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: Review Article

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ABSTRACT

Background: Morbidity after major abdominal surgery is substantial. More than 20% of patients suffer from postoperative complications that require invasive treatment and substantially increase the risk of further morbidity and mortality. Apart from surgical morbidity, non-surgical complications represent a significant proportion of postoperative complications. Cardiopulmonary adverse events account for up to 50% of postoperative complications in upper abdominal operations.

Objective: This article aimed to throw the light on how to reduce incidence of post-operative pulmonary complications (PPCs) after major abdominal surgery.

Material and methods: We searched Google Scholar, Science Direct, PubMed and other online databases for Trans-esophageal echocardiography guided goal-directed, Conventional hemodynamic management, Post-operative cardiopulmonary complications. The authors also reviewed references from pertinent literature, however only the most recent or comprehensive studies from 2010 to February 2023 were included. Documents in languages other than English were disqualified due to lack of translation-related sources. Papers such as unpublished manuscripts, oral presentations, conference abstracts, and dissertations that were not part of larger scientific studies were excluded.

Conclusion: Pulmonary complications lead to significantly increased morbidity, mortality, and length of hospital stay, especially after major upper abdominal surgery. A large variety of cardiac output (CO) monitoring devices are currently offered today that claim to allow for perioperative hemodynamic optimization. These technologies have rapidly evolved from very invasive to mini-invasive and even completely noninvasive devices. The first step for proper goal-directed therapy (GDT) implementation in the operating room (OR) is to identify the patient's surgical risk and to determine appropriate vascular access. Once established, one can choose the best available monitoring approach and the suitable hemodynamic optimization protocol.

Keywords: Trans-esophageal echocardiography guided goal-directed, Hemodynamic, Conventional hemodynamic management, Post-operative pulmonary complications.

INTRODUCTION

Following significant abdominal surgery, morbidity was high. Postoperative problems affect around twenty percent of cases, necessitating invasive therapy significantly raising risk of further morbidity and death. A sizable fraction of postoperative problems, aside from surgical morbidity, were nonsurgical in nature. Postoperative problems in upper abdomen procedures may include up to fifty percent of cardiopulmonary adverse events [(1)].

Morbidity, mortality and duration of hospital stay were all markedly enhanced by pulmonary problems, particularly following major upper abdomen surgery [(2)].

National Surgical Quality Improvement Program discovered that six percent of 165,196 cases who had major abdominal surgery experienced postoperative pulmonary problems. Several hemodynamic monitoring techniques, ex transesophageal echocardiography, pulmonary artery catheterization and pulse contour method have been used in non-cardiac surgery for customized hemodynamic management. For goal-directed hemodynamic management, Enhanced Recovery after Surgery (ERAS ®) Society working group created an evidence-based approach that incorporates cardiac output, stroke volume monitoring [(1)].

Reducing incidence of post-operative pulmonary complications (PPCs) after major abdominal surgery was the goal of this study.

Goal-directed hemodynamic therapy

An estimated 240 million anesthetic procedures were performed annually worldwide. A recent worldwide prospective assessment of surgical outcomes ("EUSOS" study) in non-cardiac surgical patients revealed a high mortality rate of four percent & significant variation across European countries, indicating need for national, even international, guidelines to improve postoperative outcomes. One of anesthesiologists' most important goals in operating room (OR) was to maintain proper tissue perfusion by optimizing intravascular volume status & stroke volume [(3)].
There were many different CO monitoring devices

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available today that make promise that they may optimize perioperative hemodynamics. From highly invasive to mini-invasive & even entirely noninvasive devices, these technologies have advanced quickly. Since GDT has shown substantial clinical evidence & advantages in lowering rates of postoperative complications, it has been accepted as standard of treatment in anesthesiology environment. Despite these encouraging outcomes, GDT has not yet been widely used, clinical practice has not embraced this strategy well [4].

Fluid treatment was still frequently delivered without proper goals or monitoring, majority of anesthesiologists base their decisions on a combination of fixed-volume estimates and empirical formulas. As a result, there can be negative clinical effects related with either hypervolemia or hypovolemia. Increased postoperative morbidity can result from both of these concerns since they can reduce amount of oxygen delivered to tissues [5].

Perioperative volume status & monitoring

Factors affecting preoperative intravascular volume:
In cases having surgery, intravenous fluid therapy was a crucial and comprehensive treatment. It has long been customary for surgery cases to fast for 8 hrs. A possible consequence of this was preoperative hypovolemia. Ensuing stress from surgery may cause a variety of endocrine reactions and ex release of antidiuretic hormone vasopressin [6].

