Use of TEE as a perioperative monitor during noncardiac surgical procedures has not been systematically studied. The American Society of Anesthesiologists/Society of Cardiovascular Anesthesiologists (ASA/SCA) guidelines for use of TEE describe two applications of TEE in noncardiac surgical population (Life threatening hemodynamic disturbance and Intensive care monitoring) as Category I indications i.e. supported by strongest evidence. Category II indications are the ones where the use of TEE may be helpful but the expert opinion is divergent, and Category III indications are the not supported by available evidence. However, these statements are based on available evidence and there is lack of data because the appropriate studied to generate data have never been performed. TEE has been shown to be superior to clinical assessment with or without invasive monitoring.

The commonest indications for using TEE perioperatively are:

- Ventricular function
- Volume Status
- Ischemia monitoring
- Assessment of response to therapy
- Trauma
• Pericardial Pathology
• Emergency TEE
• Valvular Pathology

Hemodynamic instability in an anesthetized patient, who is not only critically sick but also under the effects of anesthetics and positive pressure ventilation is indeed a challenging condition to treat. Traditionally anesthesiologists have used the Pulmonary Artery Catheter (PA catheter) for estimation of Pulmonary Capillary Wedge Pressure (PCWP), which is believed to be a surrogate measure of the left ventricular (LV) end diastolic pressure, which is an indirect determinant of the preload of the LV. Preload is technically determined by the sarcomere length, and not the pressure in the left ventricle. So any investigative modality that measures preload of the myocardium must be able to measure the dimensions of the ventricles. Hence, when TEE is compared with PA catheter, TEE is more expedient, can be inserted quickly and without employing a sterile technique, safer as it does not enter any great vessels or the heart, and is obviously more comprehensive not only in providing a hemodynamic evaluation but also an assessment of the structure of the heart. In addition, general size of the cardiac chambers as well the right and left ventricular dimensions can be easily obtained by TEE. Also PCWP and Central Venous Pressure (CVP) have been shown to be indirect measures of central volume at best and are profoundly affected by lung compliance, and intrathoracic pressures, especially in ventilated patients. Determination of intracardiac volume by determination of intracardiac pressure, especially against atmosphere and not against the surrounding intrathoracic pressure is not correct.
Pulmonary Artery Catheter: Friend or Foe?

Unreliable Friend

We are often called upon to make decisions about fluid therapy, use of inotropes and vaspressors in critically ill, hypovolemic or hypervolemic patients with normal and abnormal cardiac function. Whatever modality we choose to make these decisions should provide reliable, reproducible and rational results in a timely fashion and should be simple to use and minimally invasive. As we will realize that a PA catheter unfortunately does not enjoy any of these attributes. Dexter in 1947 was the first one to demonstrate that it was possible to measure a Pulmonary Artery “Wedge Pressure” by positioning the catheter in a distal branch of the pulmonary artery. The blood drawn in this position was fully saturated, indicative of alveolar capillary blood. Swan et al in 1970 demonstrated that a balloon tipped PA Catheter could be inserted without the use of fluoroscopy by following wave forms. Since its introduction the PA catheter has been assumed to be a reliable indicator of the “Preload” or the “Volume Status” of the patient, despite numerous studies which were published to demonstrate the unreliability of the PA catheter in measuring the LV preload.

For the PCWP to be a reliable indicator of the left ventricular end diastolic volume (LVEDV), the following criteria must be met:

1. A valid PCWP tracing must be obtained.
2. PCWP is correctly interpreted.
3. PCWP is an accurate reflection of LVEDP.
4. There is a linear and predictable relationship between the LVEDV and LVEDP.

Studies have shown that the PCWP recordings are technically inadequate in at least a third of the cases, and numerous factors in placement and calibration can give erroneous information and above all even in highly trained intensivists, there is disagreement about the interpretation of the PCWP tracing\textsuperscript{10, 11, 12}. Also the factors that determine LV preload are affected by ischemia, sepsis, diabetes, obesity, aging, tachycardia and cardioplegia and are in a dynamic interaction with the loading conditions, thus making PCWP a very unreliable index of preload\textsuperscript{5}. There is also very poor correlation between the PCWP and the LVEDV as determined by two-dimensional echocardiography\textsuperscript{13}.

A Foe?

