarding the Enhanced Recovery after Surgery ® algorithm using these following variables such as stroke volume, systemic vascular resistance, mean arterial pressure (MAP),& cardiac index [5]. A 200ml bolus of Ringer's Acetate was given subsequent to the induction of anaesthesia in cases of hemodynamic instability. Additional 200 millilitres boluses were administered until the stroke volume raised by less than ten percent. Lower dose norepinephrine by continuous infusion and/or bolus of ten milligrams ephedrine were given if mean arterial pressure was fewer than 70mm Hg and/or cardiac index (CI) was fewer than 2.5 l min/m2 in spite of a stroke volume rise of fewer than ten percent following fluid challenge. In the event of hemodynamic instability, fluid responsiveness &haemodynamic variables were commonly evaluated &managed in accordance with the described above guidelines.

In control group: The hemodynamic were managed in the following manner. A bolus of 200ml of Ringer's Acetate was administered to patients with isolated hypotension, which was defined as a 20 percent reduction in MAP below baseline or <60mmHg, if no response another a bolus of 200ml of Ringer's Acetate was given. If hypotension remained in the face of volume challenges, norepinephrine was given [10]. Colloids were given in the form of Fresh Frozen Plasma (FFP) & Packed Red Blood Cells (PRBCs) only when hypotension developed during acute haemorrhage. After the surgical procedure finished, every anaesthetics have been discontinued, & eighty percent oxygen ventilation was used. If necessary, Sugammadex 2mg/kg was administered to lessen the remaining impact of Rocuronium. Following the restoration of spontaneous breathing, cases were extubated &transported to the Post Anaesthesia Care Unit (PACU) for routine follow-up. Vital signs were documented & an ABG sample has been collected. For a period of fourteen days, all patients were monitored.
The main result was in-hospital incidence of PPCs and PPCs include atelectasis, pneumonia, pulmonary embolism, and respiratory failure [11]. The secondary outcome included acute kidney injury [12], cardiac morbidity, clinically relevant hypotensive episodes and neurological morbidity.

Sample Size Calculation:
The sample size was evaluated from the following equation [13].

$$m = \frac{\left\{Z\alpha\sqrt{[(1+\varphi)\pi(1-\pi)]}+Z\beta\sqrt{[\varphi\pi1(1-\pi1)+\pi2(1-\pi2)]}\right\}^2}{\varphi\delta^2}$$

Where: m = sample size for each group (assumes equal sized groups); Zα and Zβ are normal deviates at the significance level of 0.05 and power of 80 percent [Zα = 1.96 and Zβ = 0.84]. φ is allocation ratio = 1. π1 is the proportion of the prevalence of PPCs within the control group, which was 31% during the first 30 postoperative days = 0.31([10] π2 is the proportion of the prevalence of total postoperative pulmonary complications in the GDT group, which was 12% during the first 30 postoperative days = 0.12([10][π = (π1 + π2) /2 = 0.215, δ = π1 - π2 = 0.19, So, m = 72.1199]. And an expected drop out of 10% was added. So, there should be about **80** patients for each group.

Statistical analysis

The statistical analysis has been performed using SPSS v26 (IBM Inc., Chicago, IL, USA). The mean & standard deviation (SD) of quantitative variables were provided & compared among both groups utilizing an unpaired Student's t-test. Qualitative variables were analyzed uzing the Chi-square or Fisher's exact test when adequate, and were presented as frequency and percentage (%). Statistical significance was distinct as a two-tailed P value that was less than 0.05.

Results:

Sex, age, chronic illness, smoking, OR duration, BMI and site of operation were insignificantly different among the studied groups. **Table 1**

Table 1: Comparison of general characteristics & operation site of the examined population

		GDT (n=80)	Control (n=80)	P
Age (Years)		55±4	56±5	0.337
≤ 50yrs		15(19%)	13(16%)	
> 50yrs		65(81%)	67(84%)	
Sex	**Male**	43(54%)	44(55%)	0.874
	Female	37(46%)	36(45%)	
Chronic illness	**HTN**	18(23%)	15(19%)	0.567
	DM	22(27%)	22(28%)	
	Cardiac	16(20%)	16(20%)	
	CKD	7(9%)	9(10%)	
	Multiple	17(21%)	18(23%)	
BMI (kg/m^2)		30(±3.5)	31(±2.5)	0.502
≤ 30		22(28%)	17(21%)	
> 30		58(72%)	63 (79%)	
Smoking		21(26%)	22(28%)	0.859
OR Duration		4.5 ± 1.3	4.2 ± 1.2	0.096

Site of operation	**Liver**	15(18.8%)	15(18.8%)	**100**
	Pancreas	4(5%)	4(5%)	
	Biliary	12(15%)	11(13.8%)	
	Small intestine	10(12.5%)	8(10%)	
	Colon	11(13.75%)	12(15%)	
	Rectum	14(17.5%)	14(17.5%)	
	Bladder	9(11.25%)	10(12.5%)	
	Kidney	5(6.3%)	6(7.5%)	

Data are presented as mean ± SD or frequency (%). GDT: Goal-directed therapy, BMI: Body mass index, HTN: hypertension, DM: diabetes mellitus, CKD: Chronic kidney disease, OR: Operating room.