Urine output as an indicator of perioperative volume status:
Systemic intravascular volume was intimately linked to sufficient renal perfusion, which was why urine production has historically been seen as a measure of intravascular volume status. While, decreased blood supply to kidney (as in cases of dehydration, severe blood loss and hypotension) may result in low urine production. Urinary obstruction of urine outflow, as in case of prostate enlargement, may cause low urine output. Urine production may be influenced by a variety of events, making it an insensit
ive measure of volume of blood in circulation [7].

Monitoring of intravascular volume status (Figure 1):
This was done to ensure proper tissue perfusion by directing fluid supply. Hypovolemia (bleeding) or hypervolemia (A cases with significant cardiac failure and compensatory fluid retention) may both be linked to reduced tissue perfusion. In order to evaluate volume status, forecast fluid response throughout different surgical operations, invasive, minimally invasive and non-invasive hemodynamic parameter monitors were employed [7].

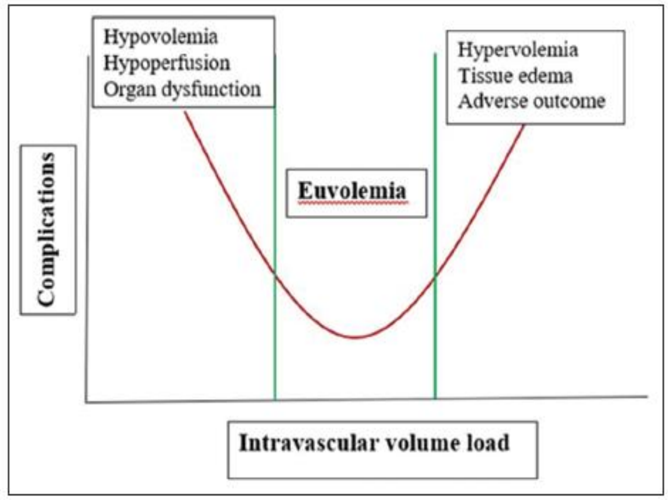

Figure (1): Intravascular volume load.

Intraoperative fluid management within enhanced recovery after surgery protocols:
As part of improved recovery after surgery (ERAS) guidelines, intraoperative fluid management must be considered a continuum spanning preoperative, perioperative and postoperative phases [8].

Goal in "goal-directed fluid therapy"

Fluid responsiveness: GDT uses Frank-Starling curve to extrapolate cases of fluid response from quantifiable hemodynamic changes. After a fluid challenge, fluid responders often show a rise in their SV of at least ten percent to fifteen percent [6].

Commonly used techniques in goal-directed fluid therapy
Conventional hemodynamic variables blood pressure, heart rate, central venous pressure (CVP) and urine output remain used by anesthesiologists to direct their perioperative fluid management [9.

Transesophageal echocardiography:
Transesophageal echocardiography may be utilized intraoperatively to obtain GDT parameters (SV, CO and CVP). Though it was frequently inconvenient to employ transthoracic echocardiography intraoperatively, less invasive technique may be performed both before & after surgery [10].

Pulmonary artery catheter (PAC):
Pulmonary arterial, right-sided intracardiac, central venous and pulmonary artery wedge pressures were all directly measured by PAC. It was capable of estimating pulmonary vascular resistance, systemic vascular resistance, & CO. As a result, PAC was regarded as benchmark CO monitoring standard that all new CO devices were evaluated against [11].

Arterial waveform analysis-based techniques
Esophageal Doppler:
By detecting blood flow (BF) velocity in descending aorta, transesophageal Doppler essentially measures thoracic aortic blood velocity to compute SV, stroke volume variation (SVV), CO and corrected flow time (FTc). Compared to transesophageal echocardiography, it was more easier to conduct and requires substantially less training [6].

Pulse contour analysis:
SV, arterial pressure, arterial compliance and peripheral vascular resistance constitute foundation of pulse contour analysis systems [6].

Plethysmography
When examining GDT in particular, most extensively researched noninvasive monitoring method has been pleth variability index (PVI). PVI determines percentage difference between minimal & maximal plethysmography waveform amplitudes during respiratory cycle. In operating room and intensive care unit, PVI has been shown to be a decent measure of fluid responsiveness [6].