Since the start of widespread use of PA Catheter, there has always been a fundamental question, “Does the use of PA Catheter increase the morbidity and mortality?”. The answer unfortunately is still not clear. There are numerous studies in the literature suggesting that the use if PA Catheter is associated with higher morbidity, hospital stay increased costs and even increased mortality\textsuperscript{14, 15, 16}. Dalen et al\textsuperscript{17} have suggested that this increase in morbidity and mortality cannot simply be explained by suggesting that the patients who receive PA catheters were sicker to begin with. Numerous explanations have been suggested for this increase in morbidity and mortality, such as susceptibility to ventricular fibrillation\textsuperscript{17} in patients with acute myocardial infarction and most important, Connors et al\textsuperscript{14} have
suggested that a PA catheter may be suggestive of an aggressive style of therapy which may be associated with a higher mortality and the therapy selected on the basis of an incorrect information may be the cause of these adverse outcomes. Dalen et al\textsuperscript{17} have actually suggested a moratorium on the use of PA catheters until this issue can be resolved by randomized clinical trials. A randomized trial of the use of PA catheter use in high risk surgical patients however did not show any increase in morbidity or mortality, but did not demonstrate any benefit of the use of PA catheter at the same time\textsuperscript{18}.

**TRANSESOPHAGEAL ECHOCARDIOGRAPHY**

**TEE and Preload/Volume**

TEE is rapidly becoming a modality of choice to determine the volume status of patients in the Intensive Care Units (ICU). The LV end diastolic area (EDA) in the transgastric short axis view has been shown to be a reliable indicator of LV preload in cardiac surgical patients even in the presence of wall motion abnormalities\textsuperscript{19}. Measurement of EDA has also been shown to help identify patients in the ICU that will respond positively to a fluid challenge with increased stroke volume and cardiac output \textsuperscript{20, 21}. Traditionally, Doppler analysis of mitral inflow patterns has been used to assess the LV and left atrial (LA) filling pressures. Factors such as pattern and rate of ventricular relaxation, mitral valve inertance and LA filling pressure affect the mitral inflow\textsuperscript{22}. Correlation between Transmitral Doppler variables and PCWP has been investigated by numerous authors with conflicting results\textsuperscript{23}, however Minoru et al\textsuperscript{23} in one of the first intraoperative use of these variables have demonstrated an excellent direct correlation between PCWP and
deceleration slope of the early diastolic LV filling and inverse relationship with the deceleration time of the early diastolic filling in patients with ejection fraction <35%. A sensitivity and specificity of 100% and 99% for a deceleration time ≤ 120ms to predict a PCWP of ≥ 20 mm Hg has been reported in patients with depressed systolic function. A combination of Transmitral Color M-mode and Doppler Tissue Imaging (DTI) of mitral annulus has been shown to be moderately sensitive and specific for prediction of LVEDP and seems to overcome the dependence of Transmitral Doppler velocities on loading conditions. Also, DTI has been shown to be a better predictor of LV filling pressures in patients with preserved systolic function. In the era of cost containment, use of intraoperative TEE may prove to be a very simple, noninvasive and reliable alternative to PA catheter for estimation of LV preload.