There was a significant lower in post complications development (pulmonary complications) and intra-operative complication development (hypovolemia and fluid balance) in GDT group based on TEE-guided algorithm than standard operating procedures group. There was insignificant difference in pulmonary complications between GDT group based on TEE-guided algorithm and standard operating procedures group. **Table 2**

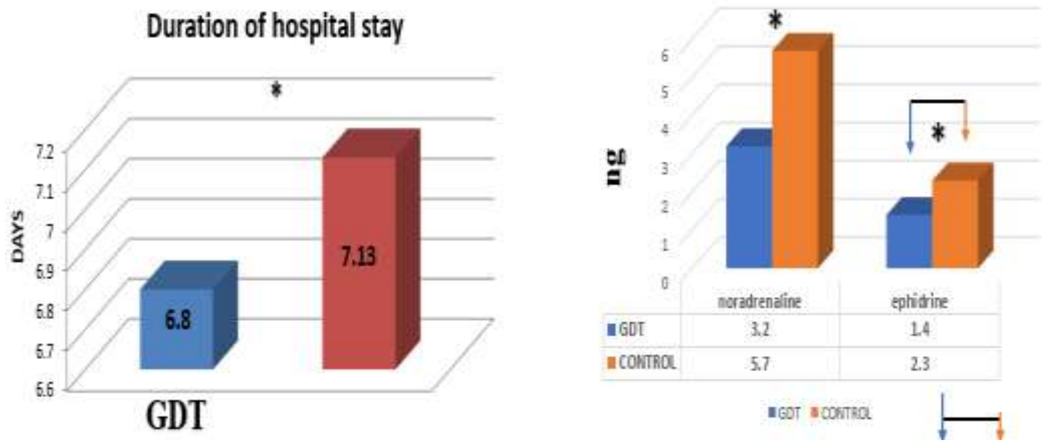
Table 2: Comparison of post-operative, pulmonary and intra-operative complications of the studied population

		GDT (n=80)	Control (n=80)	P
Complications	**Pulmonary**	7(8.8%)	16(20%)	**0.043***
	Wound infection	11(13.8%)	20(25%)	0.072
	Atrial Fibrillation	3(3.8%)	5(6.3%)	0.468
	Myocardial Infarction	1(1.25%)	1(1.25%)	1.000
	Stroke	0(0%)	1(1.25%)	1.000
	Acute Kidney Injury	5(6.3%)	9(11.3%)	0.263
Pulmonary Complications	**Hypoxia/respiratory failure**	3(3.8%)	6(7.5%)	0.303
	Atelectasis	3(3.8%)	7(8.8%)	0.191
	Bronchospasm	3(3.8%)	5(6.3%)	0.468
	Pulmonary infection	5(6.3%)	8(10%)	0.385
	Aspiration pneumonitis	3(3.8%)	6(7.5%)	0.303
	Acute respiratory distress syndrome	3(3.8%)	6(7.5%)	0.303
	Pleural effusions	2(2.5%)	4(5%)	0.405
	Pulmonary edema	2(2.5%)	4(5%)	0.405
	Pulmonary embolism	0(0%)	1(1.3%)	0.316
	Pneumothorax	2(2.5%)	3(3.8%)	0.650
Development of complications		8(10%)	21(26.3%)	**0.008***
Complications	**Fluid balance**	1152±305	1610±410	**0.001***
	Hypotension	6(7.5%)	13(16.3%)	0.087

	Hypovolemia	4(5%)	14(17.5%)	**0.012***
	Hypotension and hypovolemia	2(2.5%)	6(7.5%)	0.147
	Blood loss	670±342	970±380	0.226
Management	**Crystalloid (ml)**	2390±757	2950±1065	0.366
	Colloid (ml) **Pts**	606±440 30(37%)	835±610 33(41%)	0.722

* Significant p value <0.05, GDT: Goal-directed therapy.

The duration of hospital stays & need for vasopressors (Norepinephrine and Ephedrine) were significant lower in GDT group based on TEE-guided algorithm than standard operating procedures group (P<0.05). **Fig. 1**



(A) **(B)**

Figure 1: (A) Duration of hospital stays & (B) vasopressor requirements of the studied population

ARISCAT risk severity, HR, CVP, SPO_2, MABP and physical status were insignificantly variant among the examined groups. **Table 3**

Table 3: Comparison of ARISCAT risk score and pre-operative data of the studied population

		GDT (n=80)	Control (n=80)	P
ARISCAT risk severity	**Low risk <26 points**	15(18.8%)	14(17.5%)	0.497
	Intermediate risk 26-44 points	41(51.3%)	35(43.8%)	
	High risk ≥45 points	24(30%)	31(38.8%)	
ARISCAT score		38.41±13.03	38.74±13.87	0.879
Pre-Operative Data				
MABP		76±8	77±10	0.984
HR		82±8	81±8	0.996
CVP		5±1.7	5.5±1.4	0.839
SPO_2		97(±1.8)	97(±1.7)	0.339
	ASA 1 frequency	16(20%)	16(20%)	0.148

Physical Status	**ASA 2 frequency**	48(60%)	59(74%)	
	ASA 3 frequency	16(20%)	5(6%)	

ARISCAT: Assess Respiratory Risk in Surgical Patients in Catalonia, HR: heart rate, MABP: mean arterial blood pressure, CVP: Central venous pressure, SPO2: oxygen saturation, ASA: American Society of Anesthesiologists.