Application of GDT in the operating room:
1st step was to assess cases surgical risk and choose best vascular access. Once established, one may select appropriate hemodynamic optimization methodology and best monitoring strategy available. A cases risk factors and vascular access were taken into consideration when selecting a hemodynamic monitoring system [12] as shown in figure (2).

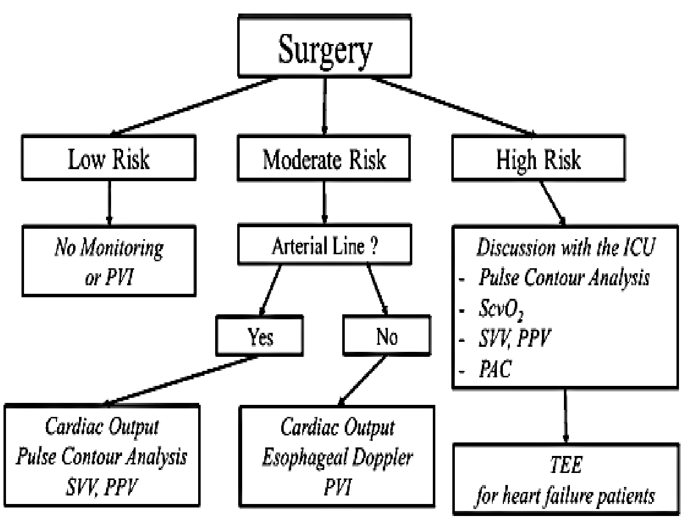

Figure (2): Suggestions for hemodynamic monitoring system selection based on case risk and vascular access.

Critical care unit; ICU, **PAC**; pulmonary artery catheter, **TEE**; transesophageal echocardiography, **$ScvO_2$**; central venous oxygen saturation, **PPV**; pulse pressure variation, **PVI**; pleth variability index, **SVV**; stroke volume variation

Protocol for high-risk surgery:
Individual mortality risks for high-risk surgical cases were greater than five percent, or they were receiving surgery that carries a five percent mortality risk. They frequently struggle to fulfill higher oxygen demand following major surgery that was imposed by perioperative surgical stress, have limited physiological cardiopulmonary reserve. Numerous therapies that can adversely affect equilibrium between oxygen demand & consumption were perioperative risk factors. Oxygen consumption (VO_2) - oxygen delivery (DO_2) relationship may be strongly impacted by nociceptive surgical stimulations, volume changes brought on by sudden blood loss or transfusions, administration of anesthetic drugs. It was essential to assess DO_2–VO_2 ratio in addition to cases metabolic requirement, which was significantly impacted by surgical circumstances [12].

In addition to CO, other cardiac variables, central venous oxygen saturation (SvO_2) was a useful tool for evaluating tissue oxygen consumption during PAC catheterization. Reduced $ScvO_2$ during perioperative phase was related with more postoperative problems, it was simpler to collect than $ScvO_2$ for use as a GDT endpoint. But further study was required, especially in high surgical risk GDT. GDT must be applied individually , as a part of broader clinical context [12].

Postoperative pulmonary complications (PPCs)
Definition & impact of PPCs:
There was variation in literature on European Perioperative Clinical Outcome (EPCO)-recommended definitions of postoperative pulmonary complications (PPCs), which may be viewed as a composite outcome measure. Pneumothorax, bronchospasm, pleural effusion, aspiration pneumonitis, respiratory infection and respiratory failure were among them. PPCs were characterized as distinct adverse events, including pulmonary embolus, acute respiratory distress syndrome (ARDS) and pneumonia. A combination of pneumonia & respiratory failure was used in over sixty percent of sixteen research that test PPCs [13].

Incidence:
An estimated 230 million major procedures take place each year. PPCs occur in major surgery in a range of less than one to twenty-three percent of cases. Postoperative respiratory failure was most frequent PPC. Numerous investigations have demonstrated that pulmonary

complications were more frequent than cardiac problems [14].

Impact

Cases who acquire a PPC were more likely to die in short- and long-term. Within thirty days following major surgery, 1 in 5 cases (Fourteen–thirty percent) with a PPC will pass away, compared to 0.2–3%. Research has demonstrated that individuals with a PPC have a much higher ninty-day death rate (24.4 vs. 1.2% Lumb and Yeung, 2018). PPCs enhance morbidity. There has been evidence of a thirteen -seventeen day increase in length of hospital stay (LOS) [15].

Pathophysiology leading to PPCs.