**TEE and Ventricular Function**

One of the commonest indications for use of TEE is assessment of ventricular systolic function. TEE provides rapid assessment of the LV systolic function by providing high quality images in multiple planes and positions. Transgastric short axis view of the LV is easily obtained by TEE and provides assessment of ventricular walls supplied by all the coronary arteries. Quantitative assessment of the LV function can be performed using mathematical formulae as Teicholz formula and Simpson’s rule for those with abnormally shaped ventricle and wall motion abnormalities. However this can be time consuming and this has been demonstrated that visual estimation of ventricular systolic function is as or more accurate than off-line Echocardiographic measurements. This is also a huge
advantage of the use of TEE, in providing real time assessment of the ventricular systolic function, although it can be significantly affected by operator expertise. Heart failure is one of the commonest diagnoses made on inpatients. Previously investigators have focused on the explanation of deterioration in systolic function to account for the symptoms. However, it is being increasingly realized that abnormalities of the diastolic function are responsible for the heart failure symptoms in almost 1/3\textsuperscript{rd} of these patients who have normal systolic function\textsuperscript{30,31,32}. Cardiac catheterization was the only modality available to the clinicians to diagnose and quantify diastolic function. With the advent of two-dimensional echocardiography and Doppler imaging, diastolic function is being diagnosed and treated more often than before and it has become a reliable, reproducible and a practical noninvasive method of diagnosis and treatment as well as longitudinal follow up in patients with diastolic dysfunction\textsuperscript{33}. Doppler echocardiography has also been used to develop more objective and quantifiable parameters of ventricular function which combine systolic as well as diastolic performance such as “myocardial performance index” (MPI), also referred to as the “Tei Index”\textsuperscript{34}. It is defined as the sum of isovolumetric contraction time, isovolumetric relaxation time divided by the ejection time. This index is easily obtained, reproducible and has shown excellent correlation with invasively measured parameters of systolic and diastolic function. MPI also does not seem to depend upon ventricular geometry, heart rate, and has demonstrated prognostic value in patients with cardiac amyloidosis and cardiomyopathy and after myocardial infarction\textsuperscript{35}. Another very important function of TEE is an accurate assessment of the function of right
ventricle (RV), because of its implications on the prognosis. A combination of two-dimensional and Doppler techniques can be used to calculate the stroke volume as well as the cardiac output. Cardiac output measured via TEE has shown good correlation with measurements made with the PA catheter, however, the accuracy depends upon a good alignment of Doppler with the flow profile and there is potential for significant error.

**Ischemia Monitoring**

Absence of Perioperative ischemia diagnosed by any means is a predictor of a favorable postoperative outcome. The response of myocardium to ischemia is manifested as diastolic dysfunction initially, followed by wall motion abnormalities (WMA) and then ECG changes followed by clinical symptoms. Transgastric short axis view at the midpapillary level has been shown to be most reliable in diagnosing ischemia related WMA but visualizing the left ventricle in multiple planes increases the detection of WMA. It has been shown that WMA can be detected on echocardiography within a few seconds of coronary occlusion. On the other hand TEE and ST segment analysis have shown poor correlation in many studies. Despite their association with ischemia, WMA detected on TEE have shown a low predictive value for association with postoperative myocardial infarction. This shows that TEE is highly sensitive for detection of ischemia, and detects occurrence of myocardial damage even before the markers for cellular damage can be detected. However, there are many nonischemic causes of WMA, such as sudden changes in loading conditions, conduction abnormalities and translational motion of
the heart. Although the present data does not clearly demonstrate that intraoperative ischemia detected by TEE relates to postoperative outcome, it does not refute it at the same time. Newer applications of TEE such as visualization of aortic branches and assess tissue blood flow to kidneys and intestines, and use of TEE guided deployment of endovascular stents during thoracic aortic repair offer exciting new uses of TEE.

**Emergency TEE**

Assessment of hemodynamic instability is one of the most important indications for TEE. Especially in cases of trauma a rapid diagnosis is essential prior to institution of therapy. Use of TEE in cases of penetrating chest injuries has shown to expedite the diagnosis e.g. cardiac injuries and institution of therapy when compared with the patients who do not have TEE for diagnosis. In critically ill patients in the ICU, use of TEE helps in reaching a quick diagnosis and improving management and outcome. Similarly there is a growing body of evidence of use of TEE during lung and liver transplantation as well.

**Therapeutic Impact of TEE**

There are very few studies in the literature that assess the impact of TEE during noncardiac surgery for category II indications. Largely it has been because of the ambiguous definition of “impact” of TEE. Suriani et al defined impact as a change of therapy or change in eventual management during the course of noncardiac surgery. Hofer et al utilized TEE in a prospective study to assess its impact for category II indications and reported that it was especially beneficial in patients with pulmonary hypertension and right ventricular failure. It is however it
is suggested that confirmation of clinical suspicion in a situation with equivocal data from other monitors e.g. PA catheter should also be defined as having therapeutic impact during the course of noncardiac surgery. Presently TEE has been suggested as the investigative modality of choice for diagnosis of Category I indications\textsuperscript{55}, and despite being a very sensitive monitor for ischemia and assessment of volume the role of TEE is not as yet very well defined for Category II indications. But it has been shown that people with advanced training in TEE use it as a monitor in preference over PA catheter\textsuperscript{56}. 
References