The mean of baseline transoesophageal echocardiography variables and throughout the surgery were presented in this table. **Table 4**

Table 4: Comparison of TEE measurements pre & post operative of the studied population

	Baseline	**Intra-operative**
SV (ml/beat)	79.6±7.6	77.7±7.4
SVR (dynes.sec.cm^{-s})	1266±140	1086±159
CO (liter/minute)	5.7±0.6	6±0.6
CI (liter/minute/m^2)	3±0.4	3±0.6

SV: Stroke volume, SVR: Peripheral vascular resistance, CO: Cardiac output, TEE: Transesophageal echocardiography, CI: Cardiac index.

Discussion

The significance of perioperative managing fluids in the postoperative recovery of cases that have undergone a major abdominal operation was noted. Evidence suggests that organ dysfunction, delayed gastro-intestinal function, & elevated complication rates following operation correlate with either insufficient or excessive fluid administration throughout the perioperative duration [14].

The main outcome of the research was that the PPCs prevalence was significantly lesser in Goal-directed therapy group according to TEE-guided algorithm than standard operating procedures group. GDT might be advantageous in high-risk cardiovascular cases. All of our cases underwent surgeries that lasted for more than three hours; consequently, they might be more susceptible to fluid overload. This is in line with Scheeren et al. [15] determined that a goal-directed approach might reduce postoperative organ damage. Hasanin et al. [16] reported favorable respiratory outcomes in the Goal-directed therapy group. This is most likely because of the significant decrease in fluid needs in the Goal-directed therapy group. Messina et al. [17] demonstrated that, Goal-directed therapy decreases postoperative complications, but not perioperative mortality, regardless of the quantity of perioperative fluid administered.

In the current research, statistically insignificant variance was observed in complications rates regarding acute kidney injury between GDT group based on TEE-guided algorithm and standard operating procedures group. Abdelrahman et al. [18] documented that the postoperative complication rate (AKI) in the two groups did not differ significantly. According to Mostafa Elebieby et al. [19], there was insignificant variance in the incidence of postoperative complications, particularly AKI, among both groups.

Also, our study results agreed with the outcomes of Bloria et al. [20] conducted a comparison between conventional fluid treatment & goal-directed fluid-guided therapy throughout craniotomy and cerebral aneurysm clipping. The study found significant variations between the two treatments throughout the intraoperative and postoperative periods. The TEE determined left ventricular outflow tract velocity time integral.

The patient's intraoperative stability & postoperative recovery might be affected by intraoperative fluid therapy [21].

Fluid replacement and/or the administration of vasoactive drugs are the theoretical advantages of GDT. Experimental data produce opposite findings in the context of managing fluids [22].

According to the intraoperative administration of fluids to cases, our research results have revealed significant lower need for inotrope in GDT group based on TEE-guided algorithm than standard operating procedures group, with insignificant variance among the two groups regarding intravenous fluids (IVF) management. Sujatha et al. [23] found that the control group demonstrated differences when compared to the other both groups. (conventional fluid therapy cases) Obtained a greater quantity of crystalloids, a reduced quantity of colloids, and an increased overall volume of fluid. The administration of fluids was similar in both the PVI & FloTrac groups.

In their study, Mostafa Elebieby et al. [19] observed that a statistically insignificant distinction was observed among both groups being studied in regards to the overall quantity of ephedrine given & the number of cases needing vasopressors for occurrences of low blood pressure. Cesur et al. [24] accepted with our findings in that conventional fluid treatment necessitates a significantly greater volume of crystalloid &total fluid volume compared to GDT.

The research was limited by the relatively small sample size. The research was conducted in a single center, and multicenter studies can decrease research errors and improve the accuracy of the outcomes. All of our cases were elective, as opposed to emergency cases. Despite the fact that the TEE was conducted by a blind specialist, we were unable to blind the anesthetist who was responsible for managing the patients. The restricted follow-up duration that concluded upon hospital discharge might have resulted in the neglecting of potential late complications.

Conclusions:

TEE-guided intraoperative hemodynamic management was correlated with a reduced incidence of intraoperative complications in extended, major abdominal surgeries, especially hypovolemia, a lower need for inotrope and a lower frequency of pulmonary complications. It is also beneficial for reducing the length of hospitalization compared to standard care.

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Conflict of Interest: Nil

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