Intraoperative changes to respiratory system:

Adverse respiratory consequences from general anesthesia include decreased central respiratory drive, extended apnea, decreased spontaneous ventilation, compromised ventilatory responses to hypoxia and hypercapnia. Alterations in respiratory muscle function result in decreased functional residual capacity and compromised oxygenation. More than seventy five percent of cases with neuromuscular blocking drug (NMBD) develop atelectasis, which has a major impact on post-procedural consequences. These alterations were most noticeable in cases who were at risk [16].

Postoperative respiratory pathophysiology

Postanaesthesia care unit changes:

Postanesthesia care units (PACUs) frequently experience hypoxia, which was categorized as a post-pandemic condition (PPC). Ventilatory response might be somewhat maintained under hypercapnic settings, but obstructed cases might not produce a typical response. After simple procedures, reduced function residual capacity (FRC) & poor oxygenation usually return to normal in a few hrs, but not after major surgery [17].

Respiratory changes beyond PACU:

Hypoxemia episodes can result from major surgery that reduces alveolar-to-arterial oxygen differential. After surgery, FRC usually drops to its lowest level one- two days later, then rises to normal in five-seven days. Most cases experience atelectasis during anesthesia that lasts for at least twenty four hours. Weeks can pass with aberrant respiratory control, including decreased ventilatory responses to hypoxia & hypercapnia. This can result in difficulties clearing airways while you sleep, obstructive sleep apnea after surgery. Following surgery, sputum retention was typical, general anesthesia may hinder mucociliary transit in airways, creating perfect environment for PPC development [18].

Preoperative risk stratification:

By identifying cases at high risk of problems, risk prediction models facilitate informed consent and best possible perioperative care. Lack of intraoperative risk factors, retrospective databases, or single bad outcomes limit applicability of many models. With PPC development rates ranging from 1.6 to 42.1%, ARISCAT-created 7-variable regression model to stratify cases into decreased-, intermediate-, increased-risk groups [19].

Risk factors of pulmonary complications:

Many risk variables, both modifiable and non-modifiable that must indicate occurrence of a PPC may be categorized as procedure-, cases-, or laboratory testing-related risk factors [20].

Non-modifiable risk factors

Age:

Frailty was more common in older cases, even after controlling for age, it has been linked to PPCs [21].

Surgery type:

Cases were at increased risk of developing PPCs after specific types of surgery [21].

Preoperative investigations:

PPC prediction has historically been attributed to preoperative spirometry & arterial blood gases. effectiveness of preoperative chest radiography (CXR) has yielded mixed results [21].

Modifiable risk factors & their management

Co-morbidity:

A diagnosis of chronic liver disease, congestive heart failure, or chronic obstructive lung disease (COPD) may independently increase risk of PPCs, as can an ASA score of II or higher. Prior to elective surgery, cases with severe OSA must begin continuous positive airway pressure therapy, their adherence must be assessed [22].

Smoking:

Quitting smoking prior to major surgery lowers risk of postoperative morbidity [23].

Preoperative anaemia:

Anaemia affects almost one-third of cases in Europe who visit pre-assessment clinics. Diagnosis & treatment may prevent other potentially dangerous complications of both anemia and transfusion limit autologous blood transfusions, save supplies and lower PPCs [23].

General anaesthesia:

It can appear apparent that cases who get central or peripheral regional anesthesia (RA) instead of general anesthesia have a lower incidence of PPCs because general anesthesia disrupts several elements of respiratory function. For instance, despite no change in thirty-day mortality, a summary of Cochrane systematic reviews revealed substantial decrease in postoperative pneumonia [24].

Postoperative respiratory support with CPAP & nasal high-flow oxygen:

There was no enough data to support idea that postoperative continuous positive airway pressure (CPAP) reduces mortality or serious respiratory problems following major abdominal surgery.

Neuromuscular blocking drugs (NMBDs) & their reversal [25]:

Respiratory impairment lead to surgical residual paralysis was widely established. These connections between PPC & NMBD management initially appear unexpected. Modern NMBDs must have no clinical effect a little hrs after emergence, according to their pharmacokinetics, but PPCs were more common in cases who get them for several days. Events that occur early in healing process may affect long-term respiratory outcomes in ways other than inability to re-expand intraoperative atelectasis. Extraction of stomach or pharyngeal secretions, insufficient clearance of airway secretions typically accompany airway manipulation during emergence were 2 examples [19].

Nasogastric tube (NGT):

Insertion of NGT has been identified as a risk factor for PPCs. An NGT during perioperative phase increases risk of a PPC in cases having abdominal surgery by 5 to 8 times. Its use ought to be limited to symptom alleviation or specialized surgical purposes because to its relationship with PPCs [19].

Other preventative measures

Preoperative physiotherapy: In cases having abdominal, PPCs & length of stay (LOS) were decreased by heart surgery, but not joint replacement surgery, preoperative aerobic activity and inspiratory muscle training (IMT). It was advised to start preoperative IMT with cases who were at a high risk of acquiring a PPC [26].

Postoperative physiotherapy & mobilization: In both general & vascular cases, I COUGH postoperative respiratory care program lowers incidence of pneumonia & unscheduled re-intubation [27].

Analgesia: In comparison to systemic opioids alone, addition of epidural analgesia to GA dramatically lowers incidence of postoperative pneumonia in general surgical population [28].

Trans-esophageal echocardiography-guided goal-directed hemodynamic Therapy: With a broad range of therapeutic applications, perioperative TEE in non-cardiac surgery offers a special way to do in-depth real-time cardiovascular assessment. When it comes to high-risk surgical procedures & high-risk cases having non-cardiac surgery, TEE might be preferred hemodynamic monitor. It ought to be easily accessible in perioperative setting to assess cardiac crises , unexplained hemodynamic instability [29].

Perioperative TEE examination

Equipment orientation: Based on piezoelectric effect concept, TEE imaging necessitates that anesthesiologists possess knowledge of echocardiography modalities, probe selection, ultrasound knobology. Specific views must have their wave depth modified and 2D gain must be maximized. For valvular diseases & higher frame rates, color Doppler imaging must be modified with a Nyquist limit of fifty-sixty cm.sec-1. In order to utilize equipment, it must be in sleep or freeze mode after exam [30].

Insertion of TEE probe: Prior to a probe being inserted under general anesthesia, cases history & permission were examined. To prevent harm, bite blocks were utilized in conjunction with a jaw raise & gentle probe direction. Turning or slightly flexing may help with assisted insertion [31].

Manipulation of TEE probe (Figure 3): TEE probe manipulation terms, ex advancement, withdrawal, twisting and angle rotation, should be understood by echocardiographers. An electronic switch controls axial rotation, 2 knobs were used to accomplish anteflexion & retroflexion. [31].

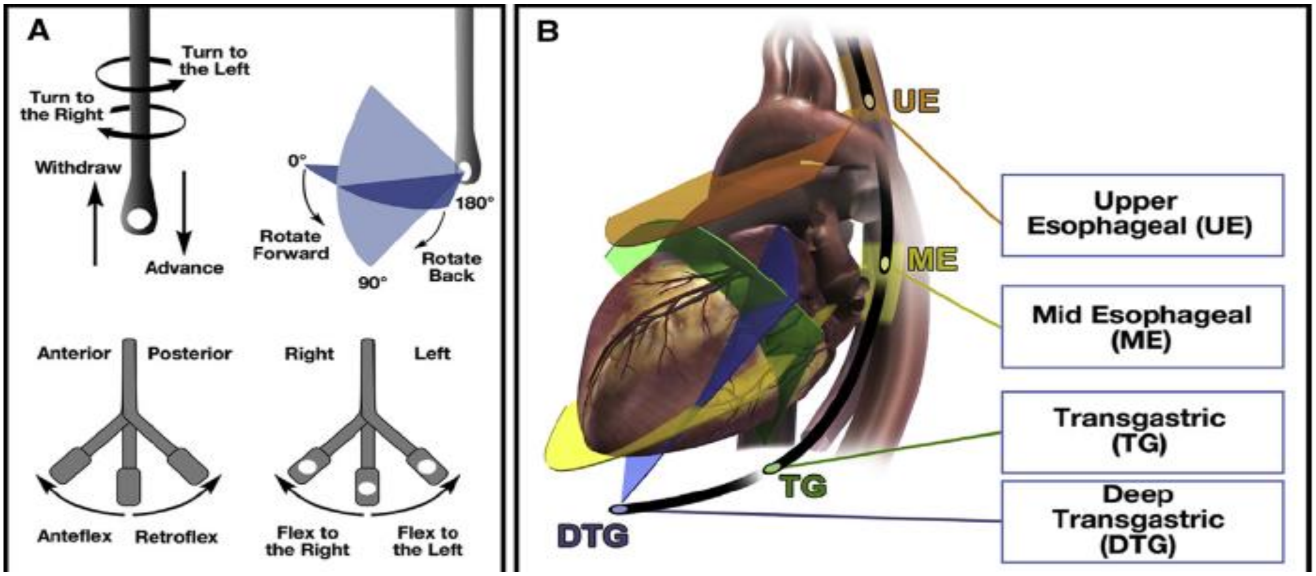

Figure (3): Image acquisition nomenclature & manipulation for transesophageal echocardiography (TEE) probes. (A) Terms used to manipulate TEE probe. (B) 4 typical TEE locations in stomach & esophagus, together with corresponding imaging planes. Reproduced from Journal of American Society of Echocardiography with permission [31].

Clinical applications for TEE: Echocardiographers need to understand terms used for TEE probe manipulation, ex advancement, withdrawal, twisting and angle rotation, which were accomplished using 2 knobs , an electronic switch [31].

Assessment of ventricular structure & function: Echocardiography may be used to monitor left & right ventricles in real time. It was necessary to evaluate both ventricles' morphology in terms of shape, size, function wall thickness, (including regional wall motion & diastology) [32].

Left ventricular systolic function:
Non-cardiac surgical cases frequently have left ventricular dysfunction. LV function may be estimated visually using qualitative ejection fraction, quantitatively using fractional area change & 2D Simpson's biplane approach. If left ventricular monitoring was required, inotropic treatment may be required [33].

Assessment of regional wall motion abnormalities (RWMAs):
Regional wall motion abnormalities (RWMAs) in left ventricle were examined using echocardiography to assess left ventricular systolic function. This technique visualizes left ventricle in seventeen segments, evaluating segmental function and identifying ischemia [32].

Left ventricular diastolic function: Cases at high risk, those experiencing dyspnea despite normal systolic function must have their left ventricular diastolic function evaluated. Degree of diastolic dysfunction can be assessed by anesthesiologists with advanced echocardiographic training using tissue Doppler measures, pulmonary venous flow and mitral inflow. Cases having aortic surgery have been known to experience changes in diastolic function & beginning of hemodynamic instability accompanied by acute diastolic dysfunction. Early detection and treatment of acute diastolic dysfunction may be necessary to lessen adverse effects of surgery [34].

Right ventricular function: An enlarged right atrium & ventricular free wall hypertrophy or dilatation may result from severe hemodynamic instability brought on by RV dysfunction. Reduced tricuspid annular plane systolic excursion, hypokinesis and aberrant septal morphology were examples of echocardiographic symptoms. Echocardiography was essential for tracking efficacy & titration of medication [35].

Assessment of preload: By measuring changes in LV size, echocardiography may be used to estimate LV volume in high-risk cases undergoing goal-directed fluid treatment. Dependable view for determining volume status by LV dimension was LV TG long-axis (LAX), LV TG SAX mid-papillary view was utilized [31].

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Assessment of cardiac output & hemodynamic monitoring: With fewer pulmonary artery catheters, echocardiography was utilized more often to evaluate cardiac output in critically ill cases. During perioperative phase, hemodynamic management seeks to preserve ideal tissue perfusion. Using heart rate & velocity time integral, one may estimate cardiac output and stroke volume. ME LAX view may be used to estimate left-sided output [31]**.**

Limitations of TEE: Setup time & requirement for probe disinfection make TEE more time-consuming than TTE. While, less invasive than other artery catheterization-based monitoring methods, TEE was more invasive than TTE that carries a risk of problems ex tracheal tube displacement & injury to esophagus, hypopharynx, or stomach. TEE does not require antibiotic prophylaxis and has a low risk of causing bacteremia [31].

Rescue TEE: Doctor must assess presence of pericardial effusion, ventricular contractility, adequacy of ventricular diastolic volume before proceeding with a rescue TEE. If cause of hemodynamic instability may not be found right away, a more thorough sixteen-view examination must be taken into consideration. It was important to take into account extracardiac diseases and other conditions that were previously stated. As aggressive hemodynamic control continues, seeking advice from a more experienced colleague must be last resort [31].

Contraindications to TEE: TEE examination was often a minimally invasive and safe technique when performed by qualified professionals. Range of TEE-related morbidity is 0.2-1.2% overall. Clinical evaluation was necessary to rule out contraindications prior to TEE probe implantation, unless assessment was not practical, as in case of unconscious cases or crises. When TEE was expected, cases must be informed of risks & advantages prior to surgery, their agreement must be sought [31]**.**

